2-day

National Conference on

"Professional Trends in Industrial & Systems Engineering"

24th – 25th April, 2018

Organized by

Department of Industrial Engineering
University of Engineering & Technology, Peshawar

Vice Chancellor's Message

Prof. Dr. Iftikhar Hussain
Vice Chancellor
UET Peshawar

The Department of Industrial Engineering, UET Peshawar is one of the most vibrant and active department in UET Peshawar which has got its flagship status in a very short span of time. The initiative of holding two-day national conference on "Professional Trends in Industrial and Systems Engineering" held on April 24-25, 2018 in UET, Peshawar is a step forward to promote the discipline of Industrial Engineering and demonstrate its application and usefulness to all types of organizations in general and industrial sector in particular.

The Industrial Sector of Pakistan has to be competitive to grow and play its important role in national economic growth. I believe that this conference has highlighted the challenges and opportunities faced by the industrial sector of Pakistan and discuss the way-forward. I would like to thank everyone in academia, industry, government and professional engineers who joined us & made this conference successful. Their contribution will be remembered the form of these proceedings for others to further the cause of research and maintained in the country. Being part of research community myself bestowed with the position of the Vice Chancellor. I shall continue the support such conferences in University of Engineering & Technology, Peshawar.

In the end I would like to that all the organizers, participants and students for playing their part in realizing and executing the idea of the conference.

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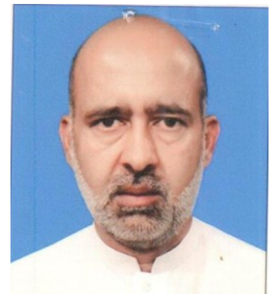
Conference Chair's Message



Prof. Dr. Sahar Noor
Chairman
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It is a matter of pleasure that the Department of Industrial Engineering has started its mature contributions in a very short span of time to the discipline of Industrial Engineering in particular and society in general. Organizing such conferences really helps build networking among academia, industry and professionals of similar interests. This two-days conference on 'Professional Trends in Industrial and Systems Engineering(PTISE 2018)" has developed sufficient interests among academia, industries and professionals from various disciplines which is evident from the number of abstracts and sponsorship received for the conference.

This book of proceedings highlights the level of enthusiasm of professionals for solution of problems in various disciplines of Industrial Engineering and allied sciences. Every idea presented in the form of paper is original and indigenous which can lead to original and sustainable solution to our local problems if we get focused and determined for promoting research in such areas. Moreover, this book of proceeding will help all those who are interested to find researchers, workers and experts of mutual interests for collaboration and cooperation.

We are committed to provide such opportunities in future in the form of national/international conferences, workshops and training to find and discuss local solutions to our local issues. We are of the strong belief that such efforts will pave the way for building sustainable knowledge-based economy for our country.

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THE UNIVERSITY

University of Engineering and Technology, Peshawar, is a premier institution of higher learning in the field of engineering sciences. Starting as a College in 1952, with an initial enrollment of only twenty students, today it boasts twenty two engineering departments, covering an entire spectrum of engineering disciplines, from the traditional, such as electrical and mechanical, to the cutting-edge technologies such as electronics, mechatronics, and industrial engineering. To-date, thousands of students that graduated are serving the needs of Pakistan, and many have achieved high positions of responsibility and excellence in their chosen fields.

Besides bachelor's degree courses, there is a robust post-graduate programme, where scholars are engaged in rigorous training and research leading to Master's and Ph.D degrees. UET also has a strong out-reach programme, under which academic linkages with the world class universities of UK, Canada, USA, Malaysia, Italy and Thailand offering invaluable training to faculty and students, through split programmes, joint research and faculty exchanges.

Over the last few years, with Higher Education Commission's support, UET had initiated a number of research and infrastructure development projects, with a portfolio of Rs. 9 billion. Major projects include "Earthquake Engineering Center", serving as a hub of applied research in South Asia, "Institute of Mechatronics Engineering", "National Institute of Urban Infrastructure Planning" and "Gems and Jewelery Center of Excellence".

In order to increase access to engineering education, particularly for the people of Khyber Pakhtunkhwa, UET has been awarded a "mega" project of Rs. 6.56 billion to develop a new campus called, "Establishment of Jalozai Campus." The Jalozai Campus promises to push boundaries for engineering education and will double its student intake from 4000 to 8000.

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OPTIMIZATION OF MAKESPAN IN JOB SHOP SCHEDULING PROBLEM USING ANT COLONY ALGORITHM

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ABSTRACT

In this study a job shop scheduling problem (JSSP) is solved using Ant Colony Optimization. JSSP deals with scheduling N jobs to be performed on M machines. Job Shop scheduling is also a challenge for the optimization of manufacturing systems. In this era of global competitiveness, shorten lead times are key to success. The main emphasis of this paper is to optimize completion-time or make-span in the job shop scheduling problem. Ant Colony Optimization algorithm is used to determine optimal solution by solving the problem related to job shop. Using this meta-heuristic technique, it has been tried to minimize the make-span, by scheduling each machine sequentially. In this research, a case study has been performed in Heavy Mechanical Complex (HMC) Taxila, situated in Rawalpindi Pakistan, where Job shop was focused to optimize makespan time by using ACO. MATLAB coding has been performed for ant colony optimization for the stated problem. After applying ant colony optimization, the minimum makespan achieved is 129. It is the best result obtained, but not the global optimum.

Keywords— Job Shop Scheduling; Ant Colony Optimization (ACO); lead-time optimization; Makespan.

1. INTRODUCTION

Scheduling can also broadly be defined as the allocation of resources to tasks over time in such a manner that a predefined performance measure is optimized. From the perspective of manufacturing scheduling, the resources and tasks are typically known as machines and jobs and the typically used performance measure is the total times of jobs. This problem has been substantially researched since early 1950's. A broad investigation of literature on scheduling problems can be established in Graves (Graves 1981), Lawler et al. (Lawler, Lenstra et al. 1993), and Lee et al. (Lee, Lei et al. 1997).

The classical job-shop scheduling problem (JSP) includes a fixed of independent jobs, each having its own processing order via a set of machines. Every activity has an ordered set of operations, each of which have to be processed on a predefined machine. The problem, acknowledged to be strongly NP-hard, is to sequence operations at the machines so that the most completion time over all jobs (C_{max}) is minimized (Jain and Meeran 1999).

The scheduling problem is how to arrange multiple jobs (or orders) in the plant. In other words, scheduling refers to use stations and parallel machines as effectively as possible to achieve goals. The problem extends the single machine or multi-machines of workstations but treated as a single machine in a single-stage or multi-stage scheduling problem. The problem is practically important and yet more complex, especially, when customer order splitting in multiple lots on several parallel machines in each station dynamically is allowed.

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Job shop scheduling problems are NP-Hard problems because we must schedule n-jobs for m-machines (Johnson 1985). Therefore, several metaheuristic techniques are developed to achieve optimal solution. Every algorithm comes with its specific set of attributes, especially, having uncertainty in solution, either it is optimum or not. Their strengths and weaknesses differ from problem to problem that is why hybrid algorithms are designed to dealwith these problems. Swarm Intelligence optimization algorithms have become one of the key tool to optimize multi objective complex optimization problems (Dorigo, Birattari et al. 2008). Therefore, Ant Colony Optimization Algorithm is selected to optimize the problem of JSSP, with objective of shortening maximum span time.

Job Shop scheduling problems have become one of the well-known combinatorial problems, having complex and difficult nature. It is by no mean easy that one can get exact solution even for a small problem as JSSP is NP-hard in true sense (Li, Xie et al. 2011). In these recent years, meta-heuristics have become popular in solving Job Shop scheduling problems using Genetic Algorithm, Tabu Search, Particle Swarm Optimization, Ant Colony Optimization, memetic algorithm etc. (Pham and Karaboga 2012, Glover and Laguna 2013). There are a number of studies in multi-objective and multi-criteria job shop and flexible job shop scheduling problems. However, up to now, there is no study considering open shop scheduling problem. In this paper, ant colony optimization is used to solve job shop scheduling problem.

Despite the fact that a best solution algorithm for the classical JSP has now not been developed, there is a trend in the studies domain to solve a much more complex model of the problem. The problem is stated as the flexible job -shop scheduling problem (FJSP). The scheduling problem of a FJSP includes a routing s ub-problem, i.e. assigning each operation to a machine out of a set of capable machines and the scheduling sub -problem, which includes sequencing the assigned operations on all machines in order to obtain a feasible schedule minimizing a predefined objective function.

Recently, various optimization techniques have been studied for solving job shop scheduling problems such as Ant Colony optimization (ACO), Particle Swarm Optimization (PSO), and Genetic Algorithm etc. (Nouiri, Bekrar et al. 2018, Zhang, Wang et al. 2018). ACO has verified its success by its own uniqueness of robustness and generalization (Ozbakir, Baykasoglu et al. 2011, Yao and Pan 2013). ACO offers best solutions to the JSSP, however, as increasing the number of jobs and machines, ACO solutions are limited. Solving such complex problems, researchers a re trying to implement other optimization techniques (Cekmez, Ozsiginan et al. 2013, Kugu and Sahingoz 2013, Turguner and Sahingoz 2014). Due to difficulties of such flexible problems, many scholars have concentrated on metaheuristic techniques to solve the FJSP. Among these are the evolutionary algorithms (Moslehi and Mahnam 2011, Chen, Wu et al. 2012, Ziaee 2014), tabu search (Saidi-Mehrabad and Fattahi 2007, Li, Pan et al. 2010, Li, Pan et al. 2011), simulated annealing (Low, Yip et al. 2006, Lei 2009), ant colony (Rossi and Dini 2007) and hybrid approaches (Xia and Wu 2005, Fattahi, Mehrabad et al. 2007, Hansen, Mladenović et al. 2008).

Low and Chong et al. (2006) have studied job shop scheduling problems based on tabu search algorithm. They have determined that the applied algorithm gives best results as compared to Ant Colony Optimization. (Chong, Sivakumar et al. 2006). Huang and Liao (2008) have studied JSSP with the objective of minimization of makespan using hybrid algorithm. They have combined the Ant Colony Optimization (ACO) with Tabu Search heuristics (Huang and Liao 2008). Low and Wu (2006) have studied the job shop scheduling problems in order to minimize the total tardiness, considering the setup time. They have developed a mixed-programming model and solved it on simulated annealing (SA) (Low, Yip et al. 2006). The model was further extended by Low and Wu (2006) to a multi-objective model (Wang, Hu et al. 2018).

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Gomes et al. have presented the JSSP considering the storage buffers. They have developed a discrete-time model, which divides the planning horizon into equal intervals. The developed model has been generalized for re-cycling of jobs among different machines (Gomes*, Barbosa-Povoa et al. 2005).

Novelty in this paper is that it uses ACO algorithm with decomposition approach to schedule a job -shop problem. Every job is scheduled according to given weight, like order criticalness and penalty cost.

2. JOB SHOP SCHEDULING PROBLEM

Job shop is a place that many standard reason work stations are placed in it. These workstations perform sort of jobs. There are four elements to describe JSSP, which are Arrival sequence, number machines Stations (machines), machines sequence, and overall performance on assessment Criterion. The overall performance assessment criterion involves many features. These are makespan, average time of jobs in shop, lateness, average variety of jobs in job shop, and utilization of machines and workers. Despite the fact that, these objectives features may be considered in JSSP, makespan is the prime focus for researchers and the most important computational problem to decide the scheduling (Sun, Cheng et al. 2010).

In this study, the objective is minimizing the makespan of jobs. There are many scenarios of JSSP shown below. There are five jobs and two machines.

2.1. Notations

The following notations are used for the formulation of JSSP.

$i =$ numbers of jobs i

$j =$ number of operations

$k =$ number of machines

$J =$ the set of jobs

$M =$ the set of machines

$O =$ the set of operations

$O_i =$ ordered set of operations of job i

T_{ijk} = the processing time of operation Oij on machine k

X_{ijk} = 1, if machine k is selected for operation Oij; 0, otherwise (in our case it is 1 for all cases)

$S_{ijk} =$ the starting time of operation Oij on machine k

$C_{ijk} =$ the completion time of operation Oij on machine k

$C_i =$ the completion time of job i

$C_{max} =$ maximum completion time for all jobs (Makespan)

V_{ik} = waiting time of job i on machine k

P_{jk} = processing time of operation j on machine k

2.2. Assumptions

- Each job will process once at a time on a machine.
- Availability of machines ininfinite.
- Jobs are independent of one another.

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- Setup time is also included to the process time.
- No priority will be given to any job

2.3. Mathematical Formulation

Makespan is actually the time of completion of last operation. In presented problem, the makespan (C_{max}) is formulated by the following equation;

$$\text{Makespan} = \text{waiting time of job before / after processing} + \text{processing time of job on machine k} * \text{if machine k is selected for operation (1 or 0)}$$

$$\text{Minimiz Cmax} = \sum Vik + \sum Pjk * Xijk$$

Constraints:

$$\text{Sij} + \text{Pij} \leq \text{Si} + 1, \text{J}$$

$$\text{Tj} \geq \text{Smj} + \text{Pmj} - \text{dj}$$

$$\text{Tj} \geq 0$$

$$\text{Sj, i} + 1 \geq \text{rj}$$

$$\text{Sij} + \text{Pij} \leq \text{Sk, L or, Sk, L} + \text{Sp, L} \leq \text{Sij}$$

3. DATA ANALYSIS

For complex JSSP, Gantt chart is suitable for scheduling the jobs . But it ignores the other factors like priorities, rules of scheduling. So in order to cover these limitations, other optimization algorithm such as genetic algorithm, Ant Colony Optimization etc. are best. By considering N=5 jobs and 2 machines job shop case, job is processed on machine 1, then go to machine 2 as presented in Table 1.

Table 1: Jobs Processing Time

Jobs	Machine 1 (hours)	Machine 2 (hours)
1	13	3
2	2	5
3	1	3
4	4	6
5	5	7

Figure 1 shows the Gantt chart for the process times of jobs. It can be observed that machine 1 have no idle time, but machine 2 has idle time of three minutes. Machine 1 and machine 2 have makespan of 35 and 38 minutes respectively. The jobs 2, 4, and 5 have to wait of 6 minutes on machine 2.

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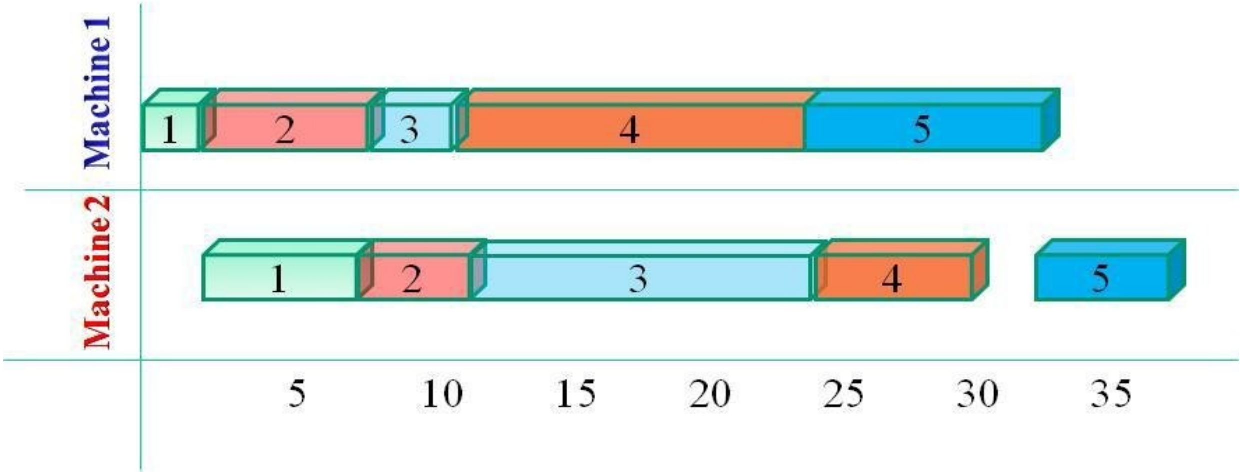

Figure 1: Gantt chart

4. ANT COLONY OPTIMIZATION APPROACH

The ACO is used to find the best way for ants to get food. The working of the algorithm start with an ant, which travels a long in search of food. On the way, he release chemicals known as pheromone that is inversely proportional to the distance covered (Chen, Lo et al. 2008). The other ants following him arrives at optimal time. They chooses the optimal path due to the concentration of pheromone. So as the concentration of pheromone are changes, the directions of optimal path also changes. The ant follows that path having high concentration of pheromone. Figure 2 depicts the working of ACO.

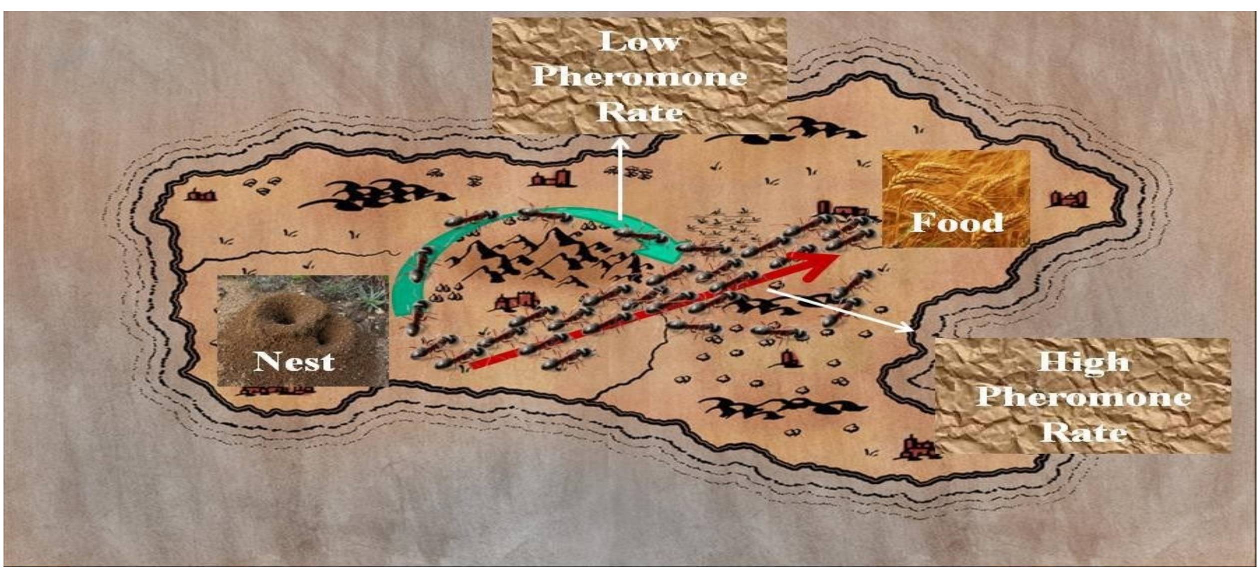

Figure 2: Working Principle of ACO (Turguner and Sahingoz 2014)

The basic steps of ACO are shown below;

- Initialization of population
- Constructing different solutions

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- Finding the local solution/ search
- Updating criteria
- Repeat the above steps until meet the stopping criteria.

4.1. Explanation

For initializing the population, considering the set of jobs and number of machines. Pheromone pairs has been selected when objective function give the minimum makespan (Rondon and Carvalho 2009). This will give the local optimum. Best pheromone are selected by applying the local optimum solutions. If next local is better than the previous, the pheromone values is increasing or vice versa. After that permutation process begins and new paths are chosen by the ants. Heuristic value is indicated as H_{ij} indicates the heuristic values and P_{ij} shows the pheromone values. The H_{ij} is determined by the pheromone values for which best feasible solution is found. Utility function is determine as a solution using Eq. (1) and Eq. (2).

$$\boldsymbol{F(utility)ij = \frac{Hij*Pij}{\sum_{i,j=1}^{i,j=n,m} Hij*Pij}} \quad \text{Eq. (1)}$$

$$\boldsymbol{Hij = \frac{1}{F(Xij)}} \quad \text{Eq. (2)}$$

Heuristic value is computed from F(X) function that X is defined as a cost. Before modifying the pheromone value, local search rule is applied. In constructing solution to the job shop problem, ants have the abilities . In solution construction of JSSP, every ants have the capabilities of recognizing (indirect communication) pheromones. The relative weight probability of pheromone of the jobs determines the ant's selection. The probability is determine using Eq. (3) ;

$$\boldsymbol{P_{ij}^{k} = \frac{[\tau_{ij}]^{\alpha}.[\eta_{ij}]^{\beta}}{\sum_{l \in N^k}[\tau_{il}]^{\alpha}.[\eta_{il}]^{\beta}}} \quad \text{Eq. (3)}$$

Solution is updating by the ants or jobs with respect to the probability of pheromone. By selecting best solution, next ants will perform better. The value of pheromone is updated before begins to next tour (evaporation value). Evaporation rate ρ can be calculated using Eq. (4);

$$\boldsymbol{\tau_{ij} \leftarrow (1-\rho).\tau_{ij}} \quad \text{Eq. (4)}$$

After complete path construction by ants, pheromone values must be updated according to Eq. (5); to

$$\boldsymbol{\tau_{ij} \leftarrow \tau_{ij} + \sum_{k=1}^{m} \Delta\tau_{ij}^{k}} \quad \text{Eq. (5)}$$

4.2. Solving Job Shop Scheduling Problem With ACO

N denotes the number of ants (number of jobs). ACO is an iterative procedure to reach the optimum solution. In this case study, considering a complex problem having number of jobs=10 and number of machines=10. A MTLAB coding has been done to solve the proposed model. The data has been presented in Table 2.

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Table 2: Input Data

M/Cs	1	2	3	4	5	6	7	8	9	10
J-1	9	8	8	15	5	5	5	5	5	8
J-2	4	4	9	8	11	5	5	3	5	8
J-3	8	4	5	2	5	6	6	1	6	8
J-4	3	11	1	8	6	3	3	3	6	6
J-5	5	8	6	2	8	1	1	6	1	5
J-6	9	6	4	9	1	2	2	8	3	4
J-7	21	5	8	8	1	6	6	4	9	11
J-8	4	1	8	3	8	8	2	3	2	3
J-9	8	3	5	5	1	6	2	3	3	2
J-10	2	8	3	11	1	5	6	11	3	6

The drawback of this technique is that the optimal solution stuckat local optimum. To avoid such situation, trials has been taken. The complete methodology for this technique is shown in Figure 3.

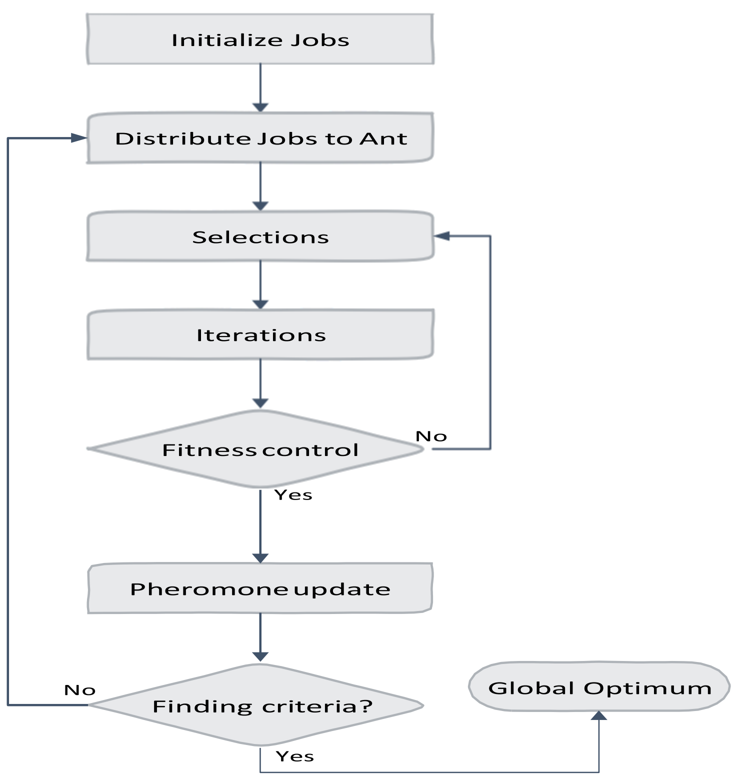

Figure 3. Flow Chart for the Proposed Model

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Initialize the population for jobs and the process times of machine was defined. After that solution has been generated to capture the minimum makespan. Achieving best results means that the job should be assigned to the machines. In this case, selecting the first job, randomization has been ignored, because the first selection might give the best result, as number of iterations will be increased. After performing iteration, the ants giving the best solution are authorized to update the pheromone values. An array was used to distribute the jobs on every machine. Fitness evaluation is necessary in order to obtain the best results. If the obtained solution was best, then update the pheromone table. If the current value of pheromone is greater than the maximum, then that maximum value should be chose and vice versa. The iteration will be repeated until the stopping criteria meet, i.e. number of iteration or makespan value is. MATLAB final results has been presented in Table 3.

Table 3: Proposed Model (MATLAB Results)

1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
150	142	149	148	151	157	160	165	153	143
152	150	143	151	149	155	157	164	150	140
149	141	152	146	143	152	143	163	148	138
145	140	156	141	156	150	134	161	145	141
143	138	146	145	143	149	134	158	145	137
150	150	143	145	141	146	140	158	145	133
141	141	145	137	140	149	132	154	141	132
141	133	152	141	133	145	133	152	140	131
130	132	145	137	131	144	132	150	139	131
.	.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.	.
129	134	132	136	130	144	131	141	135	131

5. CONCLUSION AND RECOMMENDATIONS

Ant Colony Optimization (ACO) was used to solve the JSSP with the objective to minimize the makespan.. The MATLAB results showed that ACO offer best solution for job shop problem. As it has been observed that the minimum makespan after applying Ant Colony Optimization is 129. It cannot be claim that this is the global minimum, but it is the best result as compared to other algorithms.

In future, flow shop problem may be concerned to adopt the current system, for the parallel machines with respect to the constraints and requirements. Further, Artificial Bee Colony (ABC) can be combine with ACO to obtain best optimum solution with minimum number of iterations.

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IDENTIFICATION OF POTENTIAL INDUSTRIES IN KHYBER PAKHTUNKHWA WITH RESPECT TO CHINA PAKISTAN ECONOMIC CORRIDOR (CPEC)

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ABSTRACT

China Pakistan Economic Corridor (CPEC) is subjected to modernize Pakistan's infrastructure and boost up its economy through energy projects, special economic zones (SEZ's) and modern transportation networks. There is indispensable need of industries across China Pakistan Economic Corridor, however identification of potential industries across the routes required a professional strategy and engineering techniques. According to this research, potential of major industries is identified and selected on the basis of performances from year 2000-16 in Khyber Pakhtunkhwa and its potential in the market is forecasted by using different techniques such as Linear regression analysis and polynomial regression analysis.

Index Terms---- CPEC, KP Potential Industries, Regression Analysis

1. INTRODUCTION

China Pakistan Economic Corridor is the sum of infrastructure projects and numerous energy projects. CPEC opted to boost up economies of both Pakistan and China the whole project is now worth $62 billion (Dawn News 19 Nov 2016, The Express Tribune 12 April 2017) and consist of industrial and economic zones, infrastructure, energy units and a wide range of facilities into Pakistan. It is a 3,218 kilometers long route, to be built over next several years. Pakistan linking China with markets in South Asia and Central Asia, most importantly reducing the distance between China and the Persian Gulf by 2,500 kilometers (KPEZDMC).

The government has impended to make 37 industrial parks in all four provinces and specific regions under the CPEC project to boost up manufacturing works. Population-wise Khyber Pakhtunkhwa (KP) is the third largest province of Pakistan having the population of 27.5 million. The province is rich in terms of resources and it has unexplored resources which

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are the opportunities for the new investors. Agriculture is the main source of live hood in KP. Khyber Pakhtunkhwa has 10.5% GDP share in Pakistan economy having the work of USD 30 billion. It is comprising the 11.9% of population of Pakistan. 20% of Pakistan mines & 78% of marble comes from Khyber Pakhtunkhwa (KPEZDMC).

KP is having an opportunity of numerous investment which would be greatly enhanced with CPEC. It can become a trading hub because it has abundant of natural resources and raw materials and skilled workers. The province includes the different firms like steel mills, cement plants, furniture and woods, marble industries, food industries, beverages and processing plants (KPEZDMC).

The study is made to identify Kpk major potential industries that can survive in future based on pre-historic data, analytical approach and performances. It is not only to attract the investors to invest their capitals but also to boost up economies and employments in the province. There is a lot of individual analysis is done for different core of industry success in future competitive environment in world. but still there is no such analysis for Kpk to know their potential industries that can survive as whole for successful investment.

Objective of this project is to access different economic and infrastructural growth of diligences in Kpk and identify potential industries in regard to CPEC. The other aims of this research project are the following:

- To identify the industries that have ability for survival in future
- To develop a frame work for selection of potential industries
- Finally, to bring the attention of CPEC investors and technologist toward the Kpk productive industries to implement their new competitive strategies.

2. LITERATURE REVIEW

Potential means the necessary abilities or qualities to become successful or useful in the future (Collins 2004). An industry is defined by (Collins 2011) that industry is the work and processes of collecting raw materials, and converting them into useful desired products in factories or in a system. So those industries in KP which would have a bright future of China Pakistan Economic Corridor are indicated as potential industry

Economic corridors are networks of infrastructure within a defined Tourism area designed to stimulate economic development. Corridors are the main pillars of the economic development of a country it must be developed between different countries or regions. The Asian development bank (ABD) stated corridors as the vital source of network or connection between economic agents through a specific medium which connect the supply & demand aspects of markets. (Brunner 2013)

2.1. Corridors Objectives

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Mostly corridors are considered as economic corridors and their initial objective from the beginning is to achieve a coordination of hard infrastructure and logistics services, institutional instruments and community involvement through transports that gives benefits in a broad-based development of unrealized economic potential (Hope & Cox, 2015).

Manufacturing industries in a developing area require info about market and resources that which company in the global manufacturing frontier align with the state's latest comparative options, to have a bright and successful future in high competitive environment. (Hausmann and Rodrik 2003).

2.2. Previous Terminologies: -

Theories and empirical evidence cleared that a continuous improvement and process upgradation and technological innovation and infrastructure development and institutional arrangements for business growth creates wealth (Maddison 2001), Therefore to analyze the growth of different economy sectors for future lead, for stakeholder and policy maker, to do better decision in identification of potential of industry. A company FIDEA has developed a method for analysis of growth potential in future, in which a comparison used to be done between export volume and export value benchmarking, which is recommended by company as a base for effective discussion in decisions point of view.

The value of Potential industry earning (PIE) is determined by the factors that analyze industry demands and opportunity cost of resources in term of production, so that points are used in analysis of potential industries earning (VAULT 2008).

A firm's aim is to increase profit, not to lose the economy's comparative advantage. It will follow up the economy's comparative advantage in selecting its diligences and processes in the development operation only when the relative factor prices introspect the relative abundances of factors of the money (Lin & Chang 2009). The method compares unit value between country of interest and reference countries. The goal is to assess potential of industries based on unit value increase (based on products mix and its value) among themselves, not to compare them to other countries, so more developed reference countries were chosen as the most convenient reference point. The Unit value is considered as a respectable proxy of productivity as well. The reference country selection was based on following criteria:

- Countries that would have maximum productivity at current technological level. GDP per capita is a good proxy of productivity, so we were looking for countries with significantly higher GDP per capita.

Industries with high potential in traditional sectors are good indication where human

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capital can be employed, thus can be used to validate some focus on resources on developing human capital in knowledge fields in the industry or complementary to the challenges in the industry.

Benchmarking is widely used approach for businesses to identify weaknesses and investment potential. Benchmarking as an assessment methodology is used because it gives enough focused view on the potential of industries in order to focus attention on the most promising one. It is also less risky, because it does show what others achieve so most likely it may be achievable by a study region. (2014 FIDEA SIA).

2.3. Industries in KP

For promoting economic growth, trade development, employment generation, and extensiveness, the manufacturing sector has always remained a major contributor. It is the evidence of gradual build because of its contribution in GDP & its importance has increased drastically during recent decades in the uprising of emerging issues like overpopulation, unemployment, poverty. Industrialization is an essential term for the development of an economy and standard of life. It plays a central position in all the Five-Year Plans in the economic growth of the Pakistan's economy as production of goods and manufacturing provides job and business opportunities to the people.

The table 2.2.1 show the main 12 industries in KP although there are a lot of industries with different perspective but these industries has major role in Pakistan and Khyber Pakhtunkhwa economy level and basic of this region resources, that why to analyze the future resources and markets for investors to implement the technology and invest their capital in those industries that have capability of improvement and have potential for increasing production in CPEC program.

Table 2.3.1

S. No	Major Industries of KPK
1	Cigarette Industries
2	Sugar Industries
3	Cements Industries
4	Fertilizers Industries
5	Woolen Industries
6	Cotton and textile Industries
7	Electric Bulb Industries
8	Matches Industries
9	Paper & paperboard Industries

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10	Vegetable Ghee and oil Industries
11	Beverages Industries
12	Ceramics Industries

3. METHODOLOGY

The major steps that is taken in whole research project methodology is following, for potential industries identification the KP major industries is selected by expertise and collected their data of production and performance from 2000 to 2016 through bureau of statistic Khyber Pakhtunkhwa.

The next step for analysis of data, Ms. Excel tools is used. According to regression model the data is analyzed through R square (coefficient of determination) value for linear equation line and quadratic equation curve, after that those industries is selected as a potential industry that have more than 0.7000 value of R^2.

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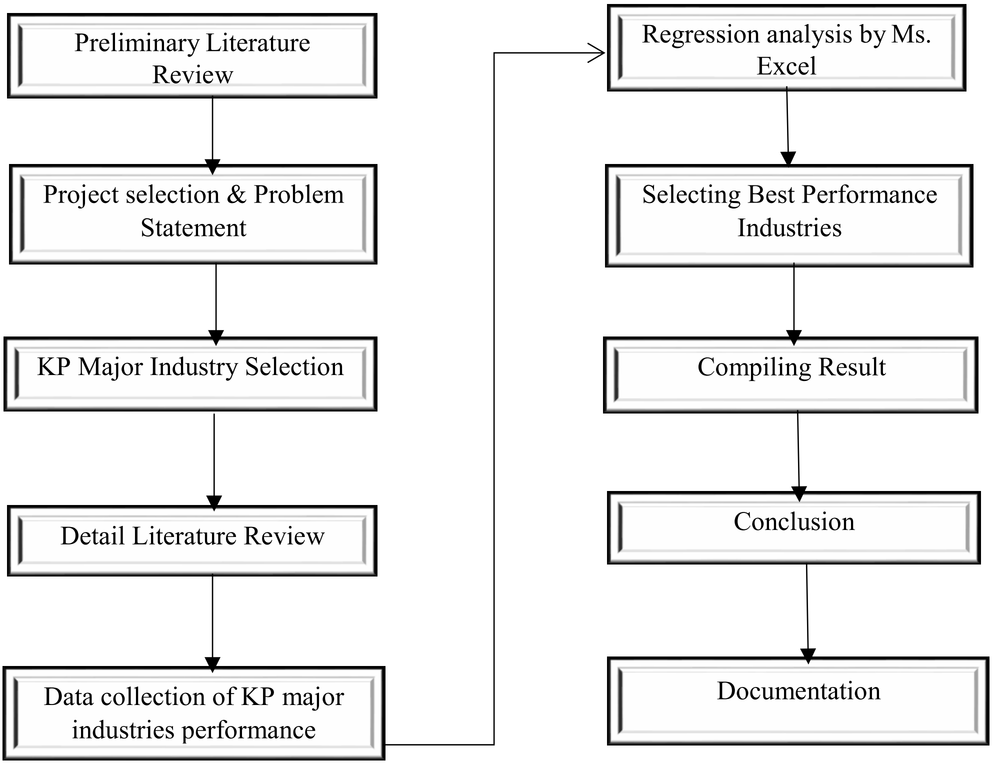

Figure 3.1 Methodology Flowchart

Different industries performance of Khyber Pakhtunkhwa has been divided in to four types of trends as shown in figure 3.2, which are:

- Type I: This type has constant production, steady performance level in past era and has high coefficient of determination value.
- Type II: It has incrementally increasing production level with the passage of time every year in past era and has high coefficient of determination value for linear regression equation line or quadratic equation curve.
- Type III: It has every step of decreasing production, lower-performance level every year in past but it has high coefficient of determination value.
- Type IV: This type of industries performance has no regular production level and has lower coefficient of determination value.

After defining the performance in different types, those industries are selected as potential industry

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that have type II performance of high value of R^2 which should be at least more than 0.7000 value which is threshold value pointed by experts of regression model of analysis and decision analysts.

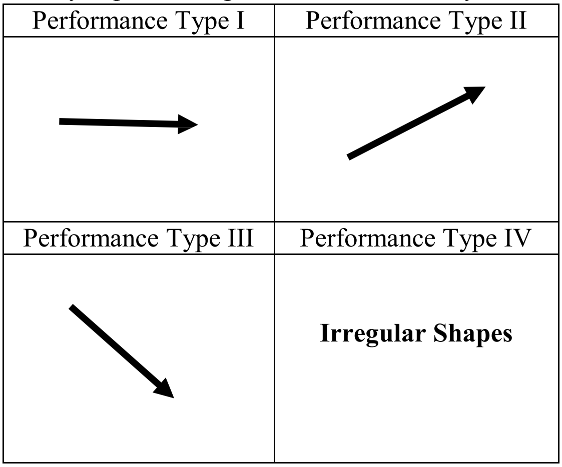

Figure 3.2 Types of performance

4. DATA COLLECTION

KP Bureau of Statistics, release publications of industrial production and employment, monthly and yearly since 1976. It gives information on production quantity and employment with respect to 12 types of large scale manufacturing industries (Cement, Ceramic, cotton, Cigarette, beverages etc.) situated in KP. The data is collected through email from statistical bureau of KP and its official website. Also, some of information are obtain from Pakistan scientific and technological information center (PASTIC).

As the data need to be tested that whether it is trustful and reliable for analysis or not, so we checked it on formative scale of normality test, that whether the data is normality distributed with 95% percent confidence interval. The P value for normality test should be greater than alpha value which is 5% (P-value > 0.05) which show that there is insufficient evidence to reject the null hypothesis (H_0) that data is following normality distribution.

The table 4.1 cleared it that all of data for different industries is normally distributed, and its p-value is greater than 0.05 which is threshold for confidence of interval. where C1,C2,C3……C12 represent 12 major industries of kP, mean value show the production average during 2000-2016 and P-value or probability value is the probability of getting a sample statistic.

Table 4.1
Normality Test result (P-Value>0.05)

Industries	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12

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Production Mean value	6660813	40579	20233	88188	48358	83329	3631.9	6422.9	118726	258034	71940	133194101
P-value	0.154	0.164	0.798	0.322	0.415	0.516	0.152	0.08	0.614	0.448	0.278	0.069

Table 4.2 shows the production data of major 12 industries in KP which includes the data for the last sixteen years from 2000-2016.

Table 4.2
Production volume of different industries Annually (2000-2016)

Years	Cement Industry Production in M.T. (C1)	Ceramics Industry Ware(Pieces) (C2)	Cigarette Industry Production in Million Nos (C3)	Cotton Industry Cotton Yarn (M.T) (C4)	Electric Industry Bulb (000 Nos) (C5)	Fertilizer Industry Production in M.T. (C6)	Matches Industry Production in Million Nos. (C7)	Paper & paperboard industry production in Million Tons (C8)	Sugar Industry Production in (M.Ton) (C9)	Vegetable Industry Ghee in M.T (C10)	Woolen Industry Blanket NO.s (C11)	Beverages Industry Production in Liters (C12)
2000-01	1924161	0	17519	60462	44819	113340	945	7245	53072	187487	51732	4412671
2001-02	1976109	0	17366	57138	43058	113340	1123	6320	129357	187148	66995	4968896
2002-03	3228029	0	13864	59386	51382	80007	2591	9198	110764	200537	63991	4379549
2003-04	4181258	13750	14063	69317	54674	92905	2630	8039	199034	219041	70864	4944266
2004-05	4632995	29545	15918	86620	66700	87340	4036	8254	104834	279477	98361	4351032
2005-06	5136146	26079	17364	106584	63010	85455	5168	6859	94545	358908	102284	5346986
2006-07	6838947	29461	20777	96697	57326	81930	5535	5842	87243	338729	64872	7842285
2007-08	7339248	32016	20606	89618	50540	92380	4601	5659	66772	338872	89147	8889115
2008-09	6874597	35639	24217	88696	48742	91821	4494	5375	32937	311226	65599	10539438
2009-10	8573131	36262	19941	96757	48825	101225	4359	1805	9140	236154	80365	83314494
2010-11	8572389	48596	19673	89377	43484	94263	3984	1674	180943	252036	55575	97681697
2011-12	8813090	59180	27248	86109	40296	68191	4757	7965	203410	283911	85567	131312219
2012-13	9328749	81515	22976	110848	44204	57822	4580	7154	62820	261817	62469	109399382
2013-14	9237287	87592	23312	121477	40643	75624	3766	6806	179051	246177	57894	161196546
2014-15	9478568	79828	23329	107131	32065	51382	2864	7388	118350	232061	85204	193378135
2015-16	10438301	89795	25548	84786	43965	46237	2678	7183	267349	194963	50119	119148911

5. ANALYSIS

5.1. Analysis of major Industries in Khyber Pakhtunkhwa on the basis of Performance

The overall performance of the selected industry is analyzed based on regression analysis technique which is a predictive analysis. The regression equation, considering one dependent and one independent variable is defined by simplest form of the mathematically formula $y = c + b*x$, where y = represent dependent variable score, c = constant, b = regression coefficient and x = score on the independent variable.

5.1.1. Linear Regression

Linear regression is a linear approach for modeling the relationship between a scalar dependent variable y and one or more explanatory variables denoted X. The case of one explanatory variable is called simple linear regression.

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5.1.2. Polynomial Regression

Polynomial regression is a form of linear regression where higher order powers (2nd, 3rd or higher) of an independent variable are included the goal of polynomial regression is to model a non-linear relationship between the independent and dependent variables.

Graphs included in this section, contain data of Production from 2000-01 to 2015-16. Performance of below Industries are analyzed based on regression analysis and multiple quadratic regression analysis

5.1. Performance of Ceramic Industry in KP

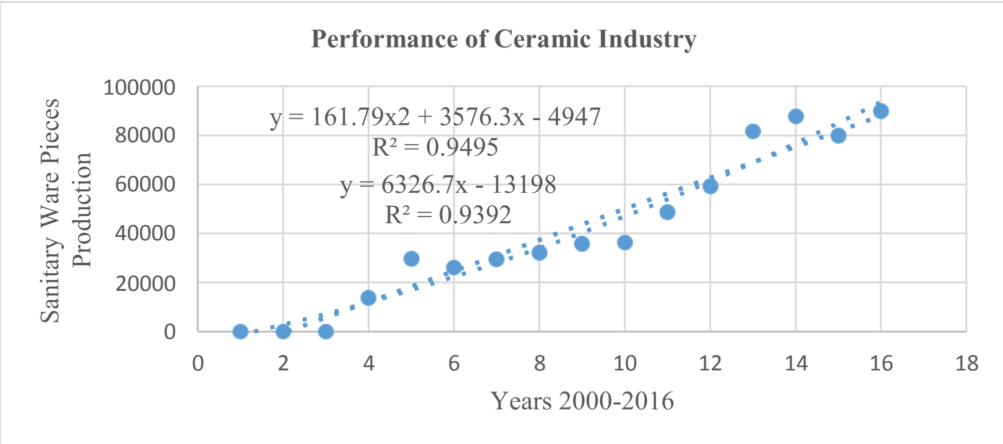

Figure 5.1.1
Performance of Ceramic Industry in KP

Figure 5.1.1 shows the performance of Ceramics Industry in KP from 2000 – 2016. A dramatic change is found there in production of sanitary ware pieces in the first five years. From 2001- 2004 noticeably production is there. Then gradually with the passage of time the production has slightly improved for the rest of remaining years and has ended the production with the figure of 89795 ware pieces by the end of 2016 having the R square value greater than 90 percent.

5.2. Performance of Cement Industry in KP

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Figure 5.2.1

Performance of Cement Industry in KP Figure 5.2.1 shows the performance of Cement industry in Khyber Pakhtunkhwa (KP) for the last sixteen years from 2000 – 2016 with the R square value greater than 90 percent. The performance of the cement firm has steeply climbed to Ten Million Tons by the end of 2016 which is a very appealing and captivating figure for the Investors and Businessmen.

5.3. Performance of Cigarette Industry in KP

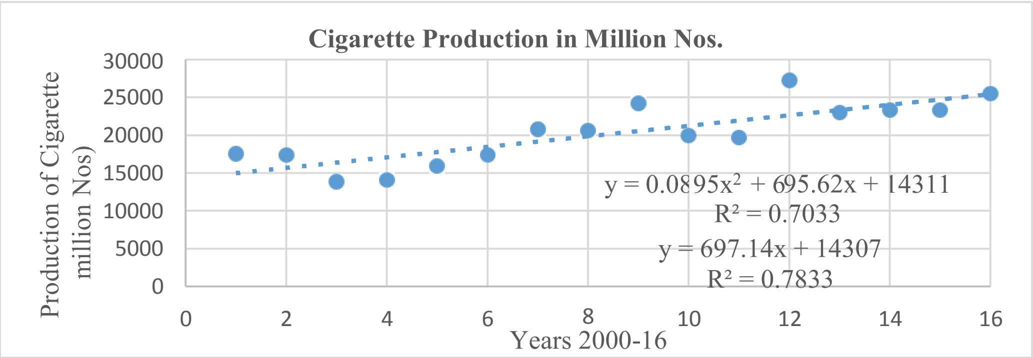

Figure 5.3.1
Performance of Cigarette Industry in KP

Figure 5.3.1 shows the Cigarette production for year 2000-16. The Production no of Cigarette for year

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2000-01 starts with 15000 million. The production of Cigarette fluctuated following a zig-zag path but the whole effect of the graph gradually increases through year 2000-16. The R value shows the co-efficient of determination for productions in different years. The regression line and equation forecasts the production just by putting the value of independent variables.

5.4. Performance of Cotton Textile Industry in KP

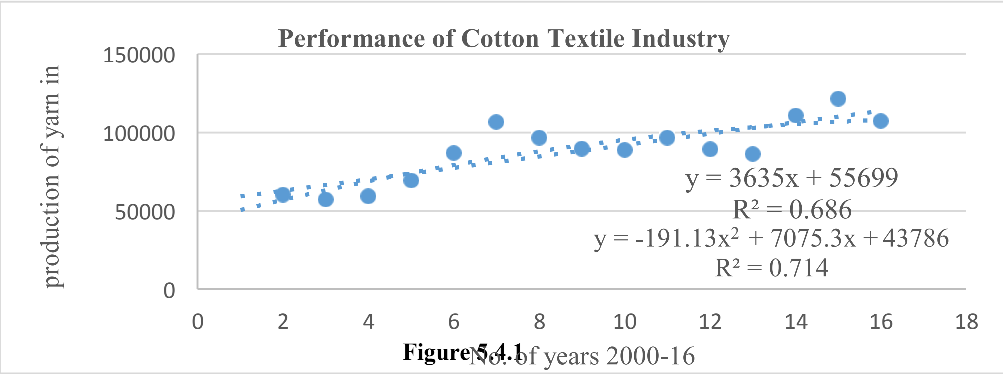

Figure 5.4.1
Performance of Cotton Textile Industry in KP

Figure 5.4.1 shows the Performance of Cotton Textile Industry in Khyber Pakhtunkhwa. The data consist of production of yarn in Cotton Textile Industry in Khyber Pakhtunkhwa since 2000-16. The production is undulated each year following sudden ups and downs. The Production in 2007 steeps up to 100000 Million tons then gradually the steep down following a zig-zag path. The overall trend of the graph shows the production increasing up gradually through passage of time.

5.5. Performance of Beverages Industry in KP

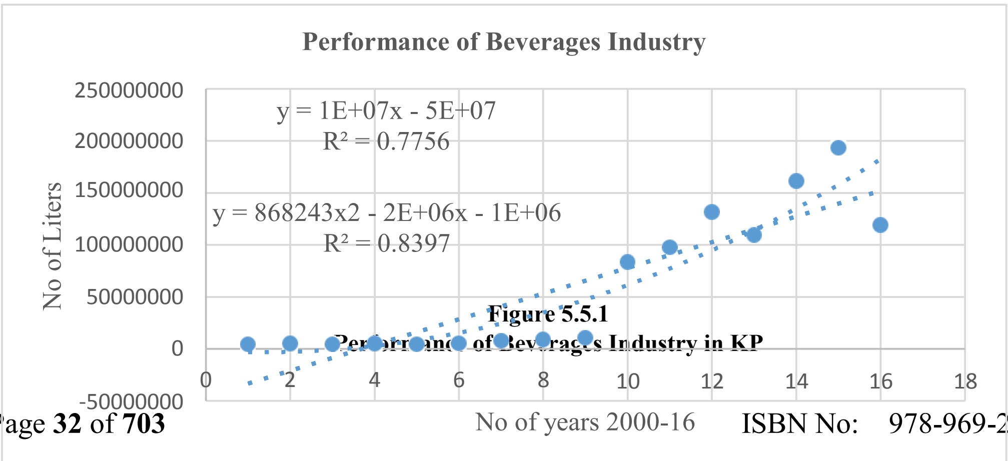

Figure 5.5.1
Performance of Beverages Industry in KP

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Figure 5.5.1 shows the performance of beverages industry in Khyber Pakhtunkhwa, where the x-axis shows time pace in years and y-axis the production in liters including general beverages all type and fruit juices from 2000 to 2016.The production of beverages industry has a steady plate production level from 2000 to 2009 of 4.5 million liters every year with a little bit fluctuation but it start its improvement after 2009 and boost up its production till 2016 with a performance of 190 million liters with slightly up down in production. The gap between 2009 and 2010 is very high which about 70 million liters, However the production is last year of 2016 have a slightly decreasing point up to 119 million.

Similarly, the rest of analysis is also done for remaining seven industries of Kpk and their result in form of linear and quadratic equations and its R^2 value is given in section 6.

6. RESULT & DISCUSSION

Table 6.1 show two type of equation for regression analysis and their two types of coefficient of determination R^2 value one is linear regression equation and it Square value and second is polynomial or quadratic regression equation and it coefficient of determination. This analysis done for identification of potential industries base on their production and set criteria of performance type II, this type of performance has following set criteria:

- Linear equation line should have positive increasing trend as shown in figure 3.2, despite of its R2 value.
- The coefficient of determination R^2 value for polynomial or quadratic regression curve should be more than 0.7000, despite of its curve negativity or decreasing trend.

Most of industry have positive increasing production trend with respect to time but their different annually production have high variability due which its R square values are below from 0.7000, so selection of it in potential industry have high risk in term of prediction their performance in future. Therefore, for reducing the risk for prediction of performance, the R^2 value of quadratic type regression equation analysis will be preferred. But some of industries have negative quadratic equation (decreasing performance curve) although it has high value of R^2 ($R^2 > 0.7000$). So for that reason those industries are selected as potential industry which has type II performance and the rest are drop out and not selected as shown in table 6.1.

Table 6.1
KP major industries performance's regression Analysis
1) Linear regression equation & it's R^2 value 2) Quadratic regression equation & it's R^2 value.

Industry Type	Regression Equation	R^2 value	Selected	Not selected
Cigarette	1).$Y=697.14x+15004$ 2). $Y = 0.0895x^2 + 695.8x + 15007$	1). $R^2=0.7033$ 2). $R^2 = 0.7833$	✓	
Sugar	1). $Y = 5073.8x + 75599$ 2). $Y = 1388.5x^2 - 18532x + 146415$	1). $R^2 = 0.1172$ 2). $R^2 = 0.2647$		✓

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Cements	1). $Y= 571843x+2E+06$ 2). $Y= 25569x^2 +955380x + 1E+06$	1). $R^2=0.9487$ 2). $R^2 = 0.9805$	✓	
Fertilizers	1). $Y = -3248x + 110937$ 2). $Y = -201.23x^2 + 172.86x + 100674$	1). $R^2 = 0.6125$ 2). $R^2 = 0.652$		✓
Woolen	1). $Y = -338.64x + 74818$ 2). $Y = -404.03x^2 + 6529.8x + 54213$	1). $R^2 = 0.0098$ 2). $R^2 = 0.2449$		✓
Cotton	1). $Y = 3635x + 55699$ 2). $Y = -191.13x^2 + 7075.3x + 43786$	1). $R^2 = 0.686$ 2). $R^2 = 0.714$	✓	
Electric Bulb	1). $Y = -996.82x + 56831$ 2). $Y = -218.45x^2 + 2716.9x + 45690$	1). $R^2 = 0.2871$ 2). $R^2 = 0.5188$		✓
Matches	1). $Y = 160.46x + 2411.8$ 2). $Y = -61.648x^2 + 1146.8x - 382.88$	1). $R^2 = 0.2691$ 2). $R^2 = 0.8543$	✓	
Paper & paper board	1). $Y = 308.81x + 3512.8$ 2). $Y = -47.369x^2 + 1114.1x + 1096.9$	1). $R^2 = 0.1677$ 2). $R^2 = 0.2339$		✓
Vegetable Ghee	1). $Y = 1094.6x + 248730$ 2). $Y = -2290.1x^2 + 40026x + 131937$	1). $R^2 = 0.0086$ 2). $R^2 = 0.6415$		✓
Beverages	1). $Y = 1E+07x - 5E+07$ 2). $Y = 868243x^2 - 2E+06x - 1E+06$	1). $R^2 = 0.7756$ 2). $R^2 = 0.8397$	✓	
Ceramics	1). $Y= 0.0012x + 116.47$ 2). $Y= -2E-08x^2 + 0.0028x + 97.216$	1). $R^2 = 0.6951$ 2). $R^2 = 0.7983$	✓	

The following Industries are selected as potential industries based on Performance Type II where R^2 value for quadratic equation should be more than 0.7 and their increasing trend based on linear regression analysis should have positive trend:

- Cigarette industry is analyzed by linear and polynomial regression line which show that this industry has positive trend of performance which increases with time and their coefficient of determination base on quadratic equation have more than 0.7 as 0.7833 > 0.7000, so we conclude that this industry has potential for future and will survive in competitive environment of CPEC in Kpk.
- Cement industry is the most vital industry for construction activities that why their linear regression equation has positive trend from 2000-2016 and its quadratic regression curve have high value of R^2, that why it is selected as a potential industry.
- Cotton industry is selected as a potential industry because it has positive trend in linear regression equation although it has lower value of R^2 than 0.7000 but its quadratic regression equation has high value of R^2, that's why based on its performance type it is selected.
- Beverages industry is covering the condition of performance type II due to which it is selected as a potential industry.
- Ceramics industry is also potential industry as it has positive increasing trend in linear regression equation line despite of R^2 value that is lower than 0.7000 but its quadratic regression equation has high value of R^2 (0.7983>0.7000). therefore, based on its performance type II it is selected.
- Matches industry is selected because it has positive increasing trend in linear equation and its quadratic regression equation R^2 value is 0.8543>0.7000, while ignoring the first one R^2 value as its performance is covering the condition of type II performance.

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The rest of industries are not selected as a potential industry because they have low value of R^2 and performance is going to decreasing side, as define by performance type II.

- Sugar industry
- Fertilizer industry
- Woolen industry
- Electric Bulb industry
- Paper & Paper board Industry
- Vegetable Ghee industry

7. CONCLUSION

To compete with the international market, the potential industries should need to identify for a region, this will not only show that's company's performance in future but also indicate the resources and market availability in that area. Finding potential industries for Khyber Pakhtunkhwa province of Pakistan is so important that it contribute in KPK region business and industrialization for upcoming era and CPEC. As the industrialization is the main pillar of any country economy level.

Data of main industries have been collected from Bureau of Statistics Khyber Pakhtunkhwa through email and their official website of production performance and have analyzed by regression analysis and identified that industries which have R^2 value high than 7.00.

Through, regression analysis of main industries production level for past time performance in KPK cleared that how much future is bright for it and have maximum chance for government and investors to get advantages from above industries in CPEC planning. Therefore, to make investment and implement new technology in Khyber Pakhtunkhwa, the investors should focus on that industries which are identified in this research paper.

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OPTIMIZING CEMENT TRANSPORTATION COST BY ANALYZING SUPPLY CHAIN NETWORK (A CASE STUDY OF TWO CEMENT FACTORIES)

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ABSTRACT

In this research, we study transport system in CHERAT and KOHAT cement factories located in Khyber Pakhtunkhwa, Pakistan, to develop an optimized system for cement delivery. Three alternatives have been analyzed. The first alternative is the one that is currently implemented that is transportation takes place through large vehicles for transporting cement from factory to market and then to each retailer within the city. Second alternative recommends that there should be a warehouse for each dealer from where the transportation to retailers will take place through small vehicles. Finally, the last alternative recommends that there should be a single warehouse for the whole city of Peshawar and the distribution scenario will remains the same as in the second alternative. A comparison is drawn for all the three alternatives and the solution with maximum savings is recommended; which in this case is the second alternative.

Keywords: Cement, transportation, warehouse, alternatives, analysis, optimization, savings.

1. INTRODUCTION

Cement has played a major role as a construction material in the history of civilization. In Pakistan, the use of cement in the large civic works can be traced from the increase in number of cement factories. CHERAT cement industry was started in 1981 and by the end of 20th century CHERAT cement became a popular brand throughout the country. Currently it is transporting most of its cement within the KPK (Khyber Pakhtunkhwa), Pakistan. KOHAT cement industry was also initiated in 1984 and earned a high reputation in the market within a few years after establishment. Today KOHAT and CHERAT are tough competitors and try to provide best quality in order to achieve a stable customer demand. These factories transport its cement to different locations based on the demand. The transportation takes place through various types of vehicles having different capacities including 300, 400, 700 bags per vehicle. Since the cost of the cement at different location differs from each other as it includes the freight cost, therefore, transportation plays a very important role in the cement factories.

In today's modern world, transportation has achieved a vital position and a minor delay in the transportation can result in a huge loss [1]. People plan more efficiently for the factors that might cause delay in transportation. By addressing some problems of domestic roads for the transportation, we may find that the transportation agencies only serve to move products regardless of management principles [2]. The importance of transportation can be gauged from the fact that some consider it as economic development matrix while others deem it as backbone for development [3] The necessity of planning for efficient transportation has gained importance over the period of time and is considered as one of the criteria for development that depends on the effective and optimal utilization of resources for moving products from production facilities to markets [4]. The presence of efficient and appropriate transportation network is one of the paramount infrastructural factors for development in any country in order to meet its transportation requirements [5].

In 4th National Congress on Civil Engineering, Sajadi et al (2011) proposed a model for increasing the efficiency and lowering cost of transportation system [6]. In this study, the main objective was considered as increasing efficiency of organizational man- power along with minimization of costs by means of timetable schedule for workforce in the field of transportation system. Operational methodology was adapted to prepare model in this problem and the given model has been solved by the aid of goal programming [7]. Afandizadeh Zargari et al (2011) presented as essay under title of "Design of transportation net- work under variable demand condition" in 6th National Congress on Civil Engineering. In this article subject of the quality of effectiveness of demand variations on subject of designing discrete transportation network was explored [8]. Moghiseh et al (2009) studied dynamic optimization of transport of sunflower oil seed cargoes in Iran. This investigation has been carried out by aiming at presentation of a mathematical model of dynamic transport to determine optimal plan for transportation of sunflower oil seeds from production regions and entry points (as supply centers) to oil extraction factories (as consumption centers) [9]. Shih LH (1997) in a study reviewed cement transportation by means of linear programming in order to lower cement distribution cost at western part of Taiwan. The results showed that the given transport cost was reduced to 74.1million USD by execution of

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cement transport plan [10].

In another study that was done by Milan et al (2003) under title of "Sugarcane transportation in Cuba", they examined the way of lowering cost of sugarcane shipment from production areas to factories by the aid of linear programming. Results of this study indicated that in the case of executing the suggested scenario, shipment cost would be deduced 41893USD per a day [11]. Transport framework is one of the noteworthy financial movements among the elements of business coordination frameworks. One-two third of the costs of endeavors' coordination costs are spent on transportation [12].
Transportation has been playing a major role in the economy of an industry since the beginning. A large amount of research work is available regarding transportation of cement. Different regions and countries have different types of methodologies and procedures for transporting the cement to its destination point [7]. Current situation of cement transportation in Pakistan needs to be improved and it has the potential to be at a better point if it uses proper techniques and process for transportation of their products. Currently the cement transportation takes place through heavy vehicles. These vehicles distribute the cement to each and every retailer that is a source of cost. Further these vehicles must have to travel through night in the main cities that is also one of the major problems. Since the research work mostly belongs to foreign countries where these problems are not addressed in the research. This research is aimed to help the cement sectors in Pakistan regarding transportation problems.

2. PROBLEM STATEMENT

Both the cement factories (CHERAT and KOHAT) transport their product by using different large vehicles. The transportation from these factories to customers (Retailers) takes place via a third party known as dealers. Dealers link the factory to the retailers from which the end user get the product. The demands from the retailers are generated and received by the dealers. The demand is forwarded to the industry and the order is then released according to the demand. The dealers do not have their own warehouse or any other place where the order can be unloaded and stored. These orders are transported directly to the retailers who have placed the order through different types of large vehicles. These retailers are located at different places and at a certain distance from each other. Since each retailer does not have too much demand to be transported in large vehicles therefore these vehicles transport demand of different retailers at a time and then unload the product at individuals 'place. Next, these vehicles have to be transported from one retailer to other that may be a major source of cost. Furthermore, cities like Peshawar do not allow large vehicles to travel during the day time in the city and have to wait till night and then transport and unload the demand.

3. OBJECTIVE

This study will try to analyze the transportation cost by determining how much impact it has on the total cost. This study aims to suggest solutions on how to minimize the overall transportation cost.

4. METHODOLOGY

Khyber Pakhtunkhwa province has several cement industries and these cement industries are commonly use the same methods of transporting their product to the customers. The information has been gathered from two most known cement production plants, Cherat and Kohat cement factories. Data has been collected in the form of questionnaire, interviewing employees and from their transportation log books.

After a detailed literature review and consultation with experts, the questions for the questionnaire were developed. In addition to the questionnaire response, to reach the problems' root cause, interviews were also conducted with various employees of the organizations mentioned above and data was collected. The analysis is based on to locate a warehouse for individual dealer or for a whole city, where the entire demand will be unloaded and then the transportation to retailers will take place through smaller vehicles. In addition, in the current scenario the demand is placed on weekly or monthly basis while the proposed solution will use a daily basis demand. The analysis will be made between the two proposed scenarios and one current practice and the one with the lowest cost will be suggested. The parameters and notations are as follow:

D_x= Demand of retailer x (No. of bags)

F_x= Freight cost for retailer x (Per bag)

I= Increase per ton per kilometer ($)

T_{dx}= Daily transportation cost of retailer x ($)

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R_d = Retailer to retailer distance (Km)

T_{Rrx}= Retailer to retailer transportation cost for x ($)

T_x= Total transportation cost of retailer x ($)

T= Total transportation cost for each dealer ($)

Latx= Latitude of retailer x

Lonx= Longitude of retailer x

C= Central location

X= X-coordinate

Y= Y-coordinate

Rc= Distance of retailer from C (Km)

Ts= Smaller Vehicle transportation cost ($)

Tsx= Smaller Vehicle transportation cost for retailer x ($)

Each of these alternative is being explained here.

Alternative 1: It is the one that is currently implemented.

$$T = \sum Tx \tag{1}$$

$$T_x = T_{dx} + T_{Rrx} \tag{2}$$

$$T_{dx} = F_x * D_x \tag{3}$$

$$T_{Rrx} = (I * R_d)/20 \tag{4}$$

20 bags of cement carry 1 ton of cement.

Alternative 2: Individual warehouse for each dealer has been analyzed here.

$$X = D_x * Lat_x \tag{5}$$

$$Y = D_x * Lon_x \tag{6}$$

$$C = [(\sum X/\sum Dx), (\sum Y/\sum Dy)] \tag{7}$$

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$$T_{sx} = T_s + R_c \quad (8)$$

$$T_x = \mathrm{F} + \mathrm{T}_{sx} \quad (9)$$

$$\mathrm{T} = \sum Tx \quad (10)$$

Alternative 3: It is similar to alternative 2 except the warehouse is city based i.e., for whole city there is only one warehouse located from which all the dealers will distribute product their respective retailers. Same formulae are used for this case as the second one.

5. DATA COLLECTION AND ANALYSIS

For data collection and analysis, tools like MS excel is used and the "Center of gravity" method has been applied throughout. The data was gathered independently for each industry regarding their number of dealers, retailers attached with each dealer and demand for each retailer.

The data collected at this stage included number of retailers for each dealer and the demand of each retailer. Now the data obtained in the form of demand for each retailer is further analyzed. For further analysis, freight cost is used that depends upon the distance from factory to customer and then from retailer to retailer, it varies with some fixed proportion. The distance from retailer to retailer was found out from google maps. An increase in the transportation cost from retailer to retailer was witnessed. In the present scenario, the total transportation cost is calculated as the summation of both the transportation cost from factory to first retailer and then from that retailer to other retailers. The calculations are done in such a manner that the transportation cost is found out by multiplying the freight cost per bag with the number of bags for each retailer. For the primary retailer where the vehicle arrives directly from the industry, total transportation cost remains the same whereas for the secondary retailers i.e., the one where the vehicle travels after unloading the demand at the primary retailer, total transportation cost does not remains the same. It includes the cost of traveling from primary retailer to the secondary retailer and is found out by multiplying the number of kilometers between the retailers and the additional cost per kilometer.

A second alternative is developed where a warehouse is established and the distribution takes place from the warehouse to the retailers.

To calculate the total transportation cost, the cost associated with warehouse was taken into consideration from where the cement has to be transported to the retailers. A warehouse for each dealer has been selected using center of gravity method.

Each dealer has its own retailers. These retailers are located on some distances from each other therefore their longitudes and latitudes were identified using google maps. The longitude and latitude are not enough to find a central location for warehouse. Hence, these values are further multiplied with the demand values that provide values for x and y-coordinates.

In order to find the central location for each dealer, center of gravity is applied. All the values of x-coordinate for each retailer is summed and then divided by the number of retailers, providing the x-coordinate for central location. Similarly the y-coordinate for central location is found out in the same manner. These x and y-coordinate presents location for the central warehouse for each dealer. Now the distance of each retailer is find out from the respective central location and smaller vehicle was considered for transporting the cement to each retailer. Finally, the total transportation cost is determined by summing the small vehicle transportation cost with the warehouse delivery freight cost from the factory.

This alternative provided a location for the warehouse for each dealer and the cost associated with each warehouse was find out that proved to be an effective choice as compared to the first one where there was no warehouse.

Now, another alternative is presented in which one central warehouse for the whole city is to be located and used by all the dealers to supply cement to their respective retailers. The rest of the methodology followed here is the same as the second one.

6. RESULTS

The total transportation cost via use of heavy vehicles like truck and trailers and small vehicles has been calculated, therefore these should be compared so that the difference is find out and saving are revealed (if any).

Since alternative one is currently implemented, therefore it is first compared with the second alternative and then compared with third alternative. In the comparison of first and second alternatives, savings for each dealer on the basis of individual warehouse is find out, while in the comparison of first and third alternative, savings are find out on the basis of Peshawar based warehouse. The total transportation cost comparison for alternative 1 and 2 for individual dealer of kohat and Cherat factories are graphically represented in Fig.1 and Fig. 2 respectively.

Table. 1: Total transportation cost (Rupees) for alternative 1 and 2 for each dealer of Cherat cement Factory

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Alternatives	Dealer 1 (Cost)	Dealer 2 (Cost)	Dealer 3(Cost)	Dealer 4 (Cost)
Alternative 1 (Currently implemented)	13015.125	9369	10514.8	13347.6
Alternative 2	4897.5	1175	4265	6026.5

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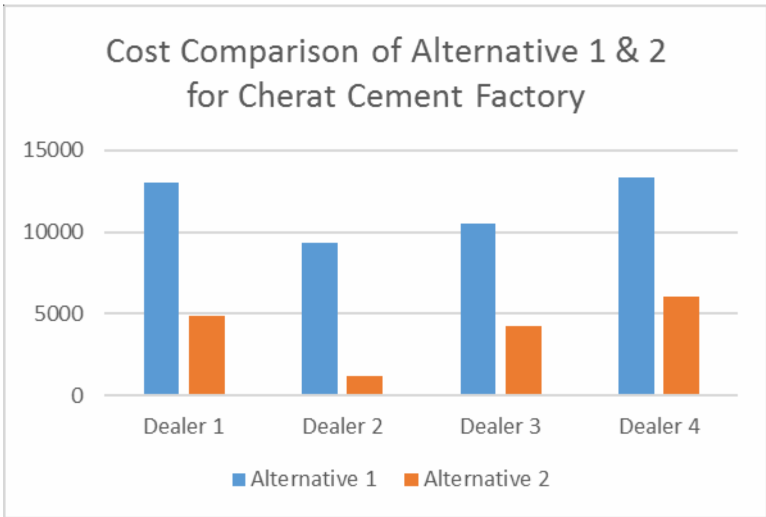

Figure. 1: Cost comparison graph (Rupees) for alternative 1 and 2 for Cherat Cement Factory

Table. 2: Total transportation cost (Rupees) for alternative 1 and 2 for each dealer of Kohat cement Factory

Alternatives	Dealer 1 (Cost)	Dealer 2 (Cost)	Dealer 3 (Cost)	Dealer 4 (Cost)
Alternative 1(Currently implemented)	8756.4	13269.3	9416.5	11600.975
Alternative 2	3425	4060	1925	4584.5

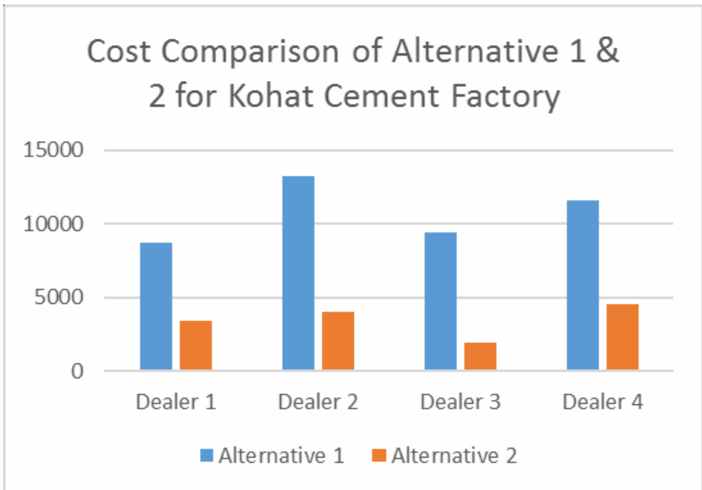

Figure. 2: Cost comparison graph (Rupees) for alternative 1 and 2 for Kohat Cement Factory

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The total savings for the four dealers of KOHAT cement factory sums to Rs. 29048.675 per day. It is an average saving on daily basis.
Similarly, for CHERAT, the total savings for the four dealer sums to Rs. 27971.1 per day. This analysis of different scenarios shows that a large amount of money that can be saved by using the alternative 2 as shown in table 1 and respectively way of transporting cement to the retailers instead of transporting it through heavy vehicles and weekly/monthly basis.

Since alternative 1 is the one that is currently implemented and the savings for alternative 2 and 3 are find out by comparing it with the first one and the savings for alternative 1 cannot be find out directly therefore the comparison between all the three alternatives is shown in terms of total transportation cost for both factories. The total cost comparison for Cherat Cement Factory is shown in the table. The Cost comparison is also shown in pie chart in figure3 and the cost comparison for Kohat cement factory is shown in Table 4 and the pie chart is shown in Figure 4.

Table. 3: Total transportation cost (in Pakistan Rupee) of each alternative Cherat Cement Factory.

Alternatives	Total Transportation Cost (Rupees)/day
Alternative 1	46245
Alternative 2	16363
Alternative 3 (Present Scenario)	24472

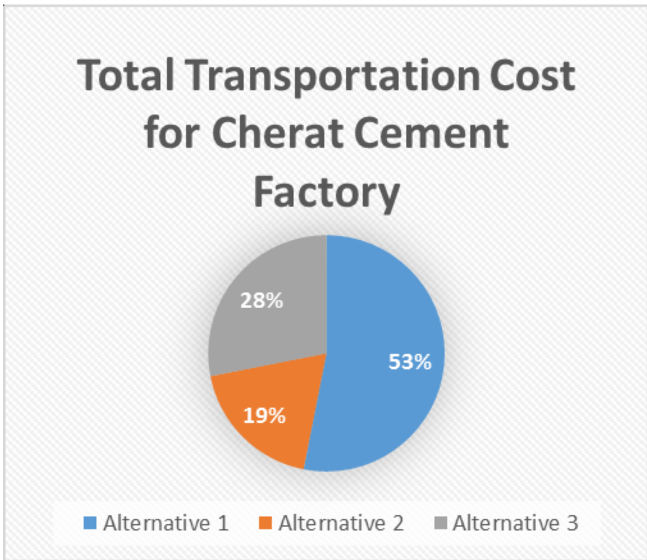

Figure. 3: Cost comparison graph (in Pakistan Rupee) of the three alternatives for Cherat Cement Factory

Table.4: Total transportation cost of each alternative Kohat Cement Factory

Alternatives	Total Transportation Cost (in Pakistan Rupee)/day
Alternative 1	43041
Alternative 2	13994
Alternative 3	19886.5

To check the alternative 3 a central warehouse has to be located which will serve the whole city. The difference in savings between transportation through small vehicles and transportation through heavy vehicles is calculated which will contribute towards the total savings for the 3rd alternative.

While implementing alternative 3, the savings for KOHAT cement dealers are 23156 rupees per day which is less than the 2nd alternative. Similarly for CHERAT cement dealers the savings are 21478 rupees per day that is also less than 2nd alternative.

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Since three alternatives have been analyzed for the individual factory therefore both these factories are being compared in terms of each alternative.

- Referring to alternative 1, Kohat cement factory provides lower cost as compare to Cherat cement factory. An amount of PKR 3204/day can be saved.
- Considering alternative 2, an amount of PKR 2369/day could be saved by choosing Kohat cement factory rather than Cherat cement.
- Comparing alternative for both factories, Kohat cement represents better option for Peshawar market as it could save an amount of PKR 4586/day as compare to Cherat cement.

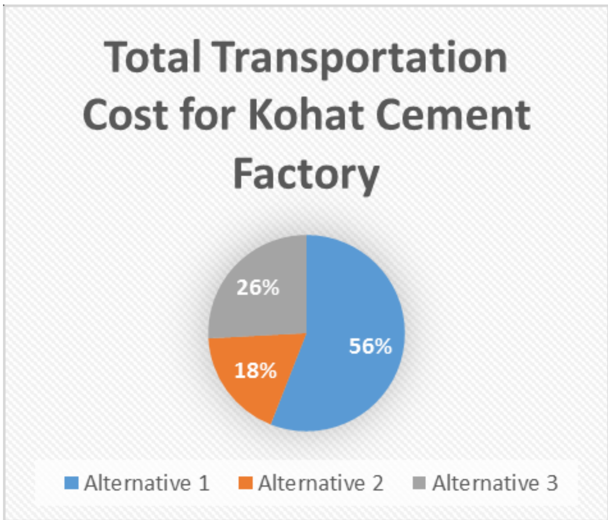

Figure.4: Cost comparison graph (in Pakistan Rupee) of the three alternatives for Kohat Cement Factory

Comparing each alternative in terms of cost for both factories, Kohat cement would save more money for a dealer in Peshawar city rather than Cherat cement. Transportation cost for Cherat cement is more than that of Kohat that could be a risk of losing market share in Peshawar city. On the basis of this comparison it could be inferenced that Kohat cement would be more profitable as compare to the other one due to low cost of transportation as compare to others.

7. CONCLUSIONS

As inferred from the title of the study conducted, the main purpose is to carry out research on optimization of transport system in cement manufacturing factories. By analyzing the current transportation and distribution system of both factories, the reason for increasing cost is the use of heavy vehicles for sub-distribution i.e. transportation from retailer to retailer. These vehicles are used for the transportation of cement from factory to the market and then within the market from retailer to retailer. This study suggests that dealers should have a warehouse where the demand from the factory will directly be unloaded and then the sub-distribution within the market from retailer to retailer will take place through small vehicles.
The other finding derived from this study suggests that if the transportation to the retailers is maintained on a daily basis rather than weekly/monthly basis, can result in a large amount of cost reduction. The distribution schedule from factory will remains the same as existing but sub-distribution will be updated to daily basis.

8. RECOMMENDATIONS

With respect to the given results and comparison of the three alternatives, it is better for the dealers/distributors to have their own warehouse from where they can distribute cement to their retailers on a daily basis through small vehicles. One more thing that must be considered is the cost of warehouse. This consideration may oppose the selection of second alternative that is each dealer having its own warehouse. By including such cost, the savings in alternative 3 increases comparatively but it doesn't exceed that of the second alternative. Therefore, it is suggested that the second alternative should be selected that is to have individual warehouse for each dealer from where they can distribute cement to its retailers individually, while the transportation from factory will take place to respective dealer's warehouse. The rest of the transportation from warehouse to retailer will be done through the use of small vehicle.

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ADDRESSING THE HUMAN FACTORS ASSOCIATED WITH SMALL SCALE INDUSTRIES

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ABSTRACT

In today's Environment every industry at risk, the human and organizational factors constitute the main stakes for safety. Furthermore, several events at industry have been used to develop appropriate risk models. The investigation on industrial accidents is, nowadays, a very important tool to identify the problems related to human factor and can support accident prevention and the improvement of industrial safety. Operation of machines is full of regulations, instructions and guidelines also addressing human factors and safety culture to enhance safety. However, even though the roots of a safety culture have been established, there are still serious barriers to the breakthrough of the safety management. One of the most common deficiencies in the case of small industries working is the respective monitoring and documentation usually lacking of adequacy and excellence. Nonetheless, the small scale industries can be exemplified from other large scale industries where activities are ongoing to foster and enhance safety culture. Basically this paper addresses the basic human factors associated with small scale industries like poly carpets factory, match factory, local textile industry, furniture factory, services industries like hospital's and transport etc... A worker and his work interrelates to each other in many aspects that have been clearly identified and mentioned in this paper. Clumsy positions while handling a job, force and repetition of various movements has been considered as the important human factors by previous research work. Poorly designed layouts resulting in various types of musculoskeletal disorders and extreme temperature conditions are also observed as major human factors. This research work will increase consciousness among the workers about human factors that may occur in small scale industries.

Index Terms: Human factors, Ergonomics, layouts, musculoskeletal disorders, Risk factor and MSDs'S.

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"1. INTRODUCTION"

The strengthening of safety culture in an organization has become an increasingly important issue for all high risk industries. A high level of safety performance is essential for business success in intensely competitive global environment. The most important objective is to protect individuals, society and the environment by establishing and maintaining an effective protection against the respective hazards

To describe the concept of ergonomics, numerous researchers have given a variety of definitions

The ergonomics is used to relate humans to their job. It addresses the psychological, behavioral and physiological factors of humans. On the basis of ergonomics study and the capabilities and limitations of the factors, experts and professionals can design a work environment or may modify the existing surrounding on the basis needs and requirements.

Ergonomics focus on the safety of the worker. It defines and measures the capabilities and limitations of a worker and then compare it with the job assigned to that worker so that one may not face health issues. Ergonomics promises optimum productivity by providing safe and productive workplace to the workers. Management achieves their goals and objectives by implementing ergonomics.

Ergonomics focus on improving quality, productivity and safety by fitting products, tasks and environments to people instead of forcing people to adapt to the work. Nature of work, its environment and the worker is considered for fitting the work to the worker.

The term Ergonomics has been defined by different researchers from time to time. Some of its definitions are highlighted as follows:

Ergonomics is a combination of the words ergo, a Greek word meaning "work" and Ergonomics, meaning "study" - the study of work. An applied science that co-ordinates the design of devices, systems and physical working conditions with the capacities and requirements of the workers. (Pao & Kleiner, 2001)

A branch of science that is concerned with the achievement of optimal relationships between workers and their work environment. (Bhattacharya, Talbott, & Kincl, 1997)

Promoting compatibility between humans and systems. (Lee, 2005)

The design of the workplace, equipment, machine, tool, product, environment and system, taking into consideration the human's physical, physiological, biomechanical and psychological capabilities and optimizing the effectiveness and productivity of work systems while assuring the safety, health and wellbeing of the workers. In general, the aim in ergonomics is to fit the task to the individual, not the individual to the task. (Fernandez, 1995)

A system of interacting components which includes the worker, the work environment both physical and organizational, the task and the workspace. (Brooks, 1998)

A common definition that can be derived from the above stated definitions is the interactions of humans, job design, machine systems and work systems.

"2. LITERATURE REVIEW"

A wide range of working conditions that can affect the worker's health are considered by ergonomics. Some of the factors that results in such situation includes temperature, vibrations, heavy loads, noise, lighting, repetitive tasks, designed workstations, tool design, chair design, work envelope and footwear etc. Shift work, meal schedules and

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breaks are also considered as major factors. These factors usually result in musculoskeletal disorders (MSDs) because of job interaction with muscles and tendons. About 90% of aged workers are victims

of MSDs.(Yelin, Trupin, & Sebesta, 1999) Billions of dollars are required to treat these MSDs.(Praemer, Furner, Rice, & Kelsey, 1992) From these statements, importance of ergonomics is realized in order to prevent these issues from further destruction.

In 1993 Sanders and McCormick The discovers and applies information about human behavior, abilities, limitations, and other characteristics to the design of tools, machines, tasks, jobs, and environments for productive, safe, comfortable, and effective human use. Then in 1995 Moray Ergonomics is concerned with the design of behavior. The same year Wilson and Corlett presents the practice of learning about human characteristics and then using that understanding to improve people's interactions with the things they use and in the environments in which they do it. In 1997 Tayyari and Smith states that Ergonomics is a branch of science that is concerned with the achievement of optimal relationships between workers and their work environment. In 2000 Dempsey states Ergonomics is the design and engineering of human-machine systems for the purpose of enhancing human performance. The same year IEAT, the scientific discipline concerned with the understanding of interactions among humans and other elements of a system, and the profession that applies theory, principles, data and methods to design in order to optimize human well-being and overall system performance. Also in 2000 Wilson Ergonomics is the theoretical and fundamental understanding of human behavior and performance in purposeful interacting socio-technical systems, and the application of that understanding to design of interactions in the context of real systems. Later 2005 Lee presents that, Ergonomics is concerned with promoting compatibility between humans and systems.

This research view article made an attempt to review such issues pertaining to handicraft sector. It highlight/covers following aspects in detail: ergonomics interventions in handicraft industries, occupational risk factor, and musculoskeletal disorders. The literatures over a decade reported that ergonomics concepts are more applied in large-scale industries like steel plant, power plant, manufacturing plants, automotive sectors etc. rather than small-scale industries like handicraft. However, applying ergonomics concepts/principles in such industries would definitely lead to increase in the work-system-worker productivity by improvement in tools, methods, work-environment, minimizing injuries and disorders. Based on literature studies recommendations are made that significant lead to improvement in productivity of such industries.(Meena, Dangayach, & Bhardwaj, 2016)

"3. ERGONOMICS RISKS FACTORS"

Usually a workplace is designed in such a manner to achieve optimum efficiency by maximum utilization of workstations. People are normally so adaptable to the work that even there is not felt need of designing a job to fit to the human. Due to lack of attention, the number of injuries caused by repetitive motions, excessive force and awkward postures has been increasing day by day. Ergonomics and human factors are often used interchangeably in workplaces. Both interrelates worker and the job demands. The basic difference is that ergonomics focuses on how a worker is affected by the work and human factors focuses on workplace design in order to provide safety.(Stubbs, 1995) Bongers in his work states that by addressing traditional and environmental risk factors, it can keep worker's injury free. (Bongers, Kremer, & Laak, 2002)

Risk and risk factors are general terms in the literature of safety and ergonomics. Risk is defined as the chance or probability of occurrence of an event and the seriousness of consequence or severity of the event. It can also be defined in terms of number of injuries or accidents resulted for a given exposure. Injuries can have categorized into two classes: one having low probability of occurrence but high severity of consequence and the other with high probability of occurrence but low severity of consequence such as slipping etc.

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Risk depends on the work environment. It may be within the work envelope or outside of the work environment that is in surrounding. Risk provides the probability of injury and the level of injury depends upon the level of risk and exposure time. Exposure time can be easily reduced as compare to elimination of the risk of the injuries.

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A site might have the risk of injury but it can be eliminated by providing proper measures to avoid long exposure times.(Berg, 2013)

Risk factors may be termed as the conditions that increase the likelihood of injury to the musculoskeletal system. Applied ergonomics literature recognizes a small set of common physical risk factors across many occupations and work settings.(Cohen, 1997) Risk factor exposures and the level of musculoskeletal injury risk are interrelated to each other but it is not too simple to be correlated easily. Physical risk factors represent a major category of risks but other risk factor that can indirectly affect the effect of physical risk factors include organizational and psychosocial risk factors. (Stubbs, 1995)

Risk factors have been mainly classified as biomechanical exposures, psychosocial stressors and individual risk factors. (Bongers et al., 2002)Poorly designed workstation, repetitive tasks, heavy loads, high forces and deviations from neutral body alignments are related to biomechanical exposures. (Council)Psychosocial stressors at work include factors such as high-perceived workplaces stress, low-perceived social support, low perceived job control, and time pressure (Bongers et al., 2002);(Rani, 2003). Factors related to gender and age, negative stress reactions and unsatisfactory leisure time or additional domestic workload are classified as individual risk factors.

Repetition, force, awkward posture, vibration, contact stress, static loading and extreme temperature are considered as primary ergonomic risk factors. Risk factors exposure represents an initial warning of more serious problems such as physical signs and symptoms that can lead to serious injury. Every work is at risk. The duration of exposure depends upon the severity of the risk, the more the exposure time more is the case severe and vice versa. Quality of life is reduced with long-term exposure. MSD injury risk can be minimized by becoming skilled in recognizing and categorizing the factors, reducing the frequency and exposure to these risk factors. Reducing risk factor exposure should make task smoother, more predictable and less variable in performance.

Although the causes of any particular case of a MSD are exceedingly difficult to identify with complete accuracy, certain risk factors are typically discussed in the field of ergonomic studies. Nevertheless, these are common factors that may give rise to a MSD in some combination and in some people. The Ergonomics Risk Factors (ERF) that are discussed in this study includes:

- Awkward postures
- Bending
- Compression or contact stress
- Forceful exertions
- Insufficient rest breaks
- Lifting
- Lighting
- Noise
- Pushing, pulling
- Reaching
- Repetitive motions
- Static or sustained postures
- Temperature extremes
- Vibration

3.1. Repetitive motions

Back pain represents the significant percentage of injuries caused by repetition (Bernard & Putz-Anderson, 1997) Repeated identical or comparable motions performed over a time frame could cause over-extension and overuse of

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certain muscle groups, which could lead to muscular fatigue. Strangely, indications often relate not

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to the tendon and muscle groups involved in repetitive motions, but to the stabilizing or antagonistic tendon and muscle bunches used to position and balance the extremity in space.

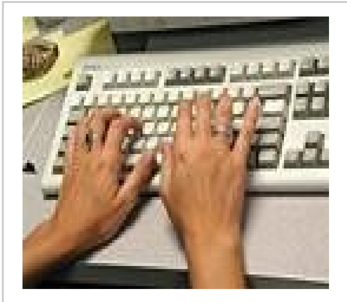

Fig.1. Back pain and hand pain resulting from repetition (Bernard & Putz-Anderson, 1997)

Sometimes, by varying tasks, muscle groups have periods of activity alternated with periods of rest, which may be beneficial in reducing the possibility of injury. Repetition also is the time quantification of a similar exertion performed during a task. A warehouse worker may lift and place on the floor three boxes per minute; an assembly worker may produce 20 units per hour. Repetitive motion has been associated with injury (Westgaard & Winkel, 1997) and worker discomfort. Generally, the greater the number of repetitions, the greater the degree of risk. However, the relationship between repetition and degree of injury risk is modified by other risk factors such as force, posture, duration, and recovery time. No specific repetition threshold value (cycles/unit of time, movements/unit of time) is associated with injury.(Armstrong, Radwin, Hansen, & Kennedy, 1986)

3.2. Force

Force is the mechanical or physical effort to accomplish a specific movement or exertion. Force can be defined as the amount of physical effort required to perform a task (such as lifting) or to maintain control of equipment or tools. Exerting a force on a person or object may overload our muscles and tendons. The force may come from gripping, lifting, pushing or pulling. The force that a worker exerts on an object is a primary risk factor. Muscles and tendons can be overloaded when you apply a strong force against an object. There are three types of activity that require force such as force involved in lifting, lowering, or carrying, force involved in pushing or pulling and grip force. In other word, force is the amount of physical effort required by a person to do a task or maintain control of tools or equipment. (Janowitz et al., 2006)

Task forces can be viewed as the effect of an exertion on internal body tissues (e.g. compression on a spinal disc from lifting, tension within a muscle/tendon unit from a pinch grasp), or the physical characteristics associated with an object(s) external to the body (e.g. weight of a box, pressure required to activate a tool, pressure necessary to snap two pieces together). Generally, the greater the force causes the greater the degree of risk. High force has been associated with risk of injury at the shoulder, neck, low back, forearm, wrist and hand. It is important to note that the relationship between force and degree of injury risk is modified by other work risk factors such as posture, acceleration/velocity, repetition, and duration.

3.3. Vibration

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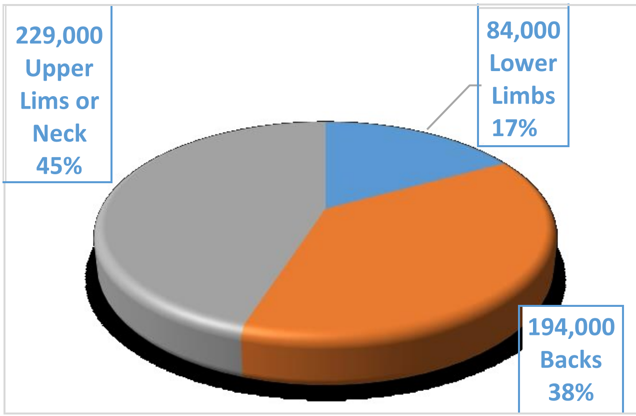
Vibrations occur when an object oscillates or rapidly moves back and forth about its stationary point, like a swinging pendulum. Vibrations are defined by the frequency (how fast the object is moving) and the magnitude or amplitude (the distance of the movement). Vibration may be defined simply as any movement which a body makes about a fixed point. This movement can be regular, like the motion of a weight on the end of a spring, or it can be random.

Vibration has been found to be an etiological factor in work environments utilizing tools vibrating in the frequency band of 20 to 80 Hz. For example, use of a chain saw or powered wood working tools for extended periods of time.

Vibration gives effects such as damage caused to body organs as a result of their being buffeted by high vibration levels at relatively low frequencies and breakdown of body tissues due either to continued resonance or to their absorption of high energy vibration. Exposure of the whole body to vibration (usually through the feet/buttocks when riding in a vehicle) has some support as a risk for injury. The following figure represents the result of survey taken in Europe. (Westgaard & Winkel, 1997)



Using a vibrating tool

Fig.2. Percentage of injuries caused by the body (Westgaard & Winkel, 1997).

3.4. Awkward Posture`

The term Posture is defined as the arrangement of body parts and limbs. Awkward posture represents the arrangement of the body parts in a wrong manner that can results in stress. Muscles, tendons and ligaments are stressed when working in awkward posture. Awkward posture usually results when a part of the body moves outside of its comfortable range of motion or too much bends or twists. Some of the examples of work activities that can results in awkward postures include:

Inclining sideways

Moving down while working at low level Reaching

overhead

Flaring the elbows to the sides Wrist bending

while moving objects Bending the neck

Twisting of different parts

Poor posture

All these postures produce stress that are directly proportional to exposure time. The position of a part of the body with the adjacent part is defined as a posture. Postural stress is introduced as an extreme posture at a normal range of motion. One of the most occurring occupational risk factor is posture. (Westgaard & Winkel, 1997) Every joint of the body has a

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specific area of movement in which it can move comfortably without inducing any pain or discomfort. The risks of injuries are increased when there is requirement of the movement outside of the range. Repetitions, prolonged reaching, bending, twisting and static works represents awkward postures. For the upper arm and shoulder area neutral posture is relaxed with the shoulders down and on the same plane, with arms at the side. Shoulder and back represents major area for awkward posture.(Cohen, 1997)

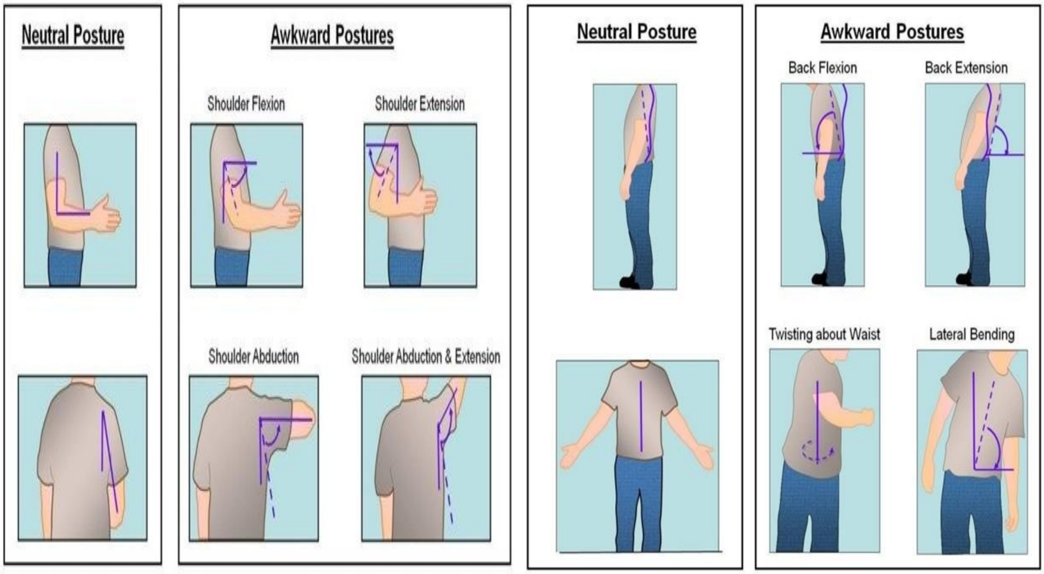

Fig.3. Postures related to shoulder, back and arm angle. (Cohen, 1997)

Working with arms stretched away from the body and outside of the comfortable range of work requires a large amount of muscular force and increases the risk of injury. Sitting positions like tilting sideways, bending forward and twisting vertebral Colom may compensate for a specific duration of time but can results in injury if become habit.

Body twist, tipped shoulders, head tilt/rotation, raised elbows and operating with hands close to the face are associated with increased risk of musculoskeletal symptoms. Risk of injury is creased with awkward posture. The risk of injury is directly proportional to the deviation of the joint. Poor work methods or the methods designed without the risk analysis provides awkward situations. Major awkward postures are associated with low back, neck and shoulder.

3.5. Contact Stress

Injuries caused by solid or sharp objects, equipment and instruments while grasping and balancing. Usually the parts of the body that are involved in this case include wrist and forearms. The risk increases while dealing edges of objects. Muscles and tendons strongly influenced when contacted these edges. Mechanical stresses result in dealing with objects like closing a sharp edged lid that has been raised to a height. Normally interaction of skin with sharp and hard objects results in local contact stress. Such pressures produced by skin and object interaction injure the nerves and tissues beneath the skin.

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Following examples represents local contact stress:

- Interaction of tool handles with the hands that are hard results in contact stress.
- Forearms and wrists interacting with hard and sharp work surfaces.
- Objects colliding sharply with body parts like hands and feet.

Exposure time represents a major factor in the effect of local contact stress. (Carr & Davidson, 2004). The more is the exposure time, the more is the effect and vice versa. Similarly, the area of the body without having much protective tissues such as palm and wrist affects more as compare to other parts of body.

Extreme temperatures that is extreme hot and extreme cold also results in contact stresses. Cold temperature can be defining as a low temperature reduces manual dexterity and accentuate the symptoms of nerve-end impairment. Cold stress results when the temperature of core body is lowered by exposing to too much coldness. Cold stress can be identified by the symptoms like shivering, clouded consciousness, extremity pain, dilated pupils, and ventricular fibrillation.

Heat stress results in exposing to high temperatures. Body internal functions can also result in heat stress.

Heat stroke is a major risk associated with heat stress that can results in death of a human body. Heat exhaustion, heat cramps, and heat-related disorders such as dehydration are less serious conditions associated with heat stress. (Engestrom, 2000)

3.6. Static Loading:

Movement represents a major factor in a human body. A human body is not designed for rest, it must have some movement in order to be comfortable and stable. A single specific position cannot be maintained by it for a long interval of time and hence feels uncomfortable when exposed to such conditions. Driving is a best example for this case. A driver feels tired when he drives for a long time. It is because of the statics position of the trunk of his body. Arms represents maor areafor injuring due to static loading. (Westgaard & Winkel, 1997)

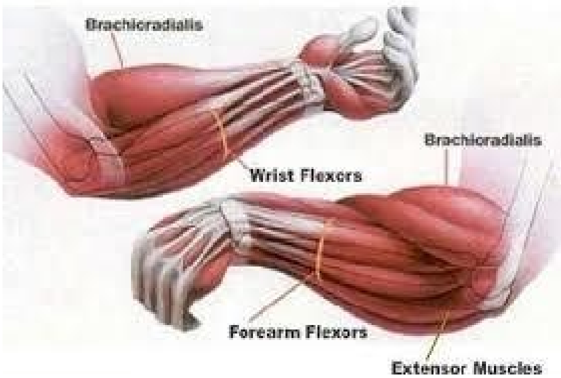

Fig.4. Static loading related muscles. (Westgaard & Winkel, 1997)

Static loading can be defined in a broad way but the basic definitions is to use a single posture maintained during a task for a long period of time. The task may involve force at a specific posture for a certain duration of time. The more the posture is awkward, the more is the risk of injury. The more is the force/load involved, the more is the risk of injury. Similarly, the more is the duration of work, the more is the risk. Risk represent direct relationship with posture, force/load

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and duration.

"4. RISK FACTORS WITH CONTROL METHODS"

4.1. High Task Repetition

Some work tasks and cycles are repetitive in nature, and are regularly controlled by hourly or every day production targets and work processes. High task repetition, when combined with other risks factors such high force and/or awkward postures, can contribute to the formation of MSD. A job is considered highly repetitive if the cycle time is 30 seconds or less.

Control methods to consider:

4.1.1 Engineering Controls – Eliminating excessive force and awkward posture requirements will reduce worker fatigue and allow high repetition tasks to be performed without a significant increase in MSD risk for most workers.

4.1.2 Work Practice Controls – Providing safe & effective procedures for completing work tasks can reduce MSD risk. In addition, workers should be trained on proper work technique and encouraged to accept their responsibilities for MSD prevention.

4.1.3. Job *Rotation* – Job task enlargement is a way to reduce duration, frequency and severity of MSD risk factors. Workers can rotate between workstations and tasks to avoid prolonged periods of performing a single task, thereby reducing fatigue that can lead to MSD.

4.1.4. Counteractive Stretch Breaks to provide an opportunity for increased circulation needed for recovery.

4.2. Forceful Exertions

Numerous work tasks require high force loads on the human body. Muscle effort increases in light of high force requirements, increasing associated fatigue which can lead to MSD.

Control methods to consider:

4.2.1. Engineering Controls – Eliminating excessive force requirements will reduce worker fatigue and the risk of MSD formation in most workers. Using mechanical assists, counter balance systems, adjustable height lift tables and workstations, powered equipment and ergonomic tools will reduce work effort and muscle exertions.

4.2.2. Work Practice Controls – Work process improvements such as using carts and dollies to reduce lifting and carrying demands, sliding objects instead of carrying or lifting, and eliminating any reaching obstruction to reduce the lever arm required to lift the object.

4.2.3. Proper Body Mechanics – Workers should be trained to use proper lifting and work techniques to reduce force requirements.

4.3. Repetitive/Sustained Awkward Postures

Awkward postures put excessive force on joints and overload the muscles and tendons around the effected joint. Joints of the body are most productive when they work nearest to the mid-range motion of the joint. Risk of MSD is increased when joints are worked outside of this mid-range repetitively or for sustained periods of time without adequate recovery time.

Control methods to consider:

4.3.1. Engineering Controls – Eliminate or reduce awkward postures with ergonomic modifications that seek to maintain joint range of motion to accomplish work tasks within the mid-range of motion positions for vulnerable joints. Proper ergonomic tools should be utilized that allow workers to maintain optimal joint positions.

4.3.2. Work Practice Controls – Work procedures that consider and reduce awkward postures should be implemented. In

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addition, workers should be trained on proper work technique and encouraged to accept their responsibility to use their body properly and to avoid awkward postures whenever possible.

4.3.3. Job Rotation – Job rotation and job task enlargement is a way to reduce repeated and sustained awkward postures that can lead to MSD.

4.3.4. Counteractive Stretch Breaks – Implement rest or stretch breaks to provide an opportunity to counteract any repeated or sustained awkward postures and allow for adequate recovery time.

"5.CONCLUSION AND RECOMMENDATIONS"

Ergonomics in small and medium scale industries has been introduced and discussed in this paper. Different risk factors have been analyzed for which proper recommendations has been given. Ergonomics usually interrelate humans, machines, work design and workplace. This interrelation has the basic objective of fitting a task to the worker rather than worker to the task. Risk factors that have been identified through the study were analyzed that could result in various musculoskeletal disorders. Vibration, repetitive tasks, heavy loads, force and awkward postures represent various risk factors that could result from tasks like gripping, pushing, pulling and lifting etc. Similarly, temperature and other environmental factors may also result in various risk factors. Workplace and work envelope also represents a large place for risks factors. It could result in different disorders resulting from uncomfortable positions.

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IMPROVING THE EFFICIENCY BY INTERRELATING SAFETY AND ERGONOMICS IN SMALL AND MEDIUM INDUSTRIES

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ABSTRACT

Safety culture and risk management has become a routine practice for manufacturing firms. Objective of this paper is to define a methodology that clarify the impact of specific ergonomics factors on various safety elements, work space, equipment and tools, the overall working environment and the worker's job. It further shows how to measure these factors quantitati vely and qualitatively and discuss the experimental procedure that can be used to simulate the interrelationship.

1. INTRODUCTION

Today the decrease of cost for workers' injuries, i lness, fa ls, amputation of fingers and other diseases represents an imperative for companies not only for the expected cost saving but also for the achievable work efficiency mostly dependent on the reduced absenteeism and interrupt ions [1]. A challenging perspective is to introduce ergonomics issues in the design of the workspace and in the way workers learn manual operations to ensure their health and prevent potential risks [2] [3]. Literature overview points out that the worker's exposure to risks is directly proportional to a set of wrong movements he/she unconsciously does during tasks execution such as manual handling of heavy loads, movement between different tasks at irregular periods of time, performing of only one function or movement for a long period, sudden lifting of loads, etc.

Awareness of risks coupled with real-time instructions to follows for right assembly while minimizing the cognitive workload could be effective to prevent injuries and keep the work performance high. Numerous are the assessment methods that have been developed in the past years, from the simple check-list to more complex techniques. In the later nowadays are also used Digital Human Models (DHMs) to represent the human presence and actions in a virtual reproduction of the workspace. In this context, the use of technologies, such as Virtual Reality (VR) and Augmented Reality (AR), may be employed to develop Virtual Prototypes in which the degree of presence of user and realism various according to the tracking technologies used. However, lack of objective guidelines that allow ergonomist to choose measurement techniques best suited for the context of use.

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This paper focus on the definition of a multipath methodology to effectively support the measurement of the ergonomic quality of the worker in his workspace and discuses about which parameters could influence the optimal definition of a set-up. Indeed, there are many parameters that can influence the outcome of the measures carried out and thus compromising the quality of the data obtained. The aim is to propose a structured approach for ergonomic evaluation both in real working environment that in an equipped laboratory. The present work starts from the consideration that only if it is possible to link the above-mentioned aspects with the results of human behavior simulations the research can find solutions to manage potential risks. This correlation actually gives evidence of the impact of ergonomics on work efficiency and injur ies' reduction and as a consequence companies are more confident to adopt the proposed strategies.

The proposed methodology is based on 10 steps allows to identify a Critical Path suitable for the use context from which is possible to obtain those that are the requirements for the development of a measuring set-up. The proposed methodology was applied on a real industrial case study concerning a four station manual assembly line of a kitchen hood. The result demonstrates the effectiveness of the proposed solution.

2. RELATED WORKS

Ergonomics (or human factors) is the scientific discipline concerned with the understanding of interactions among humans and other elements of a system, and the profession that applies theory, principles, data and methods to design in order to optimize human well-being and overall system performance. In summary, is possible to define ergonomics as the science of interactions between man and technologies which has the aim to make compatible tasks, equipment, environments and systems with the needs, abilities and limitations of people and therefore to optimize this interactio n to create the best working conditions [4] [5].

Nowadays is always more important the analysis of human factors in industry. The assessment of ergonomics has been recognized to be a key factor for the Risk Management, indeed the control and management of risks factors, such as awkward postures, repetitions and stress, allow companies to prevent accidents, improve the production efficiency and the employees' psychosocial well-being and finally a considerable average saving in yearly rejection cost and rejection rate [6].

In literature there are numerous methods that have been developed to investigate human risk factors during manufacturing operations. The traditional methods are based on direct observation by expert in ergonomics of workers in their workstation that allow the identification of the hazardous positions and movements, the estimation of the workload and the definition of the potential risk. Methods such as NIOSH lifting equation [7], Rapid Upper Limb Assessment (RULA) [8], Rapid Entire Body Assessment (REBA) [9], OCRA [10], Strain Index (ID) [11] and PLIBEL [12] are objective methods based on the posture assessment and on the workloads measure. Subjective methods are based on the observation of the human efforts and discomfort in task execution, such as Perceived Exertion and Difficulty [13] and the Function Job Analysis Technique [14].

Nowadays designers are using a User-Centered Design approach to define the workspace requirements, understood as a set of functions, layout of the equipment and physical dimens ions in order to prevent physical and psychophysical risk for workers. For this purpose, the Virtual

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Prototypes can be used to simulate in high fidelity a Virtual Factory Environment where geometries and behavior of industrial workplace are replaced and digital manikins (DHMs) are used to reproduce the human presence and actions. In this way is possible perform simulation of work tasks (operators, standard time, engaged materials and equipment) and ergonomic analysis on the Workspace given output variables such as force, resistance, awkward posture and the consequent risk of injuries. Recent studies certify the validity and the reliability of virtual prototyping methodologies for the ergonomic assessment of workspace [15] [16]. Today DHMs are included into a large range of commercial CAD software such as CATIA (by Dassault Systèmes) or in CREO (by PTC) in which they assume a set of static postures or in more complex CAD such as DELMIA (by Dassault Systèmes) and JACK (by Siemens) in which they are dynamically animated to assess ergonomics while the manikin performs scheduled tasks. Finally, there are other specific software for particular industrial field such as SANTOS, 3DSPP, or Anybody Modeling System. However, the use of these CAD systems requires expert users to place the manikin in the correct posture and a lot of effort is usually spent for preparing realistic and dynamic process simulations [17]. In addition, thanks to specific API is possible to integrate the virtual manikin with the real user by means of motion capture technologies to simulate in real time the interaction of the user with the workspace [18] developing mixed prototypes and virtual interactive mock-ups, typically named Digital Mock-Ups [19]. In this way Virtual and Augmented Reality technologies are useful tool to assess the ergonomics while the worker performs a task and thus anticipate the physical realization of the workspace.

In recent academic studies VR and AR technologies were used to develop a lot of prototypes and applied on real industrial case studies in order to help the user during assembly operations or maintenance tasks, involving both able-bodied people that disabled people. Therefore, in order to conduct a set of ergonomic analys is full interaction between user and workplace must be programmed and this make the development of the simulation very expensive, and often the technologies used are invasive, such as Head Mounted Display, therefore is limited the use in a real workplace [20] [21] [22]. Martin et al. [23] and Haggag et al. [24] have developed solutio ns in which the user is tracked in real time thanks the Microsoft Kinect. This technology is not invasive for the user that can interact naturally with the workspace and an analysis software can process the data from the tracking. The application of this technology is limited to workspace where the user does not make large movements.

In literature are very limited the research in which the most suitable technologies and the type of prototype (virtual, physics or mixed) are chosen through a structured methodology. Battini et al. [25] have developed a new theoretical framework to assess a concurrent engineer ing approach to assembly system design problem, in conjunction with an ergonomics optimization of the workplace considering technological and environment parameters. In this work are not involved virtual prototyping technologies.

3. THE MULTIPATH METHODOLOGY

The proposed methodology allows the assessment of ergonomics in every its aspect, starting from the relation between ergonomics and safety and from the risk classification to the identification of a set-up for the measure of variables linked to ergonomics and process simulation. This goal can be achieved thank to the definition of a Critical Path. The followed approach is shown in the next picture (Fig. 1). The methods' steps and a l the aspect considered are shown in Fig. 2 in which

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there is also the definition of a Critical Path for the use case study.

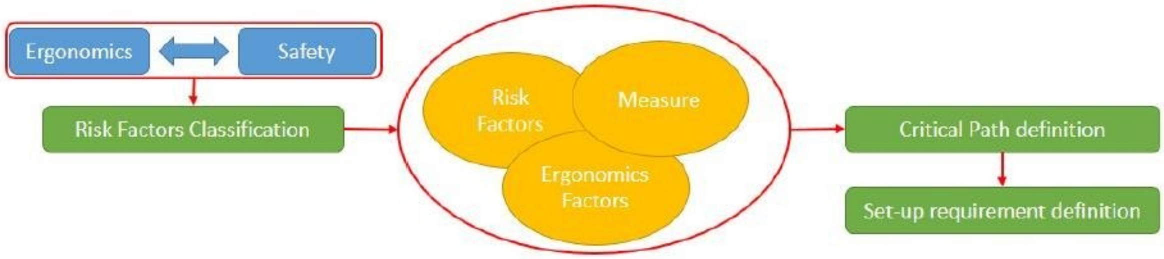

Fig. 1 – The proposed approach

3.1. Ergonomics and safety

The wellness in the work environment concern the context of health and safety, where the company not only applies the compliance with laws but also work to implement prevention actions, developing everything is possible in order to avoid accidents and the spread of occupational diseases. In general, the wellness in the workplace is based on four key points:

- Anthropocentric settings of the company organization;
- Humanization and customization of the physical environment;
- High usability of tools and equipment;
- Development of the intangible capital.

3.2. Risk factors Classification

Risk factors are defined as actions or conditions that increase the likelihood of injury to the musculoskeletal system [26]. Applied ergonomics literature recognizes a small set of common physical risk factors across many occupations and work settings. Although physical risk factors are important first-line risk factors, there are other plausible factors such as organizational and psychosocial factors that may provoke a disorder or indirectly influence the effect of physical risk factors [27]. The relationship between risk factor exposures and the level of musculoskeletal injury risk is not easily defined.

3.3. The steps of the methodology

In order to follow a structured approach to select the most suitable system to assess ergonomics of the workstation and define a list of requirements for an effective set-up, the present research firstly defined a methodology made of 10 steps (Fig. 2):

Step 1 – Definition of the Risk Factors

Based on the previous description of the risk factor classification is possible define the following four key risk factors: repetitive work, loads handling, operation that involves effort, awkward and protracted postures.

Step 2 – Definition of the factors to evaluate

Then is possible to define the identifiable and measureable variables that engage the worker during the task execution. Two macro sections are identified and a set of variables are below listed:

- Load of fatigue: that concern mental fatigue, Muscular fatigue, Repetitive work and Cardiovascular load;

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- Posture: that concern Dynamic posture (movements) and Static posture.

Step 3 – Definition of the assessment methods
From the literature on ergonomics is evident a division between physical assessment methods and psychophysical assessment methods. The physical methods are the most used by the ergonomist in order to obtain surveillance data necessary to risk management in the workplace. While, the psychophysical methods are taken into account by the ergonomist in order to assess specifica lly the mental workload. In particular studies have been demonstrated that an excessive mental workload can be cause of inefficiency, lower quality and accidents.

Step 4 – Definition of the evaluation parameters
From the ergonomic assessment methods is possible to derive a set of evaluation parameters, as consequence is possible take into account the comfort in a given posture or in a given task with the help of different criteria based on a unique measure.

Step 5 – Definition of the technologies for the evaluation
Once defined the assessment methods and the parameters required by each of them, it is necessary to individuate the suitable technologies to measure these parameters. The considered technolo gies have different complexity, indeed for example there are simple stopwatch to measure the recovery time, heart rate monitor to measure the heart rate, tracking device to measure dynamic posture of the worker, more complex electromyography to measure the electrical impulse on the muscle during the muscle tension and finally torque and force sensor able to measure the force exerted by each body segment.

Step 6 – Definition of the object of the measure
The object of the measure concerns what is possible to measure through the technologies identified in the previous step, such as times, force exerted by each body segment, movement and posture, etc.

Step 7 – Definition of the measure systems
A lot of commercial systems are available on the market, they belong at the technologica l categories described above and they are able to measure the object defined. Between commercia l systems is possible to find cheaper device as the Microsoft Kinect and other more complex and expensive systems such as the inertial device Intersense, the Animazoo-Gypsy7 exo-skeletal device and the Vicon or Optitrack tracking device.

Step 8 – Definition of the measure context
The major set of the technologies considered requires a physical context in which the operators are really part of the measure, but the data obtained from this type of context are strongly related to the worker anthropometry. Alternatively, the virtual context refers to the modeling of the workstation in a virtual environment and the insertion of a manikin in the simulation in order to simulate the interaction between the manikin and the workspace through a set of posture of the real worker. This context allows optimal ergonomic assessment for a percentile of population, indeed it is not directly connected to a specific operator.
Step 9 – Definition of constraints in the context of measure

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We have identified four factors that create restrictions for the measure context, they are listed below:

- Invasiveness of the systems: the technologies used to investigate on the ergonomics of the worker can be invasive and restrict his movements freedom, with an important impact on the efficiency;
- Illumination condition: the ambient lighting conditions may change the measure performance of the used equipment;
- Measuring range: the technologies may have measuring range not properly suitable for the work environment, especially inside a production plant;
- Environment interface: environment condition in general may affect the measure accuracy and the repeatability.

Step 10 – Definition of the measure environment
Strongly related to constrain in the context of measure, the measure environment is the environment inside which make measurements. Some types of technologies can be used only inside laboratory in which the measure condition are under control, while other types of not invasive technologies can be used also inside production plant. In this case the measure of the work may be carried out directly "on site" resulting data more useful and reliable because the operators work in is daily environment. In additions, today is necessary take into account the virtual environment in which virtual manikin are used to make measure about a simulat ion of the human work.

3.4. Ergonomics and efficiency

In order to measure the performance of the worker is necessary take into account the concept of standard time, that represent the time that the company attaches to the execution of a certain task. Indeed, efficiency is defined as the product between units produced and standard time, divided by production time declared. The standard time is obtained starting from the normal time that can be defined by factory surveys (i.e. Bedaux) or by tabular methods (i.e. MTM), at which is added the factor surcharge that takes into account three elements: increases for physiological needs (constant at 4,16%), increases for unexpected and increases for fatigue.

The introduction of ergonomics in industry represent a cost and therefore it must produce an economical benefit. The implementation of ergonomics factors determines a decrease of the fatigue of the worker and as consequence a decrease of the increases for fatigue value. Based on what just described the standard time result to be shortened and the efficiency result to be higher. In the context of mass production the increase of efficiency of just 1% leads to considerable reduction of production costs.

4. CASE STUDY

A case study is presented with the purpose to prove a multipath methodology in a real industr ia l case study.

4.1. Study Scenario

The case study focus on the manual assembly of the Cooker Hood Line TT14 produced by Elica (http://elica.com), a large-sized Italian Company, World Wide leader for the design and

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manufacturing of aesthetic hoods ensuring maximum suction, filtering performance, silence and energy efficiency. The production line analyzed regards the assembly of the product ELITE 14, a kitchen hood with width 60 cm, a pull-out drawer, a multi-speed electric motor and led lights.

For the production line under study job information and on the distribution periods of actual work and rest periods are the following: workshift 8 hours / Rest 10 minutes + 30 minutes lunchbreak / operational work 7 hours 20 minutes.

The assembly line is composed by 5 different assembly stations: the first three stations relate to product manual assembly (garrisoned by one operator each), fourth relates the automatic functionality test (no operator), the last concerns the product packaging. As a result the number of operators is in line 4, the cycle time is equal to 1:19 minutes whereby, overall, is able to realize 50.42 products / hour. We focused on the station 2, assembly motorcover, because was over- satured. Interviews submitted to the workers (6 women and 2 men for two shifts) point out some meaningful features of the assembly process where about 70% of all musculoskeletal injuries regards problems for the lower back and shoulders.

4.2. Critical Path definition

Each step of this path can be defined as input or output based on the analysis conditions that is, based on what you want to measure and how you want to do it. It is an interactive path that allows you to know the best options for the analysis in each step, leading to the unique definition of all the steps. The critical path allows the analyst to identify the optimal methods to assess physical ergonomics aspects for repetitive work (Fig.2). Human and workspace modeling was supported by the preliminary acquisition of on-site videos. Recorded tapes were processed to simulate the real sequence of operations in the virtual environment. In addition, the RULA method was applied to analyze the muscle fatigue and prolonged uncomfortable positions to identify which postures present more risks. The decision was to use DELMIA as technology to model the worker movements and postures and then to assess the main ergonomics factors impacting on injuries risk for the specific context of cooker hoods.

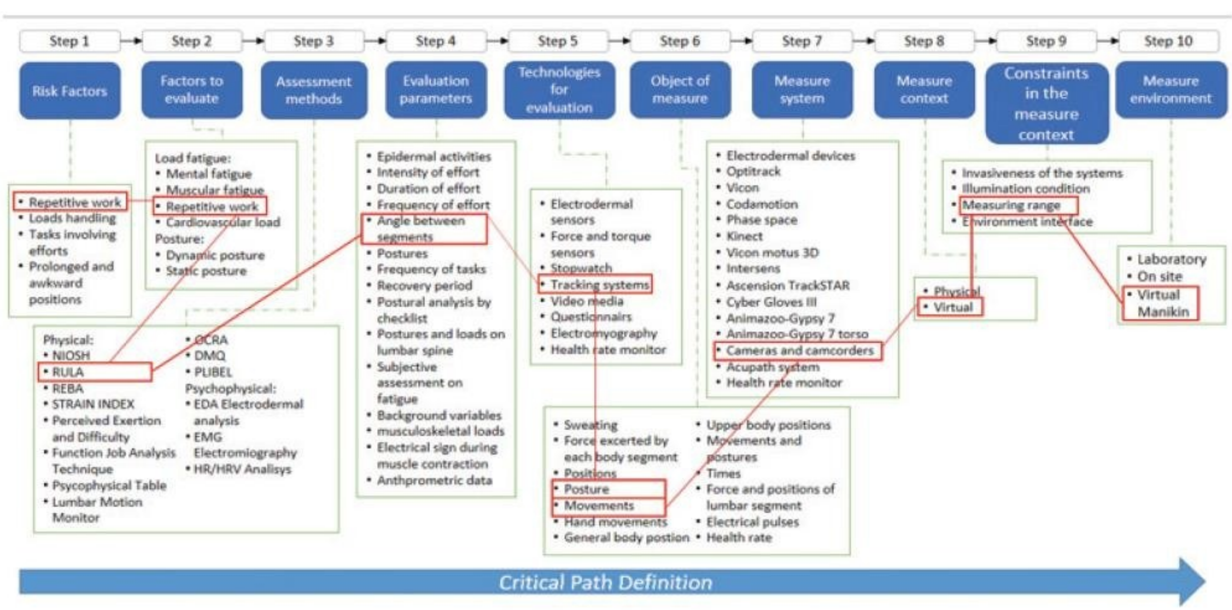

Fig. 2 – The proposed methodology with highlighted the critical path for the case study

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4.3. Study On-site and results of the simulation

Following the choice of the critical path, identified the technology to be used, it will be necessary the choice a set-up for the measurement. Was chosen to use for data acquisition suitably arranged cameras and/or video cameras inside the workspace. They have been positioned in such a way as to allow a reconstruction of the global worker activities ensuring non-invasiveness. More than one task execution was recorded for the same assembly station to have reliable and repeatable data. A relief was performed at the plant in order to obtain all geometric sizes necessary to create the Virtual Environments into the software DELMIA V5 R20.

The postural analysis carried out in this case study consists of ergonomics analysis that exploits the RULA method, a visibility analysis and an analysis of reachability. For transactions that involve lifting heavy objects was made ergonomic analysis by NIOSH method that allow the calculation of the maximum load to be lifted taking into account the initial and the final posture, the period of work and the number of repetitions per minute. For the case study was evaluated 14 out of the 22 the activities performed by the operator on the station 2. 4 of 14 activities are critical, for 3 of them were found solutions that improve the ergonomics without causing disruption of the workplace, for the remainder are no improvements were found, or at least not such as to maximize the overall ergonomics of the process.

Analyzing the activity "Grasp the drawer", both the reachability analysis and visibility analysis are acceptable from an ergonomics point of view, the posture assumed by the operator is ergonomically risky. Analysis RULA body segments affected during movement appear out of acceptable range. Action was taken on this posture by placing the body frontally relative to the object to be lifted, so that the upper limbs are less stressed and stressed symmetrically, resulting in a less waste of energy and a better ergonomics position. In the Fig. 3, RULA values for each segment of the body in the two solutions were reported. Through these analyzes improved the single station's assembly cycle time from 1:19 minutes to 1:09 minutes. This translates into a 14% short-term improvement on the cycle time. Being evaluated improvements in the medium and long term in terms of injuries.

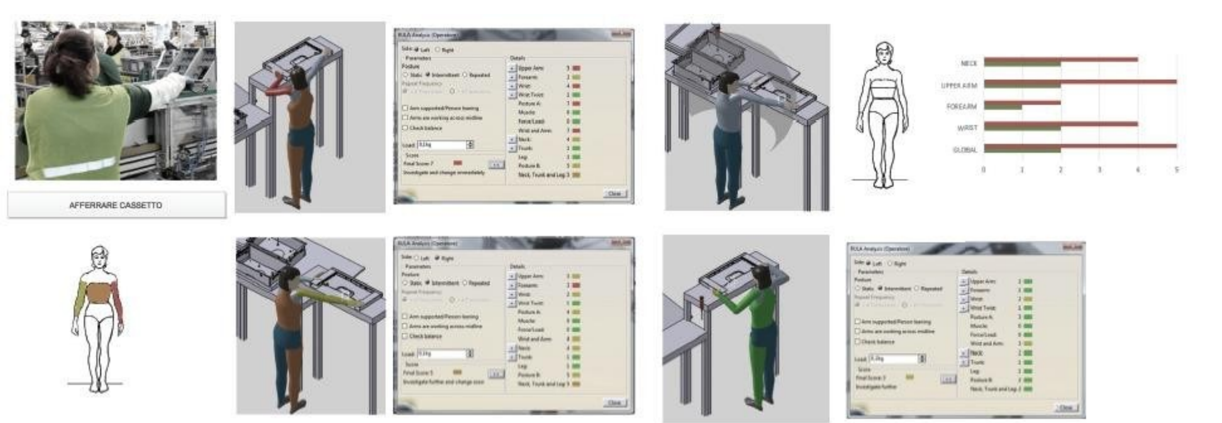

Fig. 3 – Simulation of the real posture and result of the analysis

5. CONCLUSION

The study carried out is based on the definition of a method for the evaluation of ergonomics, safety

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and efficiency of operations in seeds company manuals. This methodology is applicable to any of semi-manual assembly activities, starting from a list of risk factors, then is possible to define, through a critical path, all the characteristics necessary for the measurement and assessment of the aspects related to ergonomics, consequently to define the technical requirement for a set-up useful to measure the ergonomics both in industry plant that in equipped laboratory. The proposed methodology is focused on the efficiency of the adopted solutions; indeed, the ergonomics solutions will be applied only if economically advantageous.
Future work will be focused on the necessity to have both a real-time detection of the user movements and a reference model of the correct assembly operations to guide the workers and alert them in case of injury probability increase. This can be achieved by a Tangible Augmented Reality reference model to enhance the overall working environment.

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ANALYZING THE BEHAVIOUR AND EFFECTS OF ERGONOMICS SYSTEM AND LAYOUT AT MEDICAL LABORATORIES

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ABSTRACT

Safety must be the first priority of any organization as it is a key to success and productivity. This paper highlights the thinking of people towards the implementation of ergonomics systems and its impacts in medical laboratories. Seven medical laboratories were analyzed in various perspectives. Most of the lab operators avoid use of proper safety measures that results in damage to the body. The safety measures that were lacking includes: proper and uniform use of gloves, equipment, training, patient handling and transferring, not wearing face masks while working and the laboratory layout that may results in different types of musculoskeletal disorders and could save much of their time by avoiding unnecessary movements. Data were collected through interviews, readings were taken for two weeks continuously that shows a space for improvement.

Key words: Ergonomics, Musculoskeletal,Safety measures, Gloves

1. INTRODUCTION:

Ergonomics known as human factors engineering is the study (science) of the mutual interaction between worker and their working environment. It has a great history of influencing human centered design processes in following fields, such as automotive, service, manufacturing, and defense industry, to a lesser extent, medicine, and surgery.

Research have been done on ergonomics and Nursing in hospital/medical laboratory environment. The work place environment, activities that contributes to musculoskeletal injuries among staff and nurses, are studied and decreases by using a mixed-methods design. The method consists of small team of participants (4 male nurse and 2 stakeholders from 3 medical laboratories and a hospital). Walk-throughs of testing units and patients cells were conducted. Interview with stakeholders, team staff and patients were done after every test or examination by doctor and they were asked for MSDs and other discomfort during the whole process. Key factors contributing to discomfort among patients and staff include congested physical environment (layout of work cells, rooms), work culture and organization i.e. inadequate staffing, heavy workload, lack of medical education, and work activities i.e. manual lifting of patients, unawareness of latest technology and lack of assistive devices were identified.

This article includes several local medical laboratories in collaboration with a 20 bed private hospital overview in which ergonomics problems are noticed in terms of staff, layout, and procedures especially

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patient handling, transferring, equipment's design. Recommendations are also provided at the end. The laboratories perform the following test and operations,

1. Full blood count test
2. Blood urea nitrogen test (BUN)
3. Sugar test
4. Clinical Urea test
5. Serum glutamic pyruvic transaminase test (SGPT)
6. Creatinine blood test
7. Lipid profile test
8. Tuber Culosis Skin test (TST)
9. Genetic tests
10. Stool tests
11. Serology
12. Drug tests
13. Coombs tests

From the above factors we designed some of the basic questions related to hospitals and medical laboratories needed to be answered:

- Employee/employees are mostly at high risk for injury discomfort and illness?
- What are common denominators in between these high risk employee(s)? Job Title?Type of Injury? Activity? And Behavior? Location?
- Any record on the data base for investigation about the injury? Necessary data required for valuable and accurate analysis about the accident? For example, Connection of injured patient with staff/nurse? Or injured nurse to injured patient?
- Based on the conclusion of last accident what protective, health and safety programs are developed, implemented and enhanced which will reduced patient/staff injuries and improve environment.
- Approach used for to successfully, efficiently and implementing these programs?

After broad analysis of 5 days and some Incidents showed that 80% of the total incidents occur during

- Patient Handling
- Materials Handling
- Needle sticks and sharpness
- Slips/Falls and Trips

2. LITERATURE REVIEW

The father of Ergonomics Dr. Alphonse Chapanis wrote the first ever textbook on ergonomics named, "Applied Experimental Psychology: Human Factors in Engineering Design. He define Human factor engineering as,

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"Human factor engineering is the application of human factors information to the design of tools, machines, tasks, jobs, system and environment for comfortable, safe and effective human use."A good HFE (ergonomics) is nothing than the application of common sense and provide comfort, effectiveness, convenience, efficiency, ease of use, safety, fun, and satisfaction.

Lonnie D. Stallcup, BS, MT, a medical lab technician in US Air Force in 1988, a clinical laboratory technologist at Laboratory Alliance of CNY up to 2003 then as a physicians' office lab manager in his article provide idea about "Implementing a Lean laboratory" by forming special teams for improving overflow and lab design which require accurate space Capture by equipment's. He utilizes his knowledge and scientific principles and creativity to redesign and overhaul the clinical laboratory to effective workflow without interrupting patients care. Ergonomics success in many areas is quite obvious but what about its contribution to healthcare? A German organizations name "KommissionArbeitsschutz and Normung" shows importance of international standards and ergonomics knowledge are more useful to address risks, hazards in a medical field.

A professor of surgery named Ramon Berguer, at University of California-Davis the pioneers in the field of ergonomics and its application to surgical practice, stated:

"A scientific and ergonomic approach/analysis of hospital rooms, environment, and workload characteristics of member of modern surgical team can provide a basis for maximizing efficiency & safety of increasingly technology-dependent surgical procedures."

3. OVERVIEW OF MEDICAL ERGONOMICS

A report in 1999 suggested that about 44 000 people died each year in the US due to medical errors (more than road accidents, AIDS and breast cancer).Some researchers suggest that these incidence are contributed by human absence of attention towards part design and establishing as well as maintaining ergonomic qualities of the products. Ergonomics basically focus on design of the medical devices, laboratories, hospital and environment by risk management analysis.
Medical laboratories provide several chances for ergonomic factors that contribute to injuries and many repetitive stress (injuries) disorders. The main factors which cause these injuries are forceful exertions as well as awkward postures while patient take care, especially during and moving patients lifting. Some of the ergonomic issues includes, patient handling, awkward postures, layout, infrastructure, staff experiences, training, workplace design, equipment's design and MSD's. The following article will briefly identify these issues and will give suggestion to mitigate these stressors. Ergonomic in the healthcare (laboratory) is the Art and science of fitting the work to the person in order to prevent disorders of tissues such as muscles, blood vessels, & joints, tendons and nerves. Common disorders in laboratory staff and layout problems are:

1. Carpal Tunnel Syndrome
2. Tendonitis
3. Fatigue
4. Back Strain/Sprain
5. Hygiene and Hazardous Radiation and Chemicals
6. Improper light/light level

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7. Queuing problem (service level)
8. Staff training & Staff to patient ratio
9. Floor space and Motions
10. Patient Fatalities & others

The above potential risk factors (disorders and problems) are identified and are improve through “Ergonomic Assessment”. Key Risk Factors study involve each factor is significant; however, discomfort is more likely to develop when two or more of these factors are combined and these risk exposure is sustained for longer period. Benefits after assessment are;

• **Improve comfort**: body size (anthropometry), motion, and strength capabilities, Sensory capabilities—hearing, vision, haptic (touch and force), dexterity

• **Enhance job satisfaction:** ergonomics gives a range of human concern issues related to systems design and training by memory and Cognitive processes including situational awareness.

• **Increase productivity**: optimizing system performance while maximizing human wellbeing and operational effectiveness

• **Decrease fatigue:** by eliminating repetitive and extra movements

Protect enjoyment of many life activities: Extend work life through current knowledge and training related to systems, practices and equipment including emergency conditions.

4. HEALTH CARE FACILITIES DESIGN HOSPITALS AND LABORATORIES ERGONOMICS

This section will provide resources and information in designing hospitals and medical laboratories under observation for this article to ‘fit’ the patients and their family as well as the staff.

4.1 VIRTUAL REALITY TOOL

Is an ergonomic tool using computer graphics developed for the Institute of Naval Medicine by Virtue is to help in the design of medical laboratory and surgical environments on board ships. The end user and main purpose of this virtual reality 3D graphic simulation is a low cost, uncomplicated, simplified method of approaching and understanding, developing ergonomics databases for rapid designing layouts for medical testing and surgical rooms. It will help in changing layouts according to new advance equipment’s matching patient’s demand.

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Fig 4.1 three dimensional simulation computer graphics, useful in produce a standard basic ergonomic design for mini laboratory or operation theatres

4.2 HEALTHCARE-ACQUIRED INFECTIONS (HAIs) AND HYGIENE PROBLEM

Study reveals that *Antimicrobial* copper surfaces can reduces 58 % of healthcare-acquired infections in laboratories and hospitals.According to new research antimicrobial copper surface can reduce health care acquired infections by 58 percent as compared to hospitals and labs where patients are treated in ICU's without copper coated surfaces.About 100,000 deaths/year in US occur in 1 out of 20 hospital due to HAI's. Numerous strategies have been developed and implemented to reduce these infections and deaths but only

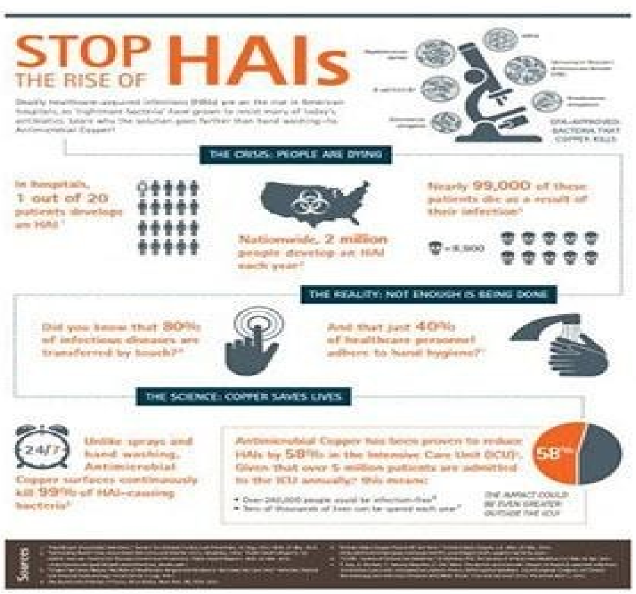

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Fig 4.2 flex about HAIs awareness

Antimicrobial copper is the successful strategy that not only works but shows continuous improvement and does not depend on human's behavior. (SHEA Journal of *Infection Control and Hospital Epidemiology*.)

The study was conducted in the following three major hospital ICU's: The Medical University of Carolina, Memorial Sloan-Kettering Cancer Center, New York City, and Ralph H. Johnson Veterans Affair.Copper Alloyed surfaced were placed in these ICUs (8 standard and 8 copper) because patients are more expose to HAIs due to their illness, interaction with procedures and workers. Total 650 patients were examined in 1 month and it was found that Antimicrobial Copper continuously killed 83% of bacteria which were causing HAIs within two hours. Only 46 patients out of 650 were diagnosed with HAIs much lower than those handled in ICUs. Antimicrobial Copper health care related equipment's and products are available today, including tray tables, IV poles, stretchers, and door hardware.

4.3 PREVENT PATIENT FALL AND HUMAN ERRORS

Talking about human errors and patient fall was observed in our research. Ergonomics and HFE design in prevention of human errors and patients fall play a vital role. Furthermore system design include technology, equipment/product, building, procedures/process design, environment which affects the frequency and severity of accidents and staff errors.The most common and important accidents which occur in hospital setting every single day across Khyber PakhtoonKhwa is "Patient fall".

Patient fall is a problem of major emphasis for hospitals and medical laboratories. Physiotherapists who are the specialist, deal with outcomes of patient falls in their practice as it causes serious problems. These falls are studied by the OPA, CPA and National Health Care forums as these falls often lead to patient death and serious disablement.Extensive research shows the factors which contribute to these falls are environmental, training, technological, procedure related, work process & as well as design related. Contributing and Causative factors partial is;

1. Patient physical ability
2. Overall layout of the room
3. Location of the furniture in the room
4. Chair, Furniture type-bed, tables, wheelchair, headphones, computers
5. Flooring surface (color, type, texture, pattern,)
6. Whole Walk space/clearance
7. Lighting levels, placement & reflectance
8. Staff to patient ratio
9. Mental ability of patients.
10. Equipment for patient transfer
11. The workplace systems, standard operating procedures, methods, and culture

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Fig 4.3 Ergonomically bad design bed

Human factor engineering and ergonomics use patient caregivers and physical & mental wellbeing while Considering the design of the above listed aspects and how these aspects interact with each other and with the number of patients fall as well as the seriousness of the fall.

5. ERGONOMIC OFFICE HUMAN SCALE PRODUCTS , FURNITURE AND COMMON LABORATORY ISSUES

Microscopes, Pipetting, Biological Safety Cabinets and Hoods, Microtomes, Mouse Bridges, Monitor Arms, Phone Headsets and ICU Beds

"MEASURE TWICE, BUILD ONCE" or 'Measure twice, cut once' is an old carpenter's axiom. Be careful, lesson, informed planning is necessary to get a positive outcome. Hurry in completion of any project will cost you in term of waste money accidents poor quality etc. In our case ideally ergonomics play a vital role in the building design where people will work. Limitation of Human body while at rest and during movement should be provide to architects, builders and designers.Intelligent laboratories design, Floor plan design evaluation, and leveraging human factor as well as ergonomics expertise, Lifting technologies and tools which could eliminate accidents. In globalization and industrialization era, service industry is the one which is progressing rapidly in any country. In Healthcare industry, office role is very important because the employee spend 70-75 % of the time in their office sitting more than sleep. So

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Furniture and equipment's around them play an important role in boosting moral, quality patients care and productivity.

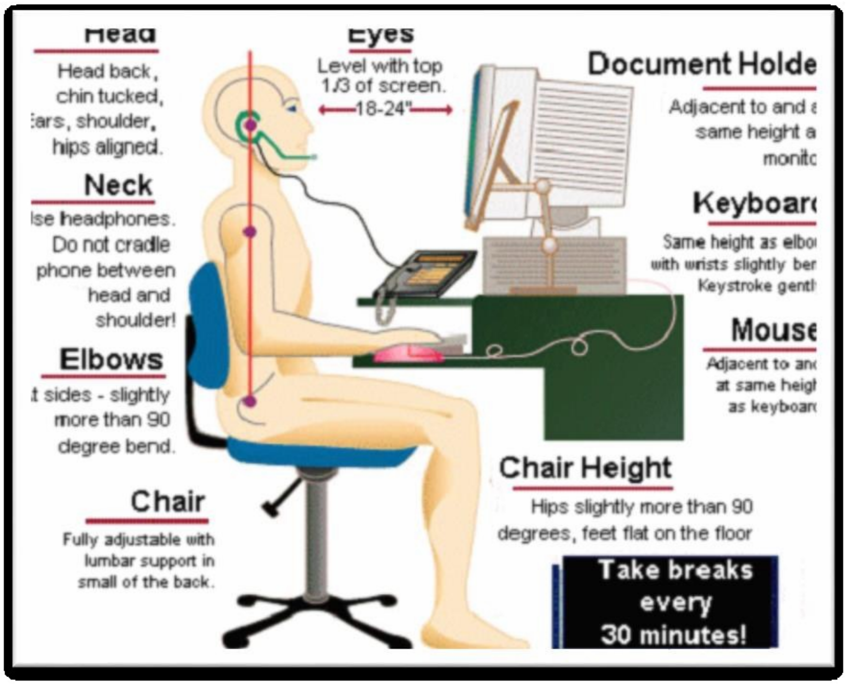

Fig 5. (A). ergonomically design footrest, chair

In this case a survey was done by the name "Furniture at Work". By collecting information from 3 medical laboratories and a private hospital staff and has been found that 90.6% of the staff accepted that uncomfortable chair, tables, layout, etc. effect their performance (productivity. Therefore furniture should be design keeping ergonomics in mind. Therefore it is very important that furniture in office should be designed keeping ergonomics in mind.

5.1 MICROSCOPES

- While viewing microscope eyepiece during standing or sitting make sure that worker will be in an upright position keeping back, shoulders and neck. This can be done by adjusting eyepiece by extendable eyepiece or tube, chair (if applicable) and work surface.

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Fig 5.1 ergonomically design microscope, eyepiece adjustment

- Keep microscope close to yourself as possible. This can be done by pulling it to edge of the working table/bench.
- Support should be provide for the arms to make it relax, for elbow near to the sides, and neutral position of wrist for adjustments.
- Cleaning and repairing of scope for easier use.

5.2 PIPETTING

- Use light-touch, electronic, or latch mode pipettes for pipetting when possible.
- Multiple finger opposed to thumb designs are preferred. During changing tips and pipetting use lightest touch when possible.
- Work supplies like beakers and trays must be placed within normal area of the worker so will be in easy reach and no obstructions while accessing.

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Fig 5.2, pipet model and using procedure

- Keep wrist position straight and neutral while working.
- Using both hand and alternative hand to pipet.
- In order to minimize twisting of neck, wrists, avoid bending and rolled shoulder use low profile tubes, receptacles and containers.

5.3 BIOLOGICAL SAFETY CABINETS AND HOODS

- While standing or sitting make sure that worker will be in an upright position keeping back, shoulders and neck in neutral and upright position.
- Keep the sash clean and glare free so one can see without tilting neck in awkward position.
- In order to minimize twisting of neck, wrists, avoid bending and rolled shoulder use low profile tubes, receptacles and containers.
- Keep the work area clean and free ofclutter.
- Unnecessary supplies should be remove. All those work should be perform which are all 6 inches inside the hood.
- Keep wrist position straight and neutral while working
- Wrist and forearm must be protected from sharp edges. Padding and foam may be used on those front sharp edge of the hood tables.

5.4 MICROTOMES

- Microtomes should be placed at appropriate height while work (see general tips, above).
- Contact pressure should be avoided. Wrist and forearm must be protected from sharp edges. Padding and foam may be used on those front sharp edge of the hood tables.Little force should be applied while turning handle wheel. Manual microtomes should be replaced by automatics ones as in these laboratories work intensity is quite high.
- Handshake position should be maintained while working on microtomes, hand in a pistol grip position

Fig 5.4 Ergonomic design microtomes

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5.5 MONITOR ARMS

Need for Monitor Arm at laboratories and Hospital, Why?

- When LCD's or monitor heights are too high or low from eye height it can cause discomfort and sometimes sever injuries in the neck back and low eye sight as users unconsciously tilt and bend their necks, back to look up or down at screen.
- For VESA (Video Electronics Standards Association) compliant monitors and LCD.
- After full adjustment when the monitor is still higher than eye height.
- For client's ease, to show them something of their concern on the screen in order to avoid sit/stand out of the monitor's view.
- For creating more desk space which will add more room for other things.
- Adjusting monitor height and distance while working throughout the day for example in case of "Graves" disease. Also working with multiple LCD's having base problem.

Fig 5.5 Monitor arms supporting LCD

5.6 MOUSE BRIDGES

Why need of mouse bridges?

- While working on computer, mouse use is not more than 25%. When mouse is used only with right hand.

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- When the person use number pad section quite rarely or using the number section above alphabets section. Using number section just 30 to 60 minutes per day.

Fig 5.6, Mouse Bridge

- Limited movement of mouse due to lack of mouse tray with previous computer.
- Pervious mouse tray forces wrist position unaligned to forearm or keeping hand away from shoulder laterally or lower from elbow height. Also having space limitation.

Where should it be located?

- At elbow height or slightly below.
- At seated posture, upright, the distance should be that of the forearm away from the body.
- Place the mouse bridge above number pad when number pad is not used or on alphabets in reverse case.

5.7 PHONE HEADSET

Need a Phone Headset

- When phone is used more than 1 hour a day in office or lab.
- Being On such a position where frequent or long phone calls are a requirement
- Cradle the phone while talking so that you can use your hands to write or type
- The phone cannot be located within an easy arm's reach

Why Necessary?

- When the "hands free" option cannot be used in certain situations
- Such sustained and frequent non-neutral postures can create muscle fatigue and discomfort
- Helps to eliminate the need for holding the phone up to the ear or tilting the head to the side to cradle the phone between head and shoulder
- When extra extension (muscles) of an arm is created for reach.

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Fig 5.7 Phone Headset, Adjustable mike, slider

Which One Should I Get?

a) Corded Headset Systems
b) Cordless Headset Systems
c) Cordless Headset Systems with line Management Capabilities

5.8 ICUBEDS

As mention above that patient fall is consider the critical issue at laboratories and hospitals specially during testing while exposure of body at radiations. In this case to provide care safety and comfort to patients, ICU beds, with special ergonomics features were suggested to them. It include both Mechanical ICU and Electrical ICU beds. Some of them are X-ray Permeable with backrest also. These beds can be tilted both manually and electrical as well.

Some of model names are;

- HF1003 - I.C.U. Bed, Electric, 7 Function with X-ray Permeable Backrest

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- ICU Bed (Seven function) with electrically operated remote controlled back rest
- HF1042 - I.C.U. Multi-function Electric Bed With Weighing Scale
- HF1099 - I.C.U. Bed, Electric, 5 Function with Extra Ventilated Platform
- HF1066 - I.C.U. Bed, Electric, Multi- Function with Sitting Position

6. CONCLUSION

As a result of the project our client is doing the following:

- Moving aggressively towards adopting and embracing the 'Total Safety Culture' philosophy. And addressing the limitations of their OSHA reporting system that were identified during the project and investigating how to capture and integrate both employee and patient incidents and how they relate to each other.
- Targeting an 80% reduction in employee injuries and related workers compensation costs both direct and indirect base based on recommendations
- The safety and well-being of the nursing staff is at the center of hospital group's strategy – nurses' are active in all phases of program development and rollout.
- Employees and management participate in specific safety task forces to promote both employee and patient safety and to develop programs, policies and procedures. Some of these task forces include: the Needle Stick Prevention Task Force, Safe Patient & Material Handing, Medication Safety, and Emergency Management. Hazard surveillance and environmental rounds are done on a regular basis. This activity provides inspection and review of all work areas. Recommendations for improvements are reviewed by the Environment of Care Committee and evaluated and implemented by management.
- Working collaboratively with OSHA and other regulatory organizations to ensure a high level of employee safety.

The following Courses were suggested for hospital and medical laboratories staff and nurses in order to provide better patient care and avoid injuries.

6.1 Manual Handling Instructor Course Background:

Individually, this course is for those who want to perform risk assessments as well as providing manual handling training practice in the workplace. Manual handling instructor course training is also required to become a nurse/staff for Patient handling in addition to the patient handling instructor course. Objectives are;

- To provide with the skill knowledge and competence to effectively design and carrying out manual handling in hospitals and laboratories.
- How to perform manual handling risk assessment
- Lift and handle objects safely
- To know about the limitations of the muscular system and spine.
- Awareness about correct lifting techniques at workplace.
- To gain knowledge about health and safety legislation for Manual Handling.

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6.2 Patient Handling Instructor 6N0234

This certified course QQI is level six (6) Minor Award caring 5credits. To provide with the skill knowledge and competence to effectively design and carrying out manual handling in hospitals and laboratories.

6.3 Nursing Theory and Practice 5N4325

This certified course QQI is level six (6) Minor Award caring 15 credits. To provide with the skill knowledge and competency for the principles, theory, and practice for the nursing process and profession to perform a range of some basic nursing skills. Objectives are;

- To understand the development of nursing profession.
- Comparing local nursing profession to worldwide nursing profession
- Stages of nursing process, knowledge and how they relate to patient care.
- Identify daily living activities and its relation to activities of patient care. Explanation of medical abbreviations and nursing terminologies.
- Importance and method of recording procedures task like blood pressure, temperature, fluid balance and respiration and precisions in administering drugs
- Practice safe lifting techniques

7. SUMMARY

The local laboratories under study for this paper include several ergonomic issues. These issues in the laboratories includes static or awkward postures, excessive and repetitive motions. Understanding human limitations early in the development of medical devices can reduce errors and avoid performance problems exacerbated by stress and fatigue. Using ergonomics in a design process can reduce the costs of procuring and maintaining products. Ergonomics can minimize the incidence of injury or longer term malaise from poor working environments. An ergonomics task analysis can help identify key components of surgical skill, ensuring that students have affordable, appropriate, valid, and reliable training. Nevertheless, the term ergonomics continues to appear in marketing literature relating to products. On closer inspection it becomes evident that a formal, documented ergonomic approach to the design of, for example, an advanced operating theatre or surgical robot, has not been conducted and that evaluations involving end users are far from adequate.

By offering operating rooms of the future, complete with multiple color TVs, voice operated systems, support robots, ceiling mounted articulated arms, teleconferencing facilities, interactive three dimensional displays, and preoperative planning simulators in no way guarantees that these facilities are fit for human use. It is often impossible to find any evidence of qualified ergonomists on the development panels for these projects, a situation that is probably commonplace throughout the medical community.

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7 CONCLUSIONS AND RECOMMENDATIONS:

This paper highlighted the importance of education in sustainable manufacturing, suggesting that education should be the primary objective in achieving sustainability. The people involved in attaining sustainability should be aware of the system they are working in and must have the ability to deal with it. It is actually the level of education and understanding of the people who are providing sustainability in shape of products and services. The more they are trained and educated the more will be better results and vice versa. Similarly these people are not only involved in manufacturing of the product but they are involved in the whole cycle of sustainability and that's why all the people in the whole cycle should understood their responsibility in order to achieve a sustainable environment.

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SUSTAINABLE CONSTRUCTION AND SOCIAL ASPECT

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Abstract
Construction industry is one of the important sectors to assess a country development. Pakistan is fast urbanizing and the infrastructure development both in urban and rural areas is on the high. Construction sector is interlinked with numerous services and manufacturing sectors. Moreover, construction environment is labor intensive. The community and society is very much strangled into construction sector. Sustainable construction considers the social aspect as well. So, a systematic study to assess the social aspect of sustainable construction needs to be carried out. This paper will focus on the analyzing the social factors involved in sustainable construction. A questionnaire is used to collect the data. Relative importance index is used to analyze the factors importance level. Clean water is the most practiced factor whereas involvement of university is at the minimum level.

1. INTRODUCTION

There is no universal definition to sustainability but strong sustainability minimizes the possibility of replacing natural resources with artificial things (Pearce, Atkinson et al. 1994, Dresner 2008). This refers to the utilization of the available resources in such a way that current generation obtains their benefits without sacrificing the needs of future generations. This research is particularly related to the analysis of only the social aspect of sustainability that affects the construction projects in Pakistan construction industry. Understanding the importance of sustainability is the first step in visualizing the common goals of sustainability and sustainable construction (Chong, Kumar et al. (2009).

Sustainable development is simply defined as "*development, which meets the needs of the present generation without compromising the ability of future generations to meet their own needs*" (WCED 1987). Sustainable development results to a state of society where living conditions and resources to meet human needs without effecting moral, balance and sustainability of natural ecosystem. Sustainable development can be defined as development that fulfills the needs of current generations without compromising the needs of future generation. However only design considerations and on site management can't achieve sustainable development (Ding (2008). Sustainable construction is not green or environment friendly only (Gunatilake 2013). The sustainability no longer only considers the environmental aspect, but also considers the economic and social aspects of sustainability (Dempsey, Bramley et al. 2011). The sustainable development is forward-looking. It is a continuous mission for future development of human society. A surly sustainable society is one that make initiatives toward development in sustainable ways (Robin and Poon (2009). Construction industry includes all those who plan, design, develop, build, alter, and maintain the built environment including clients and users (Wilkinson, Sayce et al. 2015). Clients and end users are also the important participants to deliver the sustainable development. Sustainable development is a key for ensuring the better life for present as well as future generations. Buildings and structures are a source of shelter to satisfy economic needs and safety (Abidin 2009). Limited resources have pushed contractors to think for sustainable construction (Tan, Shen et al. 2011). Sustainable assessment methods for building projects are playing a key role in introducing sustainability values (Kaatz, Root et al. (2006).

3. LITERATURE REVIEW

Sustainable performance is an important factor when observing the feasibility of a construction project in terms of its performance. Technology can contribute to sustainable development (improving living conditions but initially the applicability of Social Life Cycle Assessment (SLCA) was discussed (Lehmann, Zschieschang et al. (2013). The concept of sustainability is an approach that show a

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method/procedure toward a sustainable society (Komiyama and Takeuchi (2006). From two decades in the concept of sustainable development the aspects of life were ignored although it contained the social mandate clearly. After the failure of this approach there is need to find out new ways and method to reach the social sustainability (Vallance, Perkins et al. (2011). Complementing the factors such as needs and requirements fulfillment, resource utilization, facilities distribution, and good living environment can enhance social sustainability (Chan and Lee (2008). It is most important to consider the environmental aspects in the project it should be clearly shared with the project participants and human society (Shen, Lu et al. (2005). In these days the human resources are very important factors that increases the efficiency of any organization in productivity, and this makes it very much important in industry market and competition. Effective and efficient utilization leads to productivity growth (Kazaz, Manisali et al. (2008). Sustainable construction is one of the most critical important method and procedure to reach to the target level of sustainable development, taking into account environmental, socioeconomic and cultural issues (Shafii, Ali et al. (2006). The construction industry has massive impacts on the society, environment, economy. Social sustainability seems missing from the research radar (Zuo, Jin et al. (2012). Corporate Social Responsibility (CSR) is turning to be significant in many business models (Zhao, Zhao et al. (2012). The literature review concludes that although a number of research articles exists for sustainable construction but no one have specifically targeted the social aspect. This paper targets the social aspects within a construction environment.

4. AREA RESEARCH

The area research was conducted to determine the opinions of experts on social aspects of sustainability in construction industry of Pakistan. The questionnaire was developed based on a combination of literature review and discussion/interviews involving project managers, engineers and contractors. Total of 18 factors were finalized for the research and distributed through mail, email and by hand.

5. METHODOLOGY

Preliminary literature review helped in finalizing the research area whereas a comprehensive literature review helped in identifying the important social factors. A questionnaire was developed based on social factors in relation with project performance parameter. Then the questionnaire was investigated in order to improve and modify the questionnaire. Experts suggestions were incorporated in the final questionnaire. The final questionnaire was shared with different potential respondents by email, mails and by hand . The questionnaire was shared with approximately 70 experts and 45 to 50 responses were received. Among those responses 30 responses were complete. Finally, the analysis was done by using a statistical tool "Relative Importance Index" (RII). The methodology flow chart is shown in Fig.5.1..

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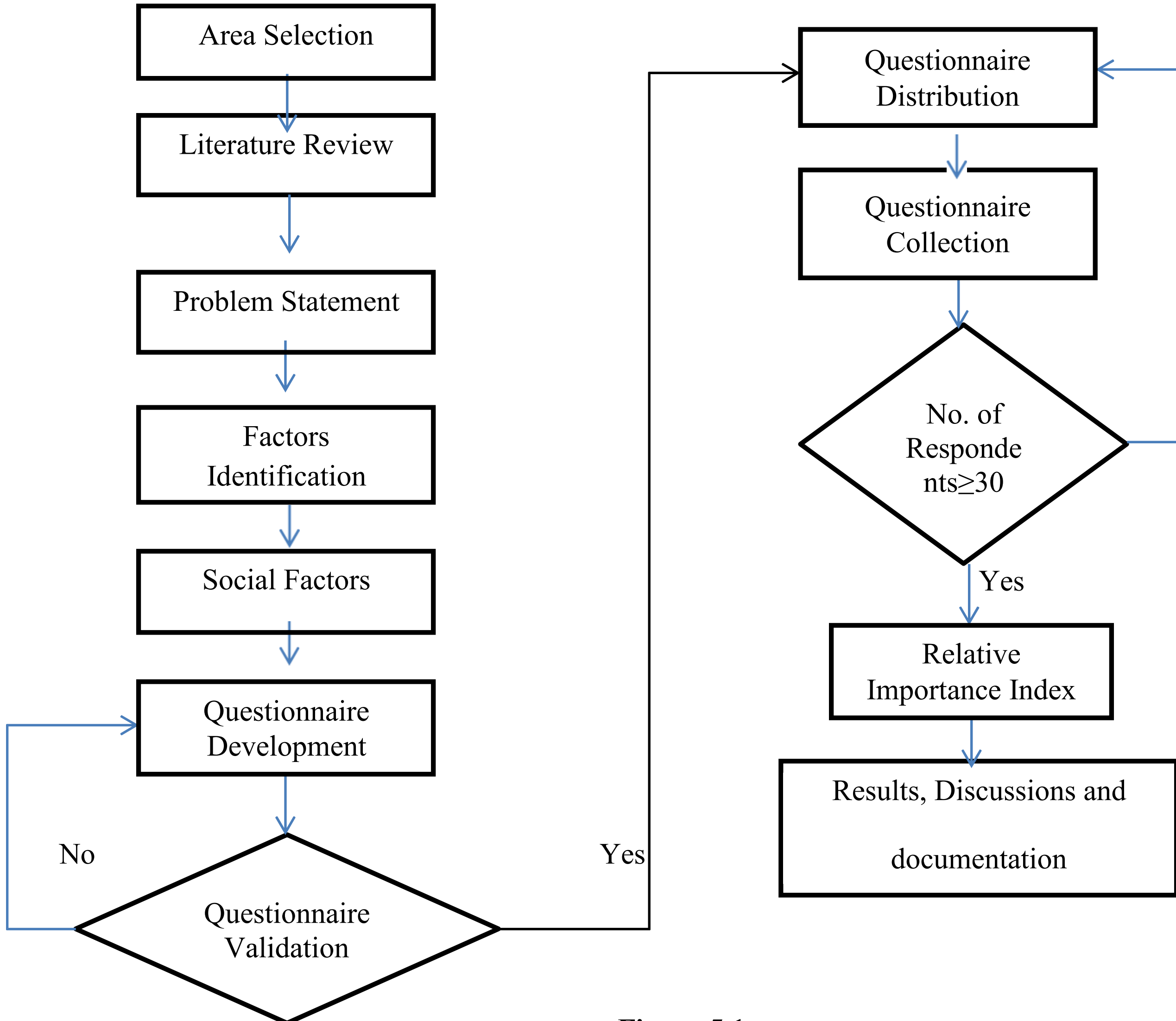

Figure 5.1

6. DATA ANALYSIS

The data analysis was done on Relative Importance Index (RII) to determine the relative priorities of the factors. Relative importance index is computed by using the following formula (Gündüz, Nielsen et al. 2012).

$$RII == \sum W/A * N \qquad (0\leq index\geq 1)\ldots\ldots\ldots\ldots\ldots\ldots 6.1a$$

Where W is the total weight given by the respondent to each factor ranging from 1 to 5, it is the total summation of each row for each factor, A is the highest weight (in this case is 5) and N is the total number of respondents (in this case 30). The factors were then arranged according to their descending order of RII values and were duly ranked. The highest RII indicates the most critical and important

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factor with rank 1 and the next indicates the second-most critical factor with rank 2 and so on. The collected data is represented with the help of a spider diagram as shown in Fig 6.1.

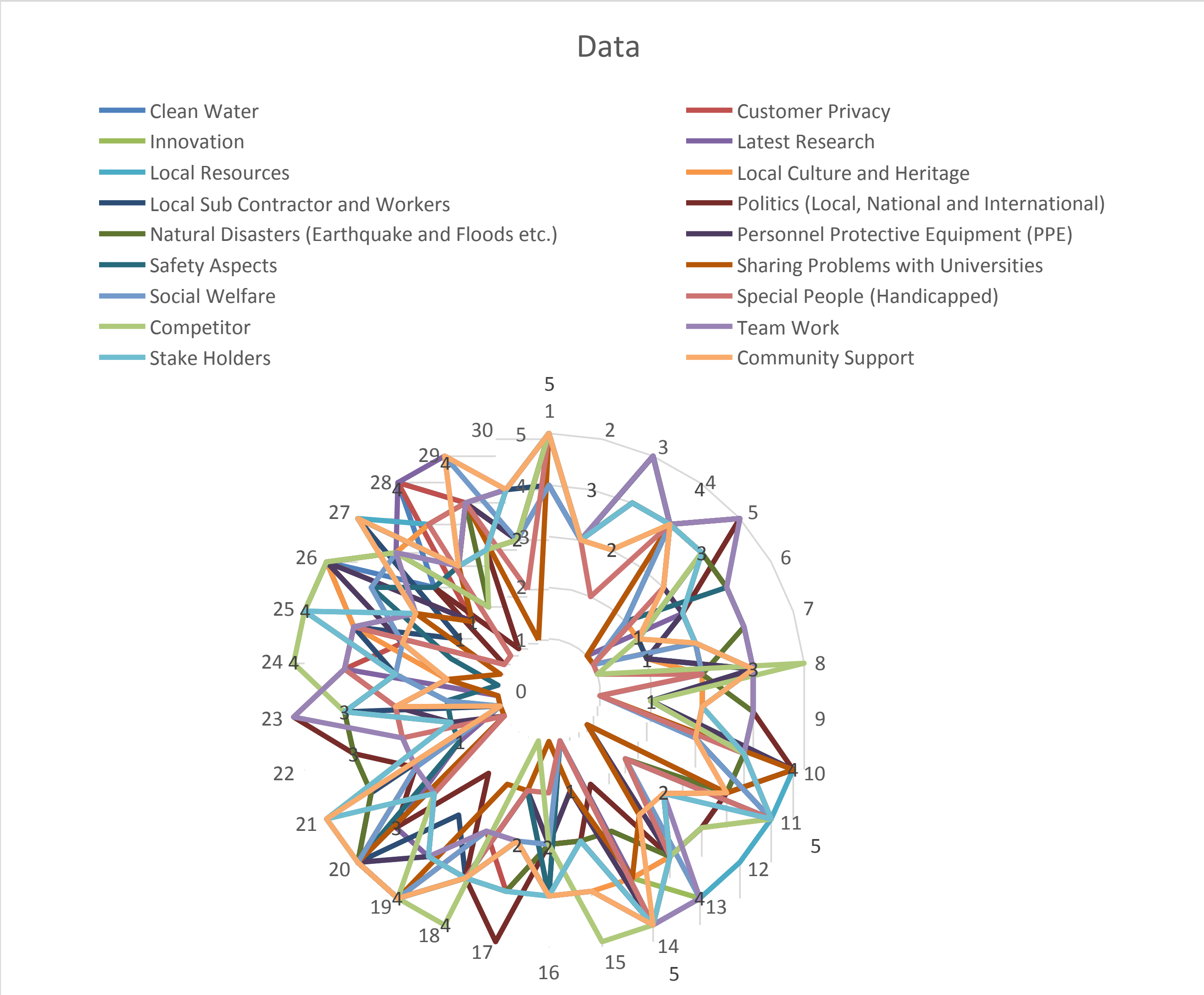

Figure 6.1 Collected Data

The data was collected on likert scale of 1-5, so the highest weightage in every row was five (5). The total number of respondents overall and for each factor is thirty (30). After the highest weightage and number of respondents was identified the overall data was then inter into the following formula,

$$RII == \sum w/A * N \qquad (0 \leq index \geq 1) \ldots\ldots\ldots\ldots\ldots\ldots\ldots 6.3$$

The collected data was then subjected to RII analysis as shown in Table 6.1. The first column in Table 6.1 represents the social factors, the second column represents the total weight of the respective factor given by all the respondents. The third column and fourth column represents the highest weight and number of respondents respectively. The fifth column shows the RII score whereas the second last columns shows the RII percentage score. The last columns shows the rank of the factor.

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Table 6.1 Relative Importance Index (RII) Analysis

Factors	Weightage	Highest Weight	No. of Respondents	RII	Percentage	Overall Ranking
Clean Water	122	5	30	0.8133	81.33	1
Team Work	118	5	30	0.7867	78.67	2
Local Resources	117	5	30	0.7800	78.00	3
Natural Disasters (Earthquake and Floods etc.)	114	5	30	0.7600	76.00	4
Stake Holders	113	5	30	0.7533	75.33	5
Competitor	111	5	30	0.7400	74.00	6
Customer Privacy	109	5	30	0.7267	72.67	7
Local Culture and Heritage	108	5	30	0.7200	72.00	8
Community Support	107	5	30	0.7133	71.33	9
Local Sub Contractor and Workers	106	5	30	0.7067	70.67	10
Politics	106	5	30	0.7067	70.67	11

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(Local, National and International)						
Innovation	103	5	30	0.6867	68.67	12
Latest Research	101	5	30	0.6733	67.33	13
Safety Aspects	101	5	30	0.6733	67.33	14
Personnel Protective Equipment (PPE)	97	5	30	0.6467	64.67	15
Social Welfare	96	5	30	0.6400	64.00	16
Special People (Handicapped)	86	5	30	0.5733	57.33	17
Sharing Problems with Universities	77	5	30	0.5133	51.33	18

7. RESULT and DISCUSSION

RII is a method which categorizes the factors on the basis of their importance. The result presents several factors that can affect social sustainability of construction in Pakistan. The last column of Tabel 6.1 shows the rank of factors. The same ranks could be visualized in Fig 7.1.

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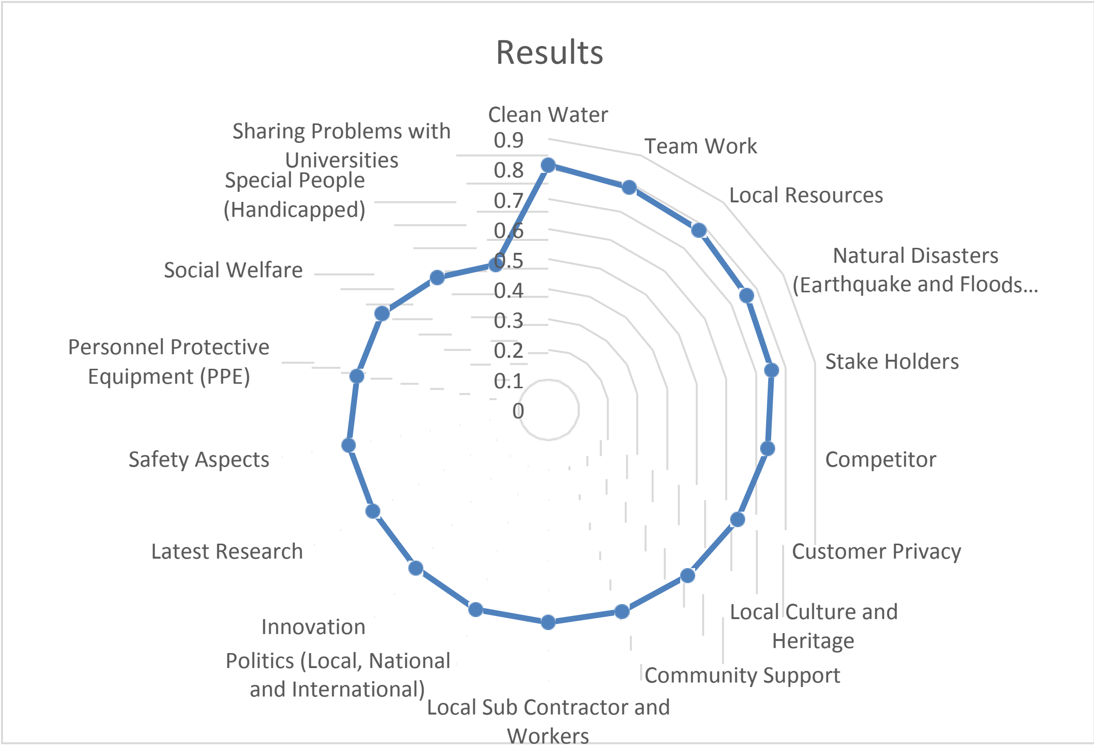

As shown in Fig 7.1, the top five relatively important factors are clean water with RII equal to 0.8133, team work with RII equal to 0.7867, local resources with RII equal to 0.7800, natural disaster with RII equal to 0.7600 and stake holder with RII equal to 0.7533. These factors show the highest coefficient index of RII value. Factors such as social welfare, special people and sharing problems with universities are ranked on the lower side. The local workers, local community, local culture and heritage are moderately important.

The results implores that the construction practioners are looking after the clean water, team, and local resources in most of their projects where as social welfare and special people are neglected in most of their projects. The problems are hardly shared with the universities.

If a benchmark of 70 percent is set then Table 8.1 shows the factors which has scored more than 70 percent.

Table 7.1 Significant Factors

Factors	Percentage	Overall Ranking
Clean Water	81.33	1
Team Work	78.67	2
Local Resources	78.00	3
Natural Disasters (Earthquake and Floods etc.)	76.00	4

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Stake Holders	75.33	5
Competitor	74.00	6
Customer Privacy	72.67	7
Local Culture and Heritage	72.00	8
Community Support	71.33	9
Local Sub Contractor and Workers	70.67	10
Politics (Local, National and International)	70.67	11

8. CONCLUSION AND FUTURE RECOMMENDATIONS

Construction industry is very much integrated within a society. Social aspect within the construction environment is of prime significance. The practioners are more interested in safeguarding their own interests and reducing costs. The investment on the local community and social fabric is rarely seen in construction projects.

Both the government and society has to update the rules to safeguard the social aspects with the construction environment. As social aspects were analyzed construction also need to be sustainable in all aspects i.e. social, environmental and economic aspect. This research need to extend further to identify the remaining aspects of sustainability as well to make the construction industry sustainable in all aspects. The research could be further extended by ranking the factors through Taguchi method, Analytical Hierarchy Process (AHP) and Analytical Network Process (ANP).

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TIME WASTAGE AND SUSTAINABILITY IN CONSTRUCTION INDUSTRY

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ABSTRACT

Construction industry plays an important role in economic well-being of a region. Construction project usually suffers from time and cost overrun. Infrastructure project involves number of processes, some of these are non-value-added processes which not only add costs but consume a good amount of time as well. A positive relationship does exist between sustainability and lean practices. This paper will focus on the quantitative and qualitative data to identify significant factors within a construction process. A questionnaire is used to collect the data. The data is then subjected to Relative Importance Index (RII) to rank the indicators. Money is the most significant whereas machine is the least significant.

1. INTRODUCTION

Lean is a tool which by removing non value added activities gives better performance (Womack and Jones 1997). Lean is such a tool that removes wastes. Waste is anything which does not add value to an operation or a process like overproduction, unnecessary motion etc. (Alarcon 1997). According to concept of Koskela the objective of lean to removes wastes and to maximize material and labour utilization within a construction environment(L. 1993).

Sustainability is meeting the present people needs without affecting future people demands (Brundtland Commission 1987). John Elkington in 1997 developed a concept that sustainability depends upon the three pillars of 'triple bottom line' (Sayce, Walker et al. 2004, Adler, Amstrong et al. 2006, Glavinich and Taylor 2008).

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2. LITERATURE REVIEW

Over the years the industries and facilities have played very important role in the fulfillment of the uprising demands but at the same time they have negative impacts on sustainability in the form of energy consumption, resources, material and also causes harm to the environment and Economy. In order to achieve the sustainability there is a need for firms to adopt such technologies and methods which are being integrated in social environmental and economic context (Gunasekaran and Spalanzani 2012). New techniques and methods are preferred in an attempt to have systems that is capable to meet the demands with minimum Environmental, social and economic damage (Pušavec 2010). For this different technologies are being utilized in order to minimize the environmental impacts, improve efficiency , decreases risk to workers health and reduce cost .For implementation of sustainable construction, the use of green material and equipment are the vital factors (Shi, Zuo et al. 2013).

The Lean tools assist the organization to improve the Environmental Sustainability and business performances (Zhan, Tan et al. 2018). It makes the performance better through the elimination of wastes related to management, man, material, and machine. The lean management reduces the non-value added activities such as rework, and damaged products in shipments, which result in a positive change to organization (Pampanelli, Found et al. 2014). The construction plays vital role in country economy if proper material management is applied. According to (Solís-Guzmán, Marrero et al. 2009, 2013, Oyedele, Ajayi et al. 2014) construction industry shared an immense portion for landfill waste. 44% was contributed byUnited Kingdom (UK) while Australia added 29%,whereas in United States (US) it is around 35%. This engender a huge cost and have negative impact on the environment. After realizing the negative impact of the wastes the countries tend to establish different policies and strategies to overcome the wastes production in construction industry (Oluwole Akadiri and Olaniran Fadiya 2013)

Omani construction industry is facing a significant challenge in the local market because of finite availability of equipment and green materials. The idea of sustainable construction is still youn in Oman and will take time to have matured processes and models. (Al Hatmi, Tan et al. 2014) implored that lack of implementation and operations requirement knowledge is present in Oman construction environment. The critical challenge for sustainable construction is the deficiency of adequate sustainable technologies.

Management in construction play a very good role. The key to a successful construction project is managing construction material effectively (A. A. Gulghane1 April 2015). Material contained a huge

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cost in construction industry, according to the studies, the material constitute 60% or more of the total cost(Patel and Vyas 2011).This huge cost creates a need for planned, well monitored and controlled material management. For the implementation of the effective material strategies, there should be a centralized material management team coordination between site and organization. The construction material management may contain similarities at the conceptual levels but they have differences at the implementation. Material planning considers material in the order of requirements(Desale and Deodhar 2014). There is immense need to properly plan and execute the material procurement. On site storage, deficiencies in the supply and demandare often cited as the major causes of productivity degradation and financial loses(Kanimozhi and Latha 2014**).** As compared to the manufacturing materials the construction materials are less homogenous, less standardize, and more numerous and the characteristics of demand are different. There should be a special type of awareness about material handling and scheduling at every stage of project to avoid improper material management (Patil and Pataskar 2013). Improper management of materials during site activities adversely affects the performance of construction projects (Kasim 2008). Therefore if the material is not managed properly it will create huge problems of cost variance and project delay(T. Phani Madhavi1 2013). It is observed that project delay occurs in 70%, 40% and 50%of government project in UK,India and United Arab Emirates (UAE)respectively dueto improper material management.

Vietnamese government have recognized time overrun as the major headache (Le-Hoai, Dai Lee et al. 2008). According to survey in Nigeria only 24 projects out of 3407 were finished on timewhereas 1517 were delayed and the remaining ones are canceled (Amu and Adesanya 2011). (Frimpong, Oluwoye et al. 2003) found that 40 % and 70% out of total projects face delay in Ghana and SaudiArab respectively. Likewise, in Malaysia the construction industry is also facing the same critical problem of time overrun (Alaghbari, Razali A. Kadir et al. 2007, Razak Bin Ibrahim, Roy et al. 2010).

Beside that the most of projects cannot be completed during its specific time, the cost overrun is also a major problem in a construction industry, unfortunately a large number of project exceeds than that that of allocated budgets(Azhar, Farooqui et al. 2008). A study by (Omoregie and Radford 2006) found that minimum average increase in the cost for Nigeria is 14%. Based on another study on 92 built structures of traffic in Slovenia,a total of 51 percent contracted projects were suffering from price overrun(Nikić 1998). (Žujo, Car-Pušić et al. 2010)reported that out of 333 analyzed projects in Croatia 81% suffered from price while in Herzegovina and Bosnia, about 41.3% of the projects did not met the contracted price.About one third of the clients reported that there projects are completed in the allocated budgets in UK construction (Jackson 2002).

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Although the construction industry generate a large number of jobs and opportunities around the world (Ali, James et al. 2015), however the ratio of the fatal incidents of construction industry is higher than other sector.In other words the construction industry is one of the greatest injury poring (Kines, Andersen et al. 2010, Sunindijo and Zou 2012, Feng, Teo et al. 2014, Seo, Lee et al. 2015). According to report stated by the urban ministry of China, construction industry in China suffered from 482, 527 and 519 safety accidents from 2012 to 2014. It is imperative to control, regulate and provide safe working environment, in order to promote a positive impact among the construction team and reducing the likeness of injuries (Liao, Lei et al. 2015).

3. RESEARCH GAP

The literature review indicates that management, money, material, machine and humans/man are important factors within a construction environment. A number of reasons could contribute to waste generation in these factors. This paper uses the Relative Importance Index (RII) to rank these factors.

4. METHODOLOGY

A number of research papers were reviewed to identify the reasons for waste generation in construction environment. With the help of academician and construction practioners, a questionnaire was developed and distributed for data collection. The questionnaire includes questions having aLikert scale from 1 to 5 representing percentage importance 0-20%, 20-40%, 40-60%, 60-80% and 80-100% respectively. The benchmark for the number of the respondents was set at 30. After that analysis was performed using Microsoft Excel. RII was calculated and result were achieved. Figure 1 shows the overall methodology adopted for this research.

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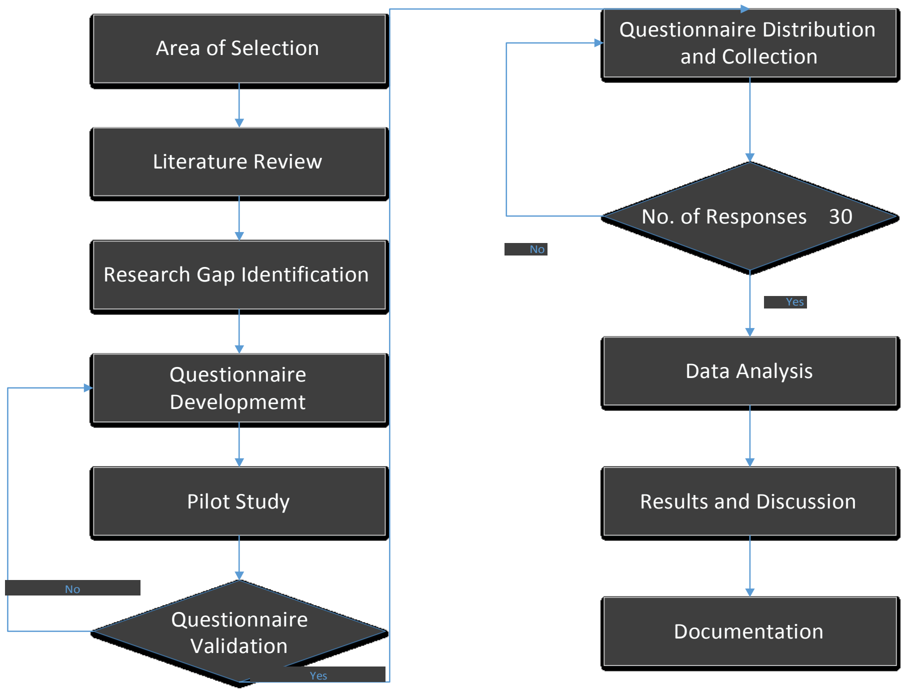

Figure 1

Research Methodology

5. ANALYSIS

Analysis was performed using Relative Importance Index (RII) through Microsoft Excel. Relative importance index was performed for the relative ranking of these factors by using following formula as shown in Eq. (1).

$$\text{RII} = \sum w/A * N \quad (0 \leq \text{index} \geq 1) \qquad \text{Eq. (1)}$$

Whereas "w" represent the total weight of the factor, "A" represent the maximum weight of each factor and "N" represents the total number of the respondents.

The identified reasons from literature review are grouped under Man, Machine, Material and Management as shown in Table 1. Under each category their values were averaged to get a mean value and then further analysis was performed on these values.

Table5. 1

Grouping of Reasons under 5Ms

Factors	Reasons
Man	Non-Skilled Labour

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	Loading and Unloading
Machine	Equipment Failure
Material	Improper Material Rework/Correcting Work Damage of Products in Shipment
Management	Improper Information Delay in Information Sharing Producing Higher Quality than required Improper Project Plan
Money	Contractors Funding

As shown in Table 2 the maximum weightage of each factor is 5 and the total number of respondents are 30. After categorizing the factors their mean values represent each main category values like Man, Machine, Material, Management and Money. Then RII is performance as shown in Table 2.

Table 5.2

Relative Importance Index Calculation

Factors	Total sum	Max Weight	Total Respondents	RII	% RII
Man	90.5	5	30	0.603333	60.33333333
Machine	85	5	30	0.566667	56.66666667
Material	91.33	5	30	0.608889	60.88888889
Management	97	5	30	0.646667	64.66666667
Money	106	5	30	0.706667	70.66666667

Then these factors were arranged in descending order to show the relative importance of each factor in order.

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Table5. 3

Ranking of Indicators

Ranking	
Money	70.66666667
Management	64.66666667
Material	60.88888889
Man	60.33333333
Machine	56.66666667

6. RESULTS AND DISCUSSION

As seen from above analysis different time wastage reasons were identified and then those reasons were integrated into main factors such as Man, Machine, Material, Management and Time and Money. Each factor has its own important. As shown in Figure 1"Money" got highest value of 70.66 that means that contractors own funding is very much critical for time overrun and time delays."Management" got second highest value of 64.67.This shows that information sharing, quality requirements and project planning is very much significant and can contribute to time over run in much larger proportion."Material" got third highest value of 60.89. This implores that damaged material, improper material selectionand rework can also contribute to the time wastage. "Man"got a score of 60.33 which is very close to the "material" value. This results suggests that unskilled labour, and there mistakes in loading and unloading operationswastes time as well. At last Machine has value of 56.67 describing that least time is wasted in construction industry because of machine failure.

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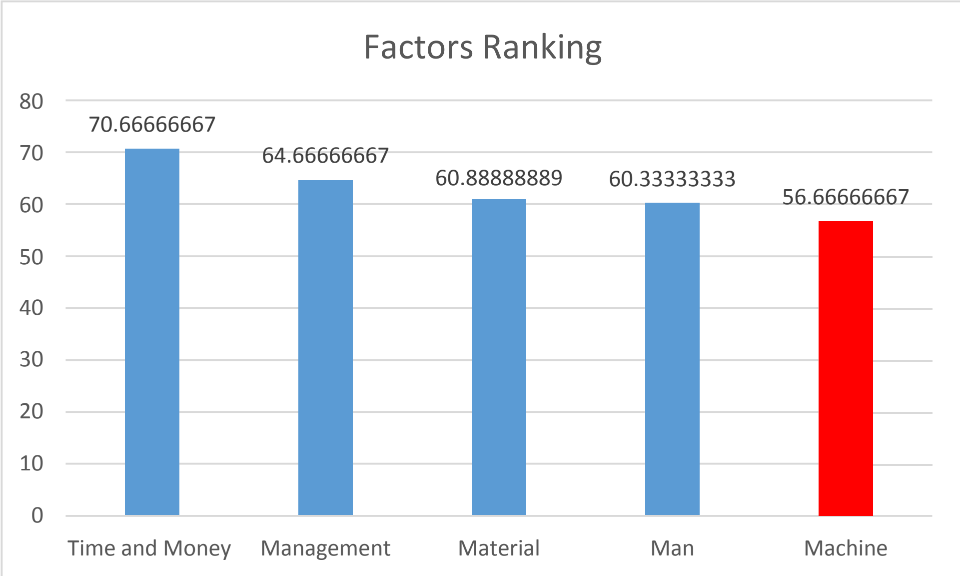

Figure 6.1

Factors Ranking

7. CONCLUSION

Construction helps in building the economy of a country but it also has bad impacts on the environment. Construction process also have non value added activities that consumes time and good amount of money. The factors that consumes time are identified. The data is collected via questionnaire and Relative Importance Index (RII)is performed for the relative ranking of factors. Money, Management, Material, Man and Machine got values of 70.67, 64.67, 60.89, 60.33, and 56.67 respectively. The analysis could be further extended to do the ranking via Analytical Network Process.

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IMPACT OF WORKING ENVIRONMENT ON THE PERFORMANCE OF EMPLOYEES: CASE STUDY OF GINNING FACTORIES

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ABSTRACT

Ginning factories are focused for the health and safety issues, particularly, when there is the question of worker`s health. The dusty air and noise are the main hazards at the ginning halls and workers` health is poorly affected by these hazards. The dust which is produced while the cotton is processed and handled causes health problems for workers [1]. Toxic agents don't only affect millions of worker`s health but also pollute the environment [2]. Therefore, it was required to conduct the study in the ginning factories of district Mirpurkhas in order to know the practices which are being carried out in terms of health and safety of workers. Four ginning factories were selected for the data collection. Questionnaire was used as the data collection instrument and 145 responses were collected from the workers who have been working in ginning halls over there. The data was analyzed in Statistical Package for Social Sciences (SPSS). Linear regression technique was used to find the impact of different health and safety hazards on the performance of employees. Results revealed that the dust has an impact on the performance of workers, whereas noise and eyes` irritation has none. Furthermore, dust was found to have an impact on eye irritation.

Keywords— *ginning, working environment, factory, Noise, Dusty air*

1. INTRODUCTION AND LITERATURE

Pakistan is fourth largest cotton supplier in this world and produce 8.7% of the total cotton supplied across the globe [3]. Large amount of dust is generated by the ginning, weaving and spinning process in the textile industries [4]. It is the global public health issue that workers are exposed to toxic wastes with in the vicinity of cotton industry [5][6]. The dust which is produced while the cotton is processed and handled causes health problems for workers [1]. Toxic agents don't only affect millions of worker`s health but also pollute the environment [2]. It has been recognized for about three hundred years that work in textile industry is hazardous [6]. Those problems are generally respiratory problems. The disease caused by cotton dust is called Bysinosis and its symptoms

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are, i.e. chest tightness, cough, asthma, irritation in trachea and breathing problems [7][1]. These problems occur due to poor work health and safety practices in the vicinity of industry. Due to frequent and being freely exposed to work is the major pulmonary threat, worker are supposed to operate in unhealthy conditions by means of workplace and working conditions[8]. With the help of management, industries can control these problems by providing the awareness of health and safety to the workers. Work health and safety is the knowledge which is applied for the protection and safety of workers at the workplace so as they can be saved from the exposure of hazards[3]. Thousands of workers are exposed to hazards on daily basis in the textile industry and the study has proposed the positive correlation between awareness and health and safety improvement [9]. Workers should be known to common safety precaution and the dust catching devices should be installed so as the diseases i.e. cough, asthma, phlegm and bysinosis can be reduced to some extent [10]. This study is aimed to identify examine the health and safety hazards and the relation between health and safety hazards and job performance of workers. So as the relevant guidelines can be proposed for those hazards can be avoided in the cotton ginning industries.

1) Working Environment

Working environment may have the greater influence on the health and productivity of workers and their physical health and mental well-being is also affected positively or negatively by the working environment [11]. Workers in developing countries spent most of their working times at the workplace and there is the highlighted difference between the home and workplace environment [12]. There are various factors which should be considered e.g. building design, workstation set-up, workplace layout, furniture and equipment quality and design temperature, space, ventilation, illumination, humidity, noise, radiation, vibration and air quality [7]. It is the basic right of the workers that the administration should provide them safe working environment [13], [14]. Injuries and disorders are greatly caused by the environment, mechanical and personal factors and these factors can also cause injuries and disorders collectively [12]. It was reported that high accident rates are led by an abnormal working environment [15]. Anticipation of potential hazards related to health and environment during planning of workplace, processes and equipment is an ideal approach; in this way the hazards can be avoided [16].

2) Air Quality

Exposure to dust lead workers to diseases and disability and also causes the serious health problems among workers throughout the world [11]. Air quality plays an important role in well-being and health of workers; poor air quality can affect the respiratory tract adversely [17]. Air is contaminated of small dust particles, which can`t be seen by an unaided eye [16]. Different types of dust exposures can cause lung`s fibrosis [10][18], asthma attacks and allergic reactions [1][8][13][18][19]. For the control of exposures and their management, it is important to identify and highlight the environmental root causes of the respiratory diseases [18].

Keeping in view all these hazards caused by dust researchers suggest to install the dust collectors in the ginning halls and the vicinity of the factory layout [7][8]. This would only lighten the air from the dust particles, even after the small amount of dust particles would be remaining in the air, therefore, workers must use the masks [3][4][6][7][10][15][20]. In this way workers can be prevented from the several diseases i.e. asthma, fibrosis allergies and skin infections.

3) Workplace Noise

Occupational noise is one of the most important hazard [7][11][14][12]. It is generated from the different types of industrial systems[16] and from the rotating machines[14]; and it is importantly considered while designing the industrial system [16]. Related hazard to the noise is hearing loss which is encountered by workers in textile [19][14], ginning, construction and manufacturing industries [19]. Hearing loss is occurred over time passage of time due to noise exposure without the usage of earmuffs [10]. Earmuffs are designed for protection of ears from the hazardous noise.

4) Irritation in Eyes

In textile industries workers suffer from eye diseases [14]. Workers are put in hazardous situations i.e. chemical hazards in industries which cause eye irritation among workers [11]. It was reported in the study that 35.2% workers were exposed to allergy or eye irritation due to chemical hazards[14]. Another study reported that eh 19.6% workers suffered from the eye infections in the textile industry [10]. Special goggles are recommended in such hazardous working environment for complete working environment [10].

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5) Performance of Employees

Worker`s performance is influenced in such an environment in which he is prone to the occupational illness [12][14]. Occupational health contribute not only in worker` health but it has also an influence on their productivity [15]. All factors are included by the working environment that affects the job performance even if they are not directly concerned with the operation [15]. It was reported that the workplace noise have an effect on the cognitive task performance and safety of the workers [7]. The workers who are engaged on daily basis in hazardous activities, their performance is hindered and job satisfaction decreases [12]. Noise is reported to have an impact on the productivity [21]. Proper lighting was also reported to be positively associated with the performance of the workers [22]. It is necessary for the industries to control all the factors which are associated with the mental and physical performance of human also the industrial productivity [20]. It is required that the enterprise should account for the health and safety performance of the workers [16]. Workplace may be looked and assessed by considering the ergonomic issues which are related with the questions for the local worker`s performance [20]. In order to maintain the production and its quality, worker`s health is essential [7][15].

2. RESEARCH METHODOLOGY

6) Study Area

There are several cotton ginning factories as shown in the figure 1. About 1000 workers contribute their services at Mirpurkhas district. The data was collected from 4 cotton ginning factories.

7) Questionnaire

Before designing the questionnaire cotton ginning factories were visited so that the commonly occurring problems can be highlighted and questions can be prepared accordingly. Questionnaire was designed after reviewing the literature and visiting the ginning factories.

8) Data Collection

145 samples were distributed among the workers employed at the ginning halls; 145 samples were collected back from them and luckily all the questionnaires were found valid.

9) Data Analysis

Data was analyzed in Statistical Package of Social Sciences (SPSS) version 22; reliability of the data was checked by using the Cron-bach alpha test and the value of alpha came out to be 0.75. Furthermore, linear regression technique was used to find the impact of different factors i.e. noise, dust, eye irritation on the job performance of the workers.

3. RESULTS

10) Normality Test

The data was analyzed in the Statistical Package for Social Sciences (SPSS) version 22. In order to reveal whether the data was normally distributed or not; the skewness and kurtosis of the data was computed. In statistical interpretation the value of skewness and kurtosis should be between +1 and -1; then the data would be considered as normal. Skewness and kurtosis of the age, experience and all likert scale questions were computed as shown in the table: 4.2. Normal probability plots of the data are given in the below given figures: 1,2,3,4,5,6,7.

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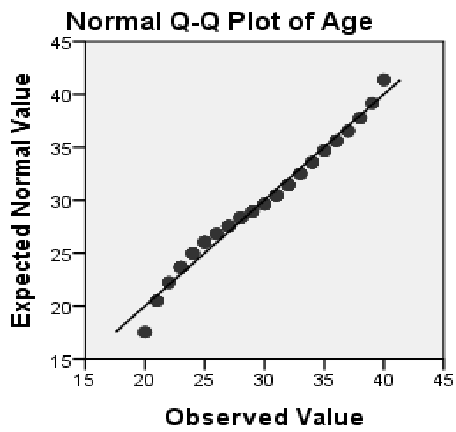

Figure 1 (Normal Probability plot of the age of respondents)

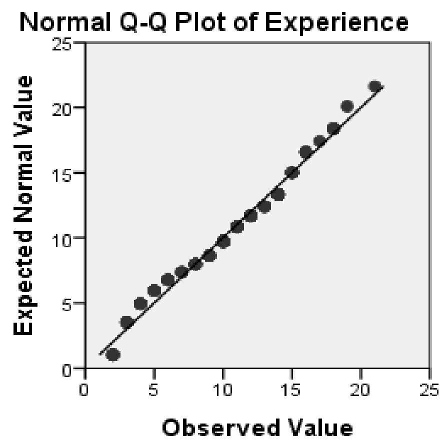

Figure 2 (Normal Probability plot for the experience of Respondents)

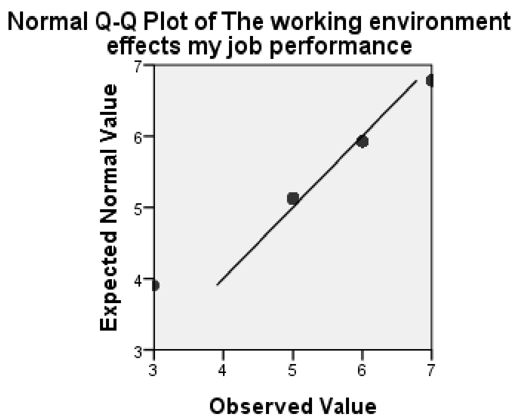

Figure 3 (Normal Probability plot of the question i.e. working environment affects my Job Performance)

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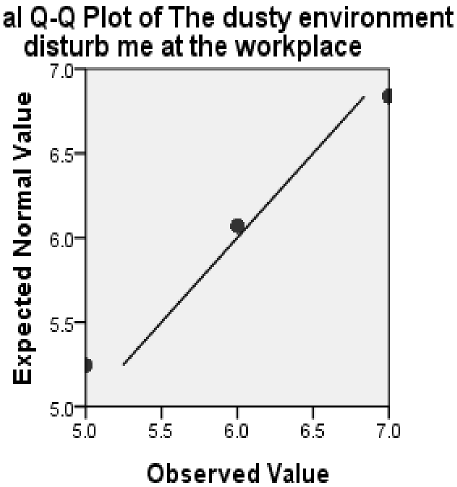

Figure 4 ((Normal Probability plot of the question i.e. dusty environment disturb me at the workplace)

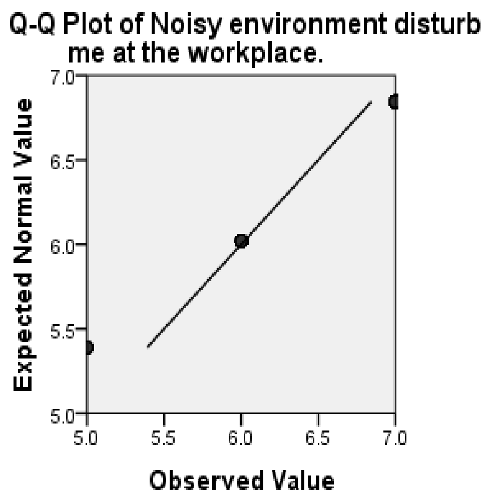

Figure 5 (Normal Probability plot of the question i.e. noisy environment disturb me at the workplace)

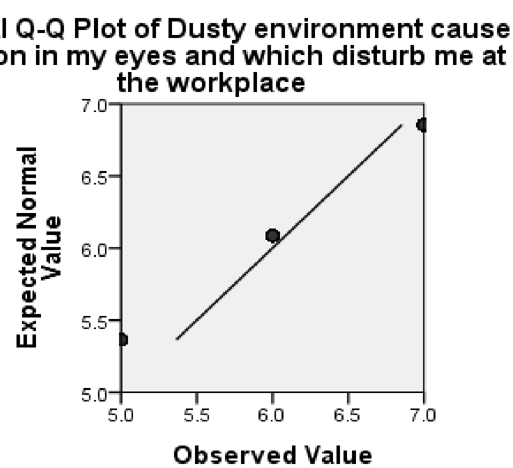

Figure 6 (Normal Probability plot of the question i.e. dusty environment cause irritation in my eyes which disturb me at the workplace)

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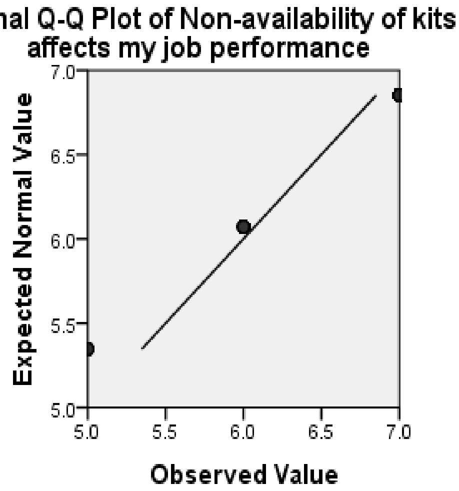

Figure 7 (Normal Probability plot of the question i.e. non-availability of safety kits affects my job performance)

Skewness and kurtosis of the likert scale questions was computed, so that the linear regression of the questions could be calculated in case if the values of skewness and kurtosis came in between +1 and -1. Skewness for the age of respondents came out to be 0.14 and the skewness was computed to be -0.974 as shown in the table: 4.2.

For experience, the value of skewness was computed to be -0.032 with the standard error of 0.201; whereas, kurtosis was calculated to be .832 with the standard error of 0.400. Skewness for Q: 2 came out to be -0.19 with standard error of 0.201 (table: 4.2); and the kurtosis for the same question came out to be .788 with the standard error of 0.400. Skewness for Q: 3 came out to be -0.315 with standard error of 0.201; and the kurtosis for the same question came out to be -0.635 with the standard error of 0.400 (table: 2). Skewness for Q: 4 came out to be -0.977 with standard error of 0.201; and the kurtosis for the same question came out to be -0.405 with the standard error of 0.400 (table: 4.2).

TABLE I. MODEL SUMMARY

	Skewness		***Kurtosis***	
	Statistic	***Std. Error***	***Statistic***	***Std. Error***
Age	.014	.201	-.974	.400
Experience	-.032	.201	-.832	.400
The working environment effects your job performance	-.019	.201	.788	.400
The dusty air disturb your job performance at the workplace	-.315	.201	-.635	.400
Noise affects my job performance at the workplace.	-.977	.201	-.405	.400
Irritation in your eyes affect your job performance	-.836	.201	-.286	.400
Your performance is affected by hand and wrist pain	.093	.201	-.802	.400
Non-availability of kits affects your job performance	-.789	.201	-.389	.400

The data was analyzed in the Statistical Package for Social Sciences (SPSS) version 22. In order to reveal whether the data was normally distributed or not; the skewness and kurtosis of the data was computed. In statistical interpretation the value of skewness and kurtosis should be between +1 and -1; then the data would be considered as normal. Skewness and kurtosis of the age, experience and all likert scale questions were computed as shown in the table: 4.2.

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11) Regression analysis of dusty air and the performance of employees

Linear regression was computed in statistical package of social sciences (SPSS). Table: 1 presents the coefficient of correlation (R) which was calculated to be 0.279, it indicates that there is a weak correlation between dusty environment and the job performance. The value of R square (0.078) demonstrates that there is 7.8% total variation in the dependent variable i.e. job performance which is quite small variation.

TABLE II. MODEL SUMMARY

Model	*R*	*R Square*	*Adjusted R Square*	*Std. Error of the Estimate*
1	.279[a]	.078	.071	.688

Results of Analysis of Variance (ANOVA) are presented in table: 2. Statistical significance of regression model was computed to be 0.001, which is <0.05. This indicates that the model is statistically significant.

TABLE III. ANOVA TEST RESULTS FROM SPSS

	Sum of Squares	*df*	*Mean Square*	*F*	*Sig.*
Regression	5.712	1	5.712	12.052	.001[b]
Residual	67.777	143	.474		

Table: 3 presents the coefficients of the linear regression model. $Y = a + bx$, this is known as the equation of regression; and the coefficients of this equation are provided in this table i.e. a= 3.540 and b= 0.318. The coefficient show that the performance of the workers is affected 0.318 times the dusty air disturbance.

$$Y = 3.50 + 0.318x \quad (1)$$

By the help of these coefficients, the equation was made as shown in in the figure: 2 and the all the values were predicted.

12) Regression analysis of noise and employee`s performance

Statistical package of social sciences (SPSS) was used in order to compute the regression results as mentioned earlier. Table: 4 presents the coefficient of correlation (R) which was calculated to be 0.063, it indicates that there is negligible correlation between the workplace noise and job performance. The value of R square (0.004) demonstrates that there is 0.4% total variation in the dependent variable which is quite small variation.

TABLE IV. MODEL SUMMARY

Model	*R*	*R Square*	*Adjusted R Square*	*Std. Error of the Estimate*
1	.063[a]	.004	-.003	.715

Results of Analysis of Variance (ANOVA) are presented in table: 5. Statistical significance of regression model was computed to be 0.453, which is >0.05. This indicates that the model is not statistically significant.

TABLE V. ANOVA TEST RESULTS FROM SPSS

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	Sum of Squares	df	Mean Square	F	Sig.
Regression	.290	1	.290	.567	.453[b]
Residual	73.199	143	.512		

Table: 6 presents the coefficients of the linear regression model. The coefficients of this equation are provided in this table i.e. a= 5.165 and b= 0.063. The coefficient show that the performance of the workers is affected 0.063 times the workplace noise.

$$Y = 5.165 + 0.063 \qquad (2)$$

By the help of these coefficients, the equation was made as shown in in the figure: 3 and the all the values were predicted.

13) Regression analysis of eye`s irritation and the performance of employees

Table: 4.7 presents the coefficient of correlation (R) which was calculated to be 0.028, it indicates that there is negligible correlation between eyes irritation and the job performance. The value of R square (0.001) demonstrates that there is 0.1% total variation in the dependent variable i.e. job performance which is quite small variation.

TABLE VI. MODEL SUMMARY

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.028[a]	.001	-.006	.717

Results of Analysis of Variance (ANOVA) are presented in table: 7. Statistical significance of regression model was computed to be 0.736, which is >0.05. This indicates that the model is not statistically significant.

TABLE VII. ANOVA TEST RESULTS FROM SPSS

	Sum of Squares	df	Mean Square	F	Sig.
Regression	.059	1	.059	.115	.736[b]
Residual	73.431	143	.514		

Table: 9 presents the coefficients of the linear regression model. The coefficients of this equation are provided in this table i.e. a= 5.787 and b= -0.033. The coefficient show that the performance of the workers is affected -0.033 times the eyes irritation.

$$Y = 5.787 - 0.033.x \qquad (3)$$

By the help of these coefficients, the equation was made as shown in in the figure: 2 and the all the values were predicted.

14) Regression analysis of dusty air and eye`s irritation

Results of linear regression analysis are presented in below given tables. Table: 10 presents the coefficient of correlation (R) which was calculated to be 0.250, it indicates that there is a weak correlation between dusty environment and the job performance. The value of R square (0.062) demonstrates that there is 6.2% total variation in the dependent variable i.e. dusty air, is quite small variation.

TABLE VIII. MODEL SUMMARY

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.250[a]	.062	.056	.596

Results of Analysis of Variance (ANOVA) are presented in table: 11. Statistical significance of regression model was computed to be 0.002, which is <0.05. This indicates that the model is statistically significant.

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TABLE IX. ANOVA TEST RESULTS FROM SPSS

	Sum of Squares	*df*	*Mean Square*	*F*	*Sig.*
Regression	3.382	1	3.382	9.507	.002b
Residual	50.867	143	.356		

Table: 12 presents the coefficients of the linear regression model. $Y = a + bx$, this is known as the equation of regression; and the coefficients of this equation are provided in this table i.e. a= 4.939 and b= 0.245. The coefficient show that the performance of the workers is affected 0.245 times the dusty air disturbance.

$$Y = 4.939 + 0.245x \qquad (4)$$

By the help of these coefficients, the equation was made as shown in in the figure: 2 and the all the values were predicted.

4. CONCLUSION

There are various factors by which the performance of workers is hindered in ginning factories. It was concluded that the dusty air has an impact (R=0.279) on the performance of workers at the workplace. Regression model was statistically significant with the p-value of 0.001.

However, noise is also reported to have an impact on the performance of workers but according to the results of this survey, workplace noise has no impact (R=0.063) on the performance of workers. The used regression model was computed to be non-significant with the p-value of 0.453. Furthermore, the results indicated that there is no impact (R=0.028) of eye`s irritation on the performance of workers; this linear regression model was also not significant (p-value = 0.736).

The impact of dust on the eye`s irritation was also investigated by using linear regression model. The coefficient of correlation (R) was computed to be 0.250, which meant there is weak correlation between dust and eye`s irritation. The regression model was statistically significant with the p-value of 0.002.

5. FUTURE WORK

Physiological measurement has been put into the section of future recommendation for researchers to carry out their health and safety research using physiological measure for the extension of this research. This research can also be conducted in spinning mills so that the lacking on the account of health and safety can be highlighted in spinning mills of Mirpurkhas. The health and safety at ginning units can also compared with the spinning units so that the weak area can be suggested for the improvement.

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IMPACT OF AGE AND EXPERIENCE ON THE SALARY EXPECTATION AND RECOGNITION OF EMPLOYEES

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ABSTRACT

Motivation is found to have an impact on the performance of employees. Therefore, it was required to know the factors which directly affect the performance of employees. Salary and recognition are known as the main factors of motivation for the people working in any organization. This study was conducted to analyze the behavior of employees in terms of salary and recognition with their increasing age and experience. The data was collected from 3 companies of Korangi industrial Area, Karachi, Pakistan. Data collection instrument was the questionnaire: 186 samples were collected from the respondents. Data was analyzed in the Statistical Package of Social Sciences (SPSS) version 22. Reliability of data was checked by using cron bach alpha test whose value came out to be 0.660. Normality of data was checked thereafter; so that the correlation analysis on the data can be conducted: after it was revealed that the data is normal, age and experience of employees were correlated with the salary and recognition of employees. Results indicated that the age and experience both have the weak positive correlation with the salary and recognition of employees

Keywords*—Motivation, Salary, Recognition, Performance of employees*

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1. INTRODUCTION

Motivation can be defined as the aim of achieving a target, it is an ability to change behavior, and leads to target-directed behavior towards the attaining the target (Uzonna, 2013). Motivation is nothing but it is the art of getting someone act as per defined motive (Burton, 2012). Enhanced output of employees is the result of strong positive motivation and employees are only motivated when their unsatisfied needs are satisfied (Aryan, 2015)(Fallis, 2013).

According to the control concept of Nineteenth century that the happy staff is more productive. It is proved by many theories and cases that work pleasure is important to achieve the organizational goals (Nadeem, Ahmad, Abdullah, & Hamad, 2014). Many of the employees need motivation to have good feeling about their job and show good performance, whereas some of the employees are motivated by money rewards and some employees by recognition (Ganta, 2014).

Motivation originates from the influence of intensity of desire, money in return of goal accomplishment (Ganta, 2014). Motivation initiate the relationship between employee performance and organizational growth (Dash, 2015). Motivation plays an important role in direction to the performance of employees (ZAMEER, Alireza, NISAR, & AMIR, 2014) . It has been concluded that recognition and incentives have the positive correlation with the motivation of employees. (Uzonna, 2013) The research was carried out to identify the impact of monetary and non-monetary motivation on employees. Non-monetary motivation are i.e. 'recognition', 'challenging work', 'advancement and opportunities', 'job autonomy', authority and job security prestigious job titles and responsibility. Monetary motivation variables are i.e. 'fringe benefits', 'salary', 'bonuses', 'pensions', 'profit sharing'. Each the factor was analyzed to have an impact of the employee performance. Results indicated that non cash rewards are more effective than the money rewards (Chien, 2008). The author has suggested techniques for employee motivation i.e. job enlargement, job enrichment and job rotation (Ganta, 2014).

The success of an organization highly depends on the performance level of employees in accomplishment of its objectives (Kiruja, 2013). Organizational behavior demonstrates three factors i.e. individuals, groups and organizational structure, and an organization needs to manage each of them in one direction so as the organizational objectives can be achieved (Jayarathna, 2014).

Literature demonstrates the employee performance includes job productivity, job quality, and job accomplishment (ZAMEER et al., 2014). Employee productivity is his output per day, and it impacts on the productivity of company. It is the main factor that contributes positively in competitive power of the company (Aiyetan & Olotuah, 2006). This is the reason due to which the companies try their best to possess the best employees and acknowledge them for their important role and contribution towards organizational effectiveness (Dobre, 2013).

Motivation has the impact on the performance of the employees, this can be reflected by the comparison of two employees i.e. less skilled and more skilled: Less skilled employee puts his 100 percent with the work because he is motivated, in contrast to this, an employee with more skills is not putting his 100 percent in his work because he is less motivated (Sajjad, Ghazanfar, & Ramzan, 2013). So it can be said that motivation play an important role in motivating the employees.

This study aimed to measure the effect of motivation on the productivity of employees in the Pakistan civil aviation authority. So as the motivation level of the employees can be accessed and propose the necessary steps to be taken to enhance the productivity of employees in the organization.

I. Salary

Salary has been highlighted as the leading factor in motivating the employees towards productive work. The study which was conducted in certain manufacturing companies which indicated that staff and poor motivation due to less salaries and rare promotions(Maduka & Okafor, 2014). The study was conducted to determine the effect of motivation and recognition on the productivity of employees. 100 samples were collected and results indicated that salaries and monetary benefits had the significant effects on the productivity of employees (Aryan, 2015). Study was conducted in training institution of Kenya which was aimed to determine the impact of motivation of the employee performance. Data was collected from the 315 administrators, head or the departments, teaching staff and non-teaching staff. The results indicated that the employees are not satisfied with the pay and work environment (Kiruja, 2013).

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II. Recognition

Recognition has been marked as the main factor which causes motivation (Uzonna, 2013)(Aryan, 2015). Recognition and empowerment was found in positive correlation with the employee motivation and furthermore the positive link between employee motivation and organizational effectiveness was also reported (Manzoor, 2011). It was concluded by (Nadeem et al., 2014) that the recognition is positively linked with the employee motivation. Recognition was indicated as the motivator for the employees (Burton, 2012). Appreciation on good work and recognition plays an important role in the motivation of employees (Dash, 2015).

2. RESEARCH METHODOLOGY

III. Data Collection

Data was collected from AAA dyeing and finishing company, Karachi. Questionnaire was used as the data collection instrument; 5 point likert scale was used in the questionnaire. 220 questionnaire were distributed among the workers of the respective company; all the questionnaires were collected back and unfortunately 20 of them were incomplete. Incomplete questionnaires were excluded from the study.

IV. Data Analysis

Data was analyzed in Statistical Package of Social Sciences (SPSS). The reliability of data was checked by using cron-bach alpha test which was computed to be 0.660. Data analysis was started with the frequencies of the demographic characteristics. Secondly, normality of data was tested and then the hypothesis were tested by using t-test.

V. Normality tests

Normality of the data was checked in the SPSS as mentioned under the heading of data analysis. Normality of age, experience and likert scale questions so that it could be known that that data was normally distributed and the suitable tests could be applied to the test the hypothesis.

TABLE I. TABLE TYPE STYLES

	Kolmogorov-Smirnov[a]			*Shapiro-Wilk*		
	Statistic	*df*	*Statistic*	*df*	*Statistic*	*df*
Age	.128	186	.000	.926	186	.000
Experience	.178	186	.000	.855	186	.000
It seems that the handsome salaries are the best tools for the motivation of workers.	.413	186	.000	.613	186	.000
Workers will still perform well even if their salary is delayed.	.357	186	.000	.712	186	.000
Recognition of good work affects your morale at work	.433	186	.000	.555	186	.000

It can be seen in the last column of table: 1 that value of significance for age experience the all four questions is < 0.05; which indicates that all the mentioned parameters in table: 1 are normally distributed.

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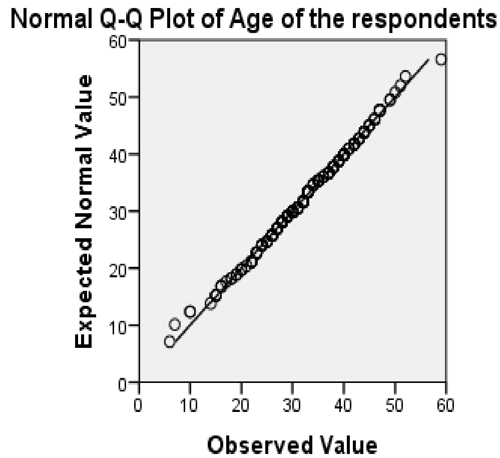

Figure 1 (Normal Probability plot of age of respondents)

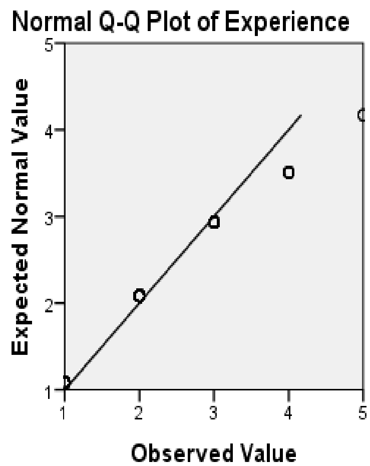

Figure 2 (Experience distribution of employees)

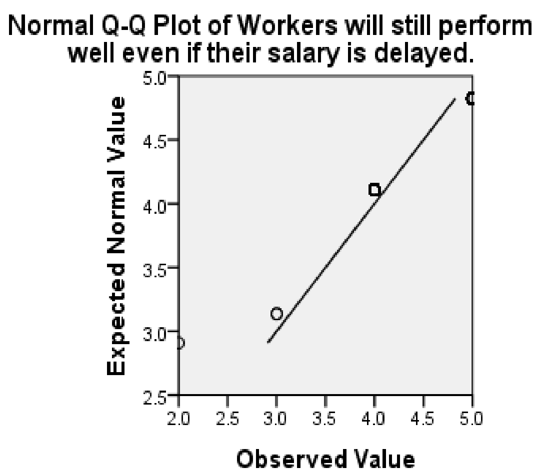

Figure 3 (Normal Probability plot of question i.e. workers will still perform well even if their salaries are delayed)

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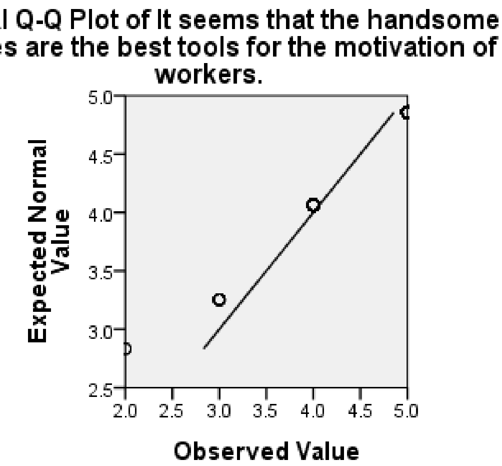

Figure 4 (Normal probability plot for the question i.e. It seems that the handsome salaries are the best tools for the motivaiton of workers)

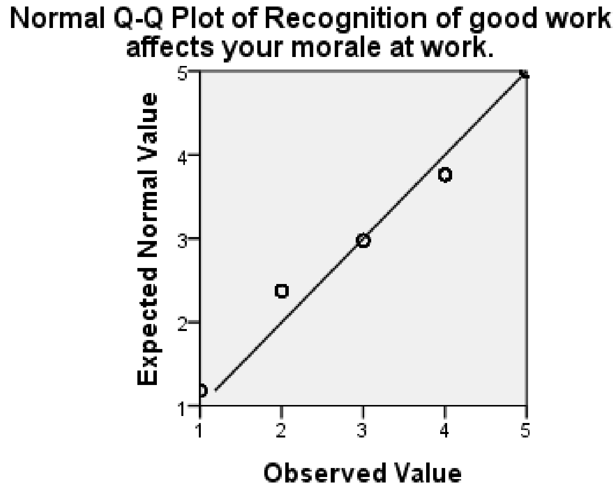

Figure 5 (Normal Probability plot of the responses)

3. RESULTS

VI. Presentation of Demographic Characteristics

1) Gender

Respondents belonged to both genders but the number of females was less. There were 38 (20.4%) female respondents whereas the number of male respondents was 148 (79.56%).

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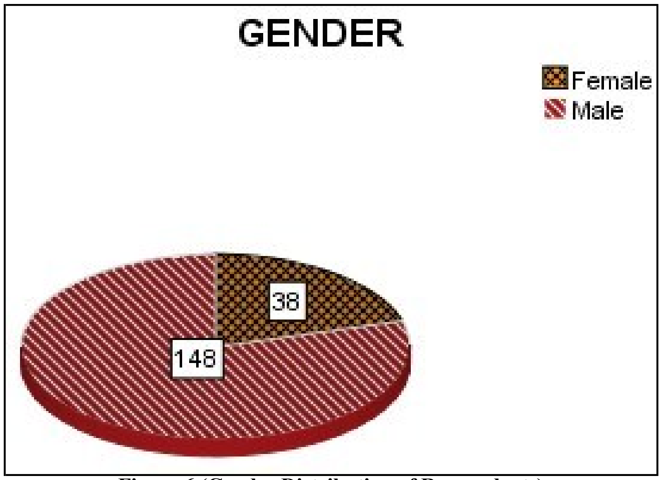

Figure 6 (Gender Distribution of Respondents)

2) *Age*

The frequency distribution of the age is presented in the histogram in figure 4.4. The mean age of the respondents was computed to be 30.51±9.772 years. On the same time the normality test of age distribution was also conducted and the p-value came out to be 0.000 as shown in the table: 1; which is certainly <0.05 and it demonstrates that the data is normally distributed.

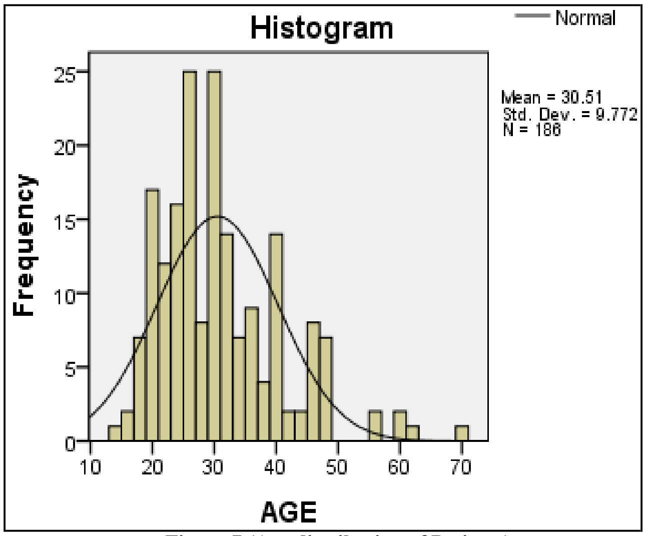

Figure 7 (Age distribution of Patients)

1) *Experience of Employees*

Experience distribution of respondents is presented in the figure: 5. An average experience of the respondents was calculated to be 9.50±8.433 years.

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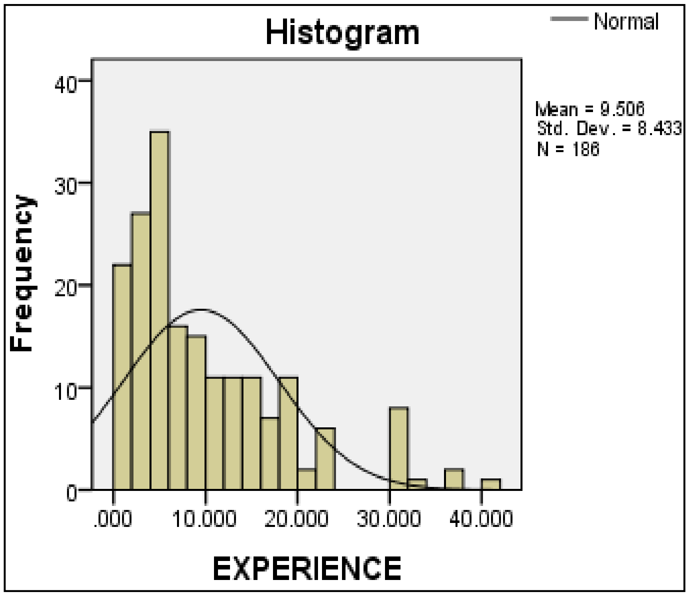

Figure 8 (Experience distribution of patients)

Normality of the experience of respondents was also tested; the p-value for the normality test was computed to be 0.000 as shown in the table: 1; since 0.000<0.05, therefore, the experience of the respondents was considered to be normally distributed. The normal curve can be seen in the figure: 5 which is passing closely to the edges of the columns of histogram (figure: 5).

2) *Qualification Distribution*

Frequencies of the qualification of the employees were taken out. There were 41 (22.04%) employees who had passed only

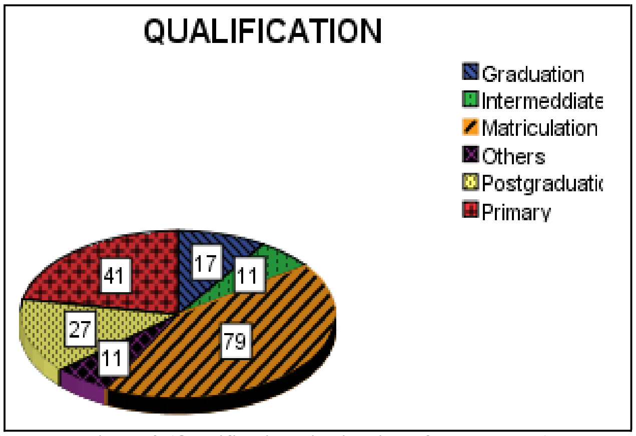

Figure 9 (Qualification distribution of respondents)

Primary education; 79 (42.4%) were matric pass; 11 (5.9%) employees were intermediate pass; the number of graduates was 17 (9.1%); postgraduates were 27 (14.5%) and there were other employees also who didn`t come in any given category, therefore, they were categorized as others; such employees were counted to be 11 (5.9%).

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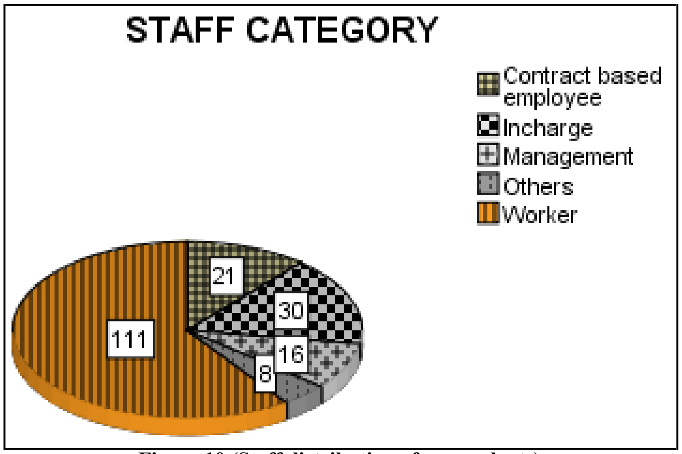

Figure 10 (Staff distribution of respondents)

3) *Staff Category Distribution*

The data was collected from the employees of different category: 16 employees (8.6%) were from the management side; 30 (16.1%) respondents were in charge; 21 (11.2%) respondents were on contract; 111 (5.9%) were workers and those employees who didn`t fall into any category were put into the others category and there were 8 (4.3%) employees in the others category.

VII. Correlations among different varibales

Pearson correlation among the various variables were calculated in statistical package for social sciences which are presented in the table II. 95% confidence interval was considered in this research. The correlation of question i.e. it seems that the handsome salaries are the best tools for the motivation of workers and the experience of employees: value of r came out to be 0.153 with the statistical significance of 0.037.

The correlation between the question i.e. workers will still perform well even if their salary is delayed and experience of employees. The value of r for this relationship came out to be r=0.181 with the 2 tailed significance of 0.013.

TABLE II. CORRELATION TABLE

	Age		***Experience***	
	P-Values	***Sig. (2-tailed)***	***P-Values***	***Sig. (2-tailed)***
It seems that the handsome salaries are the best tools for the motivation of workers.	0.127	0.085	0.153	0.037
Workers will still perform well even if their salary is delayed.	0.137	0.063	0.181	0.013
Recognition of good work affects your morale at work.	-0.032	0.665	0.108	0.143

4. CONCLUSION

It was concluded that age was not significantly associated with the included motivational factors; whereas, experience of employees was positively associated with the motivation of employees caused due to their handsome salaries. Experience of employees was also found to be in positive association with the work of employees even if their salaries are delayed.

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5. FUTURE WORK

For the extension of this research, working environment, behavior of top management, training and development and recreational facilities should be considered for future work. And the impact of these mentioned factors should be investigated on the motivation of employees at the same study area.

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ERGONOMICS MANAGEMENT: A PROACTIVE FOCUS OF CNG STATION IN PAKISTAN

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ABSTRACT

Ergonomics plays a vital role in the service industry as compared to any other field. Compressed natural gas (CNG) station has been selected to address a new domain concerning human factors and human safety. As for the business point of view, CNG stations are one of the leading sectors in the region from which government is earning revenue. The analysis of current methods, safety equipment and design of CNG station used for different purposes. The suggestions were placed in front of the manager and CEO of the CNG station to replace and invent new methods which must meet the specifications required for rapidly changing technology. The orders have been placed for some of the items. The construction and modification of design as it is underway in selected CNG station to provide a safer environment for the workforce.

***Index Terms*—** Ergonomics, CNG (Compress Natural Gas), Safety, Accident, Emergency Valve

1. INTRODUCTION

Ergonomics is the scientific discipline concerned with the understanding of interactions among humans and other elements of a system, and the profession that applies theory, principles, data, and methods to design in order to optimize human well-being and overall system performance.

Natural gas can provide energy for the transportation sector, houses, and generation of electricity. Natural gas is composed essentially of methane, which can be obtained also through anaerobic fermentation of different organic products yielding biogas (60% methane). CNG is stored at 3,600 psi in storage tanks. It occupies 1/300th of space when compared to the same unit at atmospheric pressure.

In a step towards adopting environment-friendly fuel and to save foreign exchange, CNG was introduced by the Government of Pakistan in the country in 1992. Due to the available price differential between CNG and gasoline/diesel, and investor-friendly policy and regulatory framework. CNG sector has shown tremendous growth over the last ten year in the country.

The ergonomics in CNG filling station is the primary focus. It has never been considered by individuals to acquire the knowledge of human factors principle and the proper working environment in which service is provided to the people. Thus, innovation in the current system age necessary to meet the demands. CNG station possesses a certain tool that has really important to understand and deal with them for the purpose of safety and ergonomics. It must be known that only those operations have been discussed those must be improved. The areas that come under consideration includes managers office, CNG panel room, blow-down tank section, CNG compressor, generator, cooling tower, CNG dispenser and customer satisfaction.

The purpose is to use in-house tools in order to understand the principles of human factors in the proper working environment. CNG station was selected due to a particular reason as people do not give proper attention to humans and the stress they carry due to lack of safety and other operations. The health and safety at a workplace must be promoted amongst workers to pinpoint dangerous factors, the corrective measures for such situation are properly conveyed for minimizing accident through behavior and attitude training (Salminen, 2015). The assessment of Life Saving Appliances (LSA) and their functioning is important as on certain occasion these LSA does not function as per requirements due to environment behavior that could mainly be due to knowledge gap (Power & Ré, 2014).

There is a proactive human organization safety technique to identify the potential hazards based on engineering theories (Sawyer & Berry, 2015). It had been found by (Naeini & Mosaddad, 2013), that the 71% of students do not have a fair knowledge of ergonomics and its importance in the workplace. The workplace injuries can be minimized by new development

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in science and technology through safer machinery, better process and safer protective equipment (Kim, Park, & Park, 2016). It has been observed that about 25% of sick leaves in organizations are due to musculoskeletal disorders. At Siemens,

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ergonomics is promoted and considered as one of the basic pillars of growth of the organization. Training is conducted and check sheets have been developed for preliminary analysis for identifying potential improvements (Labuttis, 2015).

2. MATERIAL AND METHODS

The study of different sections in CNG station where ergonomics is not been followed are discussed in details below.

2.1. Managers Office

It is the office in which the manager performs his duties. The main purpose is to perform all the required purchasing and daily updating record. In the main office, the following areas that are worker unfriendly and are avoiding the human factors principles.

The chair provided to the manager is not good enough. As it does not have a proper design which can fulfill ergonomics requirement. If a person sits on it for a long time that will have backbone problems. The tyres beneath the chair were broken and furthermore, it cannot be adjusted according to the height. The chairs for people visiting the office are comfortable. We can observe Fig. 1 in which all the types of chairs present in the office.

Fig. 1. Managers Office

There is no proper cooling/heating system in the office as in extreme weathers it is difficult to perform duties. It can be observed in Fig. 1 that the locker is kept in an awkward position behind the chair. While the objects on the table must be rearranged. The safety measures are not up to standards. The emergency numbers are not displayed, which is one of the greatest drawbacks. As in case of emergency fire brigade has to be called and the manager is not present in office thus imagine the destruction that can occur. The manager is unaware of the performance of the system at a particular time while he is present in his office. There maybe some part of the system not working properly which are unidentified by the worker and can cause a serious accident.

2.2. CNG Panel Room

The panel room consists of CNG panel and uninterruptable power supply (UPS). The panel can be seen in Fig. 2, on which the pressure of different parts of CNG filling station under working condition could be observed. It also shows the time for which system is under working condition after maintenance work was performed.

Fig. 2. CNG Panel

UPS is installed in panel room to provide continuous electrical power to station controls in case of complete power disruption, including a failure of the backup generation system. UPS provides sufficient time to respond when complete power failures occur. In Fig. 3 the UPS used is shown which is used in the selected CNG station.

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Fig. 3. Uninterruptable Power Supply

The worker's interaction with panel controlling is important as all the minor details about the function of whole CNG station are obtained from here. The worker while taking readings must pay attention to UPS as the space between them is small. There is air conditioner installed to keep the temperature of the room as low as possible because panel cannot sustain high temperature.

The equipment required for maintenance have no proper place and record. While UPS batteries are not given proper care a perfect example is in Fig. 4, the battery is now of no use as it is broken. Now, it can only be sold in scrap.

Fig. 4. Broken Battery

During maintenance, workers are not provided with proper safety equipment. They may touch the circuit which hazardous. Similarly, in case of fire, no device is present in the panel room. The internal circuits present in the panel are shown in Fig. 5.

Fig. 5. Internal Circuits of Panel

2.3. Blow-down Tank Section

The blow-down tank sends back excessive gas into the compressor. After approximately 40 minutes the blow is repeated. The timing of blow could be set accordingly. It has vent silencers that are used in conjunction with systems that utilize a pressure relief valve. There is sewage tank that separates gas from liquid and drains the waste, water or oil. The whole system consists of gas blow tank, sewage tank, brake valve, relief valve and pipelines. Blow-down tank and sewage tank should work together for environmental protection. The Fig. 6 shows a typical Blow-down tank used at CNG stations in Pakistan.

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Fig. 6. Blow-down Tank

The worker's interaction with the tank quite often to perform maintenance tasks. They are not following health and safety specifications required to accomplish these tasks that increase the risk of damages. The Blow-down tank during the release of pressure has the high sound that can damage hearing.

The method for pressure inspection from gauges for compressed gas has no standards procedure. While these improper methods could be dangerous. The timing of blow-down is set manually and minor error could cause greater damage. The methods of maintenance are not according to the standards, a sudden opening of any valve can cause damage to a human in term of fatal injury or frostbite as shown in Fig. 7, which requires proper care to minimize its effect.

Fig. 7. Frostbite

The system is not designed properly as gauges are installed at a height from which the reading was taken but it is not easy for the workers to read it. The specified place is not designed for the blow-down tank. The safety precautions are not followed properly. There must be bought new safety systems. The fire alarms, automated emergency valves are not present and sprinkled water system must be installed.

2.4. CNG Compressor

The gas enters compressor station from the pipeline where it passes through a natural gas scrubber vessel which is designed to remove liquids, dirt or other particulates from the gas before it enters the compressors. Water and natural gas are removed by the scrubber are sent to a double-walled holding tank for further processing or disposal.

The turbine compressor that is the heart of the compressor station which consists of two main components gas turbine and compressor. The compressor mechanically re-pressurizes the gas in the pipeline using an impeller. The energy required to drive the compressors is provided by the gas turbines that are mechanically coupled to the compressor impeller. The gas turbines are powered by a portion of the natural gas that flows through the pipeline. Each turbine compressor unit is managed by the control system. It has safety shuts if a fault condition is observed. The compressor room present in the selected CNG station is given in the Fig. 8 as shown below.

Fig. 8. Compressor Room

Compressor room is considered as the heart of all the processes in CNG station. Thus, workers interaction become more important, if they do not perform tasks properly and a small mistake can cause the greater damage which none of the individuals can imagine. The method used for taking the reading was not perfect mainly because of dirty screens and gauges. If proper

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steps are not followed than frostbite can occur. The effects of frostbite can be seen in Fig. 7. It is just an example but this can cause to be a disaster and an individual could be paralyzed permanently.

The methods used for checking the temperature must be improved. The method currently used is not as good as there was an error in readings of the gauges installed in the system. So, this must be given priority in order to be on the safer side by reducing the effects of an accident.

The methods for oiling the machine is not as per standards, it stops the machine from performing effectively as wear and tear is reduced by better oiling process. Similarly, there is no proper. As the oil and gauges are not maintained properly which is a major cause of improper readings from the gauges. Similarly, the joints were not tightened properly in some cases and it was alarming as the bells are ringing for the accident if the minor flame accident is brought to the room. During installation of equipment, the emergency paths are not identified in such high-risk environment. It can be observed in Fig. 8 that this room has only one door with no other escaping path.

The room is provided with a fire extinguisher and emergency valves. In case of emergency valves, the safety standards are not followed because of their mechanism and structure as shown in Fig. 9. But the fire extinguisher is in good shape as shown in Fig. 10. The worker is not provided with a proper chair as shown in Fig. 11. It can cause pain in backbone if used for the larger time period.

Fig. 9. Emergency Valves

Fig. 10. Fire Extinguishers

Fig. 11. Current Chair for Worker

2.5. Generator Room

The generator converts mechanical energy into electrical energy. It uses diesel as a fuel. It is used whenever there is load shedding of electricity. Caltex Mobil oil is used and must be changed after it has been used for 150 hours. The generator present in selected CNG station is shown in Fig. 12.

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Fig. 12. Generator

In generator room, the worker has to interact with a generator to “on/off”, it quite often due to a current shortfall of electricity in Pakistan. Their worker has to insert oil and diesel as it can run properly. The smoke is present in the room and it becomes difficult for workers to perform their duty properly. The noise of generator is high enough to damage the hearing of the worker present in this room or even near it.

Due to smoke, consumption of fuel and no proper exhaust system, the generator room has a high temperature which affects the health of worker and can cause death due to suffocation.

The improper method of oiling and fueling makes floor slippery thus increasing risks of an accident. The floor is not clean due to an improper method of oiling and fueling. There are other things placed on the ground as there are no proper methods for storing. The equipment is all over the floor and on the wall as shown in Fig. 13, there is not a single place defined to keep these items. It becomes difficult to find them when needed. It can cause brutal injuries to the worker if a minor mistake on his disposal occurs.

Fig. 13. Improper Storage

In generator room no safety precautions have been taken, the fire extinguisher is not present and exit path is not defined in case of emergency. The fire alarm or cutoff circuit is not present. It must be given proper care as it constitutes critical location for being near compressor and storage room which can be more disaster to the building and people.

2.6. Cooling Tower

The cold water form cooling tower with help of electric motor is supplied to decrease the temperature of compressed gas while hot water is brought back to be cooled again. It has the capacity of 30 tons/hour. The fan cools the water by using electricity. In Fig. 14, the cooling tower installed in selected CNG station is shown. The cooling tower is installed on the 1st floor. It can be seen in Fig. 15 that there are no proper stairs to reach it. The method for oiling is not perfect as the jug marking is used for this purpose. The sand was attached to it and can affect the efficiency of the machine. The jug is not given proper cleaning care. The jug showed in Fig. 16 must be replaced. It must also be noted that the place to keep the jug safe is not specified. It could be lost any time even if fast air blow in the region where CNG station is operating.

Fig. 14. Cooling Tower

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Fig. 15. Current Stairs

Fig. 16. Oiling Jug

The station has no proper place to keep the container of cooling oil. It has been placed in open air at the roof as shown in Fig. 17. In case of rain, oil can come in contact with rain thus the whole composition may change and then oil will be of no use. The sand particles can also mix with oil in the container.

Fig. 17. Cooling Oil

The upper part of the cooling tower is open with no protective cover, it could be observed clearly in Fig. 18. Similarly, at the bottom end where cold water is stored it again don't have proper cover. In case some impurities enter inside it can block the path of flow of cold water which will increase the temperature which could cause the whole place to explode.

Fig. 18. No Protective Cover

It must be kept in mind that at cooling tower no measures have been taken for safety testing of the equipment. It can also be used for other purposes if utilized properly and effectively. After 7 days the cooling tower is cleaned, the methods used for cleaning are improper as equipment is not maintained. There are two cooling towers installed out of which only one is in working condition. Similarly, the maintenance of oiling is not up to standards set by the supplier. The selected CNG station is located in the hilly area thus weather can change soon, the different cooling fan used for different seasons. There is no proper method to analyze the weather forecast and when it going to change. Currently, one cooling tower is functioning and fan changing becomes more important while weather changes.

2.7. CNG Dispenser

Fuel dispensers are used to pump fuel into vehicles and calculate the cost of the fuel transferred to the vehicle. In Fig. 19 a typical CNG dispenser is shown which is used in selected CNG station.

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Fig. 19. CNG Dispenser

It can be seen that worker directly interacts with dispenser during the fueling process. The training of workers must be carried out according to new ergonomics principles which give workers a view about taking preventive measures. The fueling nozzle and fueling hose used in the selected station is not according to international standards, while the knob used is not according to human factors principles. In Fig. 20 the widely used fueling hose is shown.

Fig. 20. Current Fueling Nozzle and Fueling Hose

The place designed for filling gas inside the vehicles is lower than normal. It can cause backbone pain to the worker due to the repetitive task. The worker does not analyze the reading of pressure properly while the reading process of sales not up to mark due to deviation in the meters. For cashier, there is not a proper place to sit and place cash. It is shown in Fig. 19 at the right side of CNG dispenser. For workers, there is no proper place to rest that can cause pain in foot and backbone of the worker. It can affect the efficiency of the worker's performance. It must be given importance as the behavior of the workers can increase the revenues. There is no the suitable place to keep dustbins. In Fig. 19 dustbin is shown but it is not the proper place to keep it. In case of an emergency such as large gas leakage press the red shutdown button will stop the flow of gas. On the other hand, the emergency valve is not at the proper place as in case of emergency it is difficult to use this valve as shown in Fig. 21. There is no self-serve CNG dispenser. They can reduce the workload from the workers. At the same time, it can increase the customers. The self-served CNG dispenser has only one difference as it uses a credit card and a small processor which can make transactions from banks.

Fig. 21. Emergency Valve

Similarly, Fig. 19 shows that fire extinguisher high above to use in case of emergency. The height of people in Pakistan is less than the height of installed fire extinguisher.

2.8. Customer Satisfaction

Customer satisfaction is important for any successful business. There were certain things related to customers which can be introduced and thus standards could be set in the region. The scrap on the floor required to be removed. There is not a single sign to convey people about throwing waste as in Fig. 22 is prohibited.

Fig. 22. Scrap on Floor

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There is no specified place for dustbins, the size and design of dustbins are not according to required standards. There is not a single place for customers to sit and rest as most people travel long distance. They do not have a place for eating food items. There must be a place designed to help customers for rest. There is not a single place for customers to smoke. They do not have specified place to smoke. The customers must be provided with proper washroom facilities. There must be a separate place of ladies washrooms. They must not be near different sections of CNG station. Ladies and gents washrooms must be away from each other to provide safety of women. The facility of drinking water is not as per defined standards of the different health-related organization. The tab was present there which was changed after the study was performed. There are certain food items that are not available to the customers. These food items include sandwiches, burgers, coffees, and tea. They can be sold at the tuck shop present.

3. RESULTS AND SUGGESTIONS

There are certain steps taken for improvement in the current system. They have been discussed in detail according to their respective sections.

3.1. Managers Office

A new improved chair has been purchased for a manager which is comfortable, adjustable and moveable. It will help the manager to perform the given tasks easily. For summer, a proper cooling system is being introduced by installing an air conditioner in the office. While during winter electric heater will be used inside the office. The location of the locker is changed by moving the table slightly across and fitting the locker inside it. A proper arrangement of items on the table to ensure housekeeping. The bottle and flower have been removed from the main table. The emergency number is written on the paper and placed on the table near the telephone. All the workers are instructed about the numbers which they stored in their mobile phones. So, they are able to use them at any time needed. The suggestion about the office is that it must have emergency shutdown button which could be used in case of emergency, it was proposed to buy a panel on which whole system functions could be observed and proper action could be taken at the proper time.

3.2. Panel Room

Workers direct interaction with the panel is more important than any other machine as it is the only place from which behavior system could be studied. The visual inspection is also important. All the workers are trained to operate panel and about different readings that appears on the screen. The maintenance equipment is kept on a new shelf bought to meet the requirements for proper identification and placement. Thus, ensuring housekeeping. While lifting batteries which are most heavy item, asymmetric movement of trunk must be avoided. The batteries of UPS are given proper care to maintain them in working condition. The proper safety measures have been taken by installing a fire alarm, fire extinguisher and gloves for maintenance.

3.3. Blow-down Tank Section

The proper training program arranged for workers to understand the working of the blow-down tank. The briefing about the hazards it possesses is conveyed. The proper methods for taking the reading of pressure from gauges were also taught. The ear muffs as shown in Fig. 23 to reduce the effect of sounds are provided while working in noisy areas.

Fig. 23. Ear Muffs

The chances of frostbite are been reduce by proper care by using face shield and gloves. The gauges have been brought down and aligned so observing the pressure became easy. The floor is marked for identifying hazardous areas and emergency exits are mentioned. There must be fencing as shown in Fig. 24 to improve the safety of hazardous area where customers can come in contact with machinery, it will help them to keep away and maintain safer distance. The automatic emergency valves and sprinkled water system must be purchased and installed.

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Fig. 24. Fencing

3.4. CNG Compressor Room

The worker's direct interaction with machines is improved by training. It is one of the necessary steps to increase the safety as the proper method for observing the readings is introduced. Face shield and gloves are provided to eliminate the chances of frostbite. The information about visual checking of gas leakage as it forms ice is conveyed. With the introduction of digital thermometer, it became possible to check readings easily and precisely. The method used for lubricating the machine is performed by oil gun. The periodic maintenance is introduced for gauges.

The design of compressor room is not been according to safety standards. There is only one path to enter the room as seen in Fig. 8, but it is a poor design as shown in Fig. 25, it is proposed to change the design of the room to best by diagonal paths for ensuring escape routes.

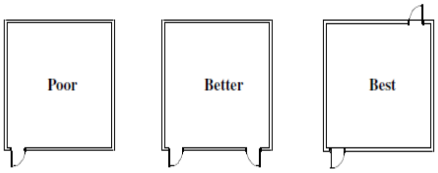

Fig. 25. Room Design

The fire alarm has been installed while sprinkled water system is proposed to be installed. The floor has been marked to show the path in case of emergency. The safety valves have been brought up from the ground by adjusting height, the emergency valves are changed to press a button instead of rotating and workers are provided with a proper chair.

3.5. Generator Room

Workers direct interaction with the generator is made safer by installing an exhaust fan to remove smoke as no such fan was present in generator room as shown in Fig. 12. The ear muffs showed in Fig. 23 are provided to overcome the effects of noise. The high temperature is natural when the generator is operative, it is been minimized by an exhaust fan. The oil guns are shown in Fig. 26 are used for oiling with proper instruction about the usage. Proper cleaning the floor on daily basis is conducted to get rid of the slippery floor. Housekeeping of materials and equipment in shelves of store based on as it makes easy to find them whenever needed thus minimizing the chances of accidents. The fire alarm has been installed. While the sprinkled water system is proposed to be installed.

3.6. Cooling Tower

It was proposed to construct stairs to visit roof which will provide safety and ease in material movement. Thus, saving workers energy as climbing will be eliminated. To improve the method of oiling the oil guns shown in Fig. 26 is used which help in decreasing oil loss and replacing the oil jug. The oil will be placed in store room when stairs construction is completed.

Fig. 26. Proposed Oil Gun

Workers safety has been improved by buying protective covering, filters of the cooling tower and through training. Maintenance is an integral step at the cooling tower as a minor mistake can cause a severe accident. Proper maintenance planning and regular

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checking of cooling tower regarding safety are made compulsory. A new cooling tower has been purchased, which acts as a standby for breakdown maintenance and climate change.

3.7. CNG Dispenser

Workers interaction with dispenser has been improved through training and by replacing the old fueling hose with pistol grip design as shown in Fig. 27. Their breakaway at the CNG dispenser is installed to provide additional safety between dispenser and fueling hose.

Fig. 27. Proposed Fueling Nozzle and Fueling Hose

Cashier and worker are provided with new table and chair similar to one shown Fig. 28. The dustbin currently present are removed from the workstation.

Fig. 28. Proposed Table and Chair

The emergency valve has been removed from the hole and placed near the cashier. Self-serve CNG dispensers are proposed to be installed for minimizing workload and increase the customer satisfaction.

3.8. Customers Facilities

The plastic bottles and shopper should be thrown in dustbins. In Fig. 29, newly purchased dustbins which are installed at desired locations considering safety.

Fig. 29. New Dustbins

The CNG station does not have a proper place where customers can sit to eat and smoke, the area as shown in Fig. 30 can be used for this purpose as it is on safer distance from all dangerous sections.

Fig. 30. Empty Space

Similar chairs as shown in Fig. 31 have been purchased for customers to sit are placed in the empty area shown in Fig. 30..

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Fig. 31. Tables and Chairs for Customers

Washrooms construction is almost completed as shown in Fig. 32 will be used by gets while the old ones have been specified for ladies.

Fig. 32. New Washrooms

Drinking water cooler as shown in Fig. 33 is installed to provide purified water.

Fig. 33. Water Cooler

4. CONCLUSIONS

The improvements suggested above in managers office, panel room, blow-down tank section, CNG compressor room, generator room, cooling tower, CNG dispenser, and customers facilities have been discussed in details. Thus helping in implementing ergonomics and ensuring human safety. For a long time period, to sustain the implementation is significant which could be achieved by convoying the importance to new hiring and periodic training of all the workers.

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ASSESSMENT OF SUSTAINABILITY COMPONENTS TO SUPPORT GROWTH IN A CERAMICS MANUFACTURING COMPANY

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ABSTRACT

Growing number of manufacturing companies are realizing and treating sustainability as an important objective to increase growth and competitiveness. Sustainability in manufacturing is the creation of products not only through economically sound processes but minimizing the environmental impacts and considering the social aspects as well. In this study we develop a framework and applied it to a local industry related to ceramics. This framework is based on the three aspects of environmental, social and economic parameters of sustainability in order to investigate and measure the current state of the company in the areas of energy utilization, machines availability, hazardous emissions etc. By measuring the current state and suggesting improvements in relation to the aspects of sustainability will support to increase their operational efficiency, reduce costs and waste, and give competitive advantage for environmental friendly manufacturing processes.

Index Terms— Economic Sustainability, Environmental sustainability, manufacturing process improvement.

1. INTRODUCTION

Sustainable manufacturing efforts are aiming to reduce the resource consumption through improved efficiency in manufacturing processes, decrease the amount of waste and emissions and reduce the energy consumption through manufacturing activities. In recent years, growing number of companies realizing the benefits of sustainable manufacturing. As it is related to the making of fabricated items through financially stable procedures and reduces the negative ecological effects. For the next generation manufacturing systems, it is necessary to adopt, integrate and implement the latest approaches to achieve economic benefits for all stakeholders (Koren et al, 2018).

Among the basic materials, ceramic is an important class of material used mainly in the building construction. In the last few decades its production output is constantly increasing due to increase in its demand. This increase in production has a negative impact on environment (Barros, 2007). During the production of ceramic tiles large amounts of energy intake are required and high amount of pollutants are discharged, which adversely impact the environment (Bovea, 2010). Due to the growing demands of environmental friendly products, many researchers have worked on to reduce the energy intake and pollutants to the environment. These studies include improving the material used in ceramics tiles, controlling and monitoring the manufacturing processes, used various approaches to minimize the emissions and carried out life cycle assessment of the production processes (Montero, 2009; Garcia et al 2011).

It has been observed that the local ceramics industry is based on traditional manufacturing processes and faces problems related to energy utilization, machines availability, hazardous emissions etc. Therefore there is a need for sustainability analysis of ceramic industry. In this paper sustainability analysis of FORTE tiles is performed by measuring the factors that impact sustainable production processes and suggestions for improvements to increase growth and competitiveness in their processes.

1.1. Literature Review

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Manufacturing companies must follow sustainability measures as a strategic goal. This could be achieved to perform a sustainability assessment of the products and manufacturing processes (Rosen and Kishawy, 2012; Garetti and

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Taisch, 2012).This assessment must involve measurements of resource utilization, pollution emission, waste generation in all manufacturing activities. Measurements must use performance metrics and approaches for computing them. Impact analysis must be compared against the industry standards.

Ness et al. (2007) discussed that sustainability assessment is associated with the family of impact assessment tools. Hasna (2008) added a technological view and proposed that an integrated assessment is "to assess the social, environmental, technological, and economic dimensions of projects, policies, and programs." The researchers provided the approaches to describe sustainability assessment. These approaches aim to support decision making to satisfy social, environmental, and economic goals. Various authors (Barros, 2007; Garcia 2011, Gbededo 2018) researched on the social, economical and environmental aspects to identify the key problems regarding sustainability; developed techniques and methods to address these concerns, and developed sustainability indicators to assess and improve overall performance etc.

Literature shows that researchers have worked on various aspects of sustainability, this research advance the discussion on the topic to develop a framework to assess the current practices in a company that impact the product life cycle and its manufacturing in addition give suggestions for improvements regarding sustainable processes.

2. METHODOLOGY

Initially, we have studied the application of sustainability in the ceramic industry. We observed that local ceramic industries are based on traditional manufacturing processes without considering the sustainability effects on manufacturing processes. For this purpose we collected data in four phases of the product development process namely pre manufacturing, manufacturing, usage and post usage phases. Then the assessment of the sustainability components is performed using the product sustainability index. The sustainability index identify weak areas and the factors that impact the production processes. Based on this framework; suggestions are proposed that will improve the current state of the manufacturing process.

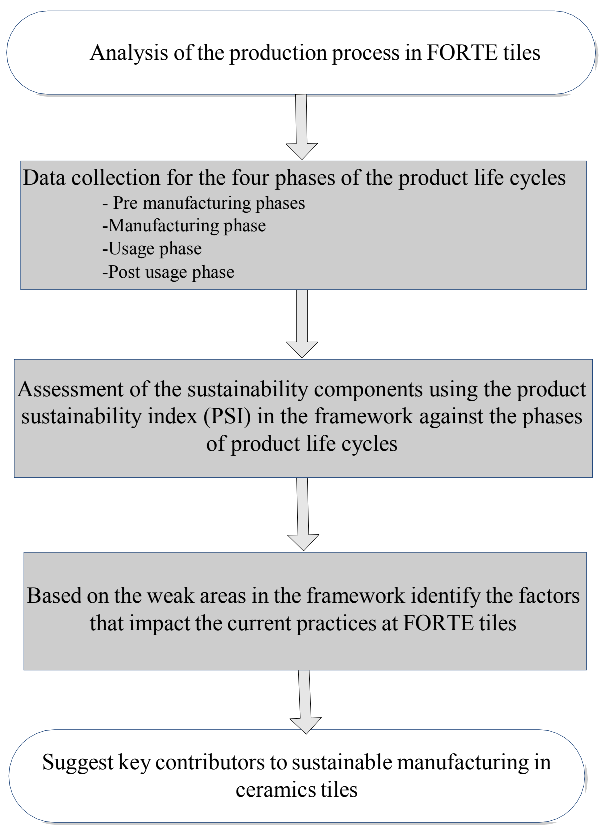

Fig. 1: Research Methodology

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3. INTRODUCTION TO CASE COMPANY

Frontier Ceramics is a private company popularly known as FORTE. The FORTE brand in market is recognized for Ceramic Tiles manufacturing. FORTE tiles has dealership network with more than 60 authorized dealers across Pakistan. In 2006 the group has taken Frontier Ceramics Limited. The company is expert in the manufacturing of ceramic tiles having a brand name “FORTE” which has created greater trust and loyalty within the marketplace.

The company has a huge work force of almost 500 workers. It operates 24 hours a day in 4 shifts and has a daily production capacity of almost 6000 sq meter tiles. The company has a big setup which is divided into following major departments:

- Administration
- Research and Development Center
- Raw Material Inventory
- Body Preparation Section
- Production Section
- Maintenance Department
- Finished Goods Inventory

3.1. Process Flow Chart

The main steps in the process of manufacturing ceramics tiles by FORTE Company are shown in the following flow chart.

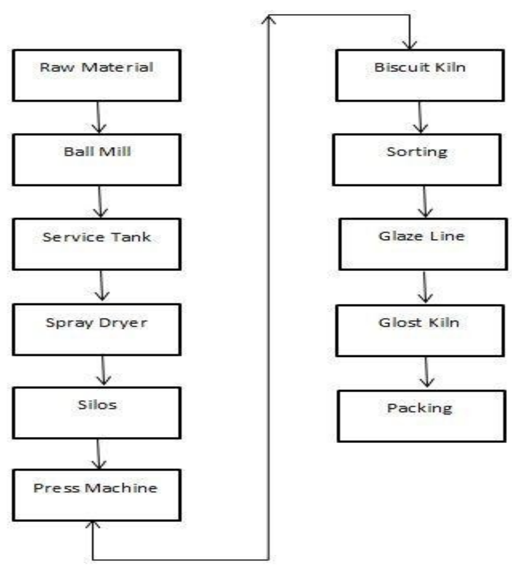

Fig.2: Process Flow chart at FORTE ceramics

Initially, the process starts from scaling raw materials which is sent to body section where ball mills are used for mixing and grinding the raw material.

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Fig.3: Raw Material for tile production

The ball mill make slip from the raw material (see fig 3) which is transferred to storage tanks. In the next step, the slip is injected into the spray dryer which evaporates water from the slip and converts it into powder form. The powder having desired amount of moisture is transferred through a conveyor belt to silos for storage. The mixture from the silo is continuously transferred to a tank above the press machines. At this point the discrete manufacturing system of the factory starts.

Fig.4: Press Machine presses the powder into the desired size

The press machines (see fig 4) presses the powder into desired size. After pressing the powder the tile called green biscuit is produced. The tile transfers through conveyer belts towards brushing section which removes dust from the tiles and forward to the kiln (see fig 5) for heating and removing moisture. Through conveyer these tiles are transferred towards the inspection section. In this section the strength of each tile is checked, the week tiles fell from the conveyer and the hard tiles passes under the brushes again to remove dust and make the surface clean. These tiles are transferred towards engobe and glazing section, and then it is transfer towards the printing section where the tiles are printed by a desired colors and designs. Then the tiles are transfer towards the rollers where batches of nine and eleven are made and then the roller transfer the batches towards the second kiln where it again get heated.

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Fig.5: Kiln to heat the tiles

Finally, the tiles are transferred towards sorting section where the workers sort the tiles into five types which are named as :

- Classic
- Standard
- Commercial
- Sub-standard
- Waste

After sorting ; the workers pack different types of tiles in different boxes and then it is transferred to store.

Fig.6: Tile Packing for storage

4. SUSTAINABILITY FRAMWORK

The product sustainability index (PSI) which is the weighted sum of different sub-indicators of three main sustainability indicators, is a method proposed by Jaafar. We used this index in our framework to measure the sustainability components. For example, at manufacturing phase, the PSI value of societal indicator is calculated using equation (1).

………………………….   (1)

Where,

= influencing factor ranges from 0-5 for the societal indicator at manufacturing phase.

n= number of influencing factors considered.

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Similarly, the PSI values for environment PSI $_{(en\_mn)}$ and economy PSI $_{(ec\_mn)}$ components for various stages of production process can be calculated. In addition to that, sustainability components across all four life-cycle stages can be calculated by averaging the PSIs in the horizontal row for that particular sustainability component.The PSI value for a single indicator can also be calculated by taking the average of the sustainability components at different phases of production. Equation (2) is used to find out the total product sustainability index (PSI $_{TLC}$).

…………………………… (2)

During different phases of product life cycle, the impact of indicators on sustainability is shown in the following framework.

Table. 1: Framework for sustainability – analysis based on the ceramics manufacturing company.

Sustainability Components		A Framework for Total Life Cycle Evaluation Using Sustainability Components									
		Pre-Manufacturing Phase	Score Out of 5	Manufacturing Phase	Score Out of 5	Usage Phase	Score Out of 5	Post Usage Phase	Score Out of 5		
	Environment	Raw Material Processing	2	Production	2	Material Disposals	3	Recyclability	0	PSI $_{en}$ =	31
		Design for Environment	1	Hazardous Waste Produced	1	Intended Functionality	3	Remanufacturability	0		
		Quality of Raw Material	2	Smoke Emission	2	Hazardous waste generated	2	Redesign	0		
								Material Disposals	1		
		PSI $_{(en\_pm)}$ =	33.3333	PSI $_{(en\_mn)}$ =	33.33333333	PSI $_{(en\_us)}$ =	53.333	PSI $_{(en\_pu)}$ =	5		
			◔		◔		◑		◔		◔
	Society	Worker Health	3	Work Ethics	2	Customer Feed Back	2	Reuse	0	PSI $_{so}$ =	28
		Worker Safety	2.5	Ergonomics	1.5	Accomodate Consumer Requirments	2	Recovery	0		
		Ergonomics	2	Work Safety	1.5	Functional Improvement	1				
				Worker Health	2						
		PSI $_{(so\_pm)}$ =	50	PSI $_{(so\_mn)}$ =	35	PSI $_{(so\_us)}$ =	25	PSI $_{(so\_pu)}$ =	0		
			◑		◔		◔		◔		◔
	Economy	Raw Material Cost	3	Production Cost	1.5	Product Cost	1	Recycling Cost	0	PSI $_{ec}$ =	39
		Transportation Cost	3	Packing Cost	2	Quality Cost	1	Remanufacturing Cost	0		
		Labor Cost	2	Cost due to accidents	1	After Sales Services cost	1	Disassembly Cost	0		
				Inventory Cost	1.5			Disposal Cost	0		
				Cost due to defects	1						
				Energy Cost	2						
				Employees Training	1						
				Material Handling Cost	2						
		PSI $_{(ec\_pm)}$ =	80	PSI $_{(ec\_mn)}$ =	60	PSI $_{(ec\_us)}$ =	15	PSI $_{(ec\_pu)}$ =	0		
			●		◕		◔		◔		◔
		PSI $_{pm}$ =	54.4444	PSI $_{m}$ =	42.77777778	PSI $_{u}$ =	31.111	PSI $_{pu}$ =	1.66667	PSI $_{TLC}$	33
											◔
			Symbol	●	◕	◑	◔				
			Score	Excellent >=74%	60%=<Good<74%	40%=<Average<60%	Poor <40%				

The framework measures the sustainability components with respect to the total life cycle in a manufacturing company. For FORTE tiles the overall product sustainability index (PSI $_{(TLC)}$) value of 33% lies in poor category. The results also show how much the industry is sustainable under the three main components that is related to Environment, social and Economic aspects.

In this framework the PSI value for environment is 31%, PSI value for social component is 28 % and the PSI value for economic component is 39%. Similarly from the assessment of the four life cycle stages, usage phase and post usage phase have very poor values such as 31% and 1.67 % respectively. However pre manufacturing phase and manufacturing phase lies in the average range with 54% and 42 % PSI value.

Based on this analysis, this company lies in poor category with respect to sustainability issues which needs an improvement in their production processes.

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5. SUGGESTIONS FOR IMPROVEMENT

In the framework low score for environmental design, hazardous waste, no recycling, high emission will cause the environmental pollution, effect human health and increase the product cost. Similarly, no employee training, low score for accidents prevention, causes safety issues and impact overall productivity. Furthermore, low scores for functional improvements, high energy utilization, and no attention to quality will cause low quality production, loose customer confidence.

With the measurement of the key sustainability components with respect to total life cycle evaluation, it is possible to identify the factors that impact the current practices at FORTE tiles. Based on current practices suggestions for improvements are shown in the following table.

Table. 2: Current practices at FORTE ceramic company and suggestions for improvement.

Sustainability Indicators	Current practices at FORTE company identified in the framework	How the current practices impact the production processes	Suggestions for improvement
Environmental (PSI of 31% lies in a poor range)	Low score for environmental design Very low score for hazardous waste control in manufacturing process No recycling and remanufacturing of the tiles Low score for energy utilization and emission	Causes Environmental pollution May effect human health Increase in waste Increase energy utilization cost	Implement standard operating procedures Implement ISO 9000 and ISO 14000 quality standards Measures to reduce waste Reduce energy utilization and emissions
Societal (PSI of 28% lies in a poor range)	Low scores for any functional improvements	Reduce productivity and customer satisfaction	Employee training and involvement Mechanism for customer feedback
Economical (PSI of 39% lies in a poor range)	Low score for cost due to accidents Low quality cost Lack of employees training	Causes safety issues Low quality product Low production and quality	Health and safety strategies Improve scrap reduction *Improve productivity by measuring overall equipment effectiveness (OEE)

*Overall equipment electiveness (OEE) is a useful measure of the efficiency and effectiveness of the manufacturing processes by measuring the Availability, performance and quality of the production machines.

The analysis from the framework and visual observations at the FORTE Company shows a lot of weak areas (Table 2) in the production of the ceramic tiles. In order to improve growth and competitiveness, key contributors to sustainable manufacturing in ceramics tiles are suggested in the following figure.

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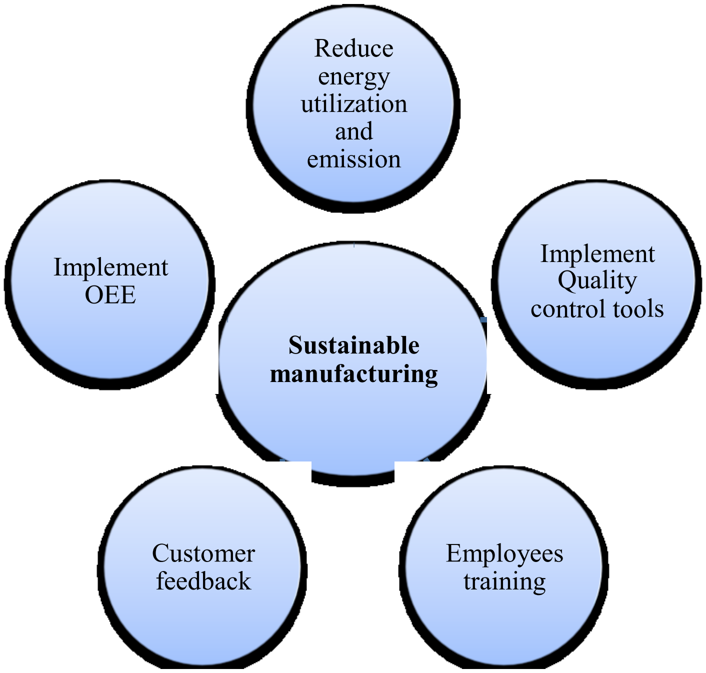

Fig.7: key contributors to sustainable manufacturing in ceramics

From the assessment in the framework it is clear that all the sustainability components against the four life cycle stages is having a very low scores such as 31%, 28% and 39% respectively. So this framework is a good indicator for the initial assessment of the sustainability components. In the FORTE tiles it is observed that there is no mechanism to assess and control the key indicators for sustainable processes. Therefore based on the analysis key contributors are suggested for sustainable practices in a ceramics industry.

6. CONCLUSION

On the basis of sustainability analysis, key parameters have been analyzed and a framework has been developed. Results from the sustainability framework shows that the case company is 33% sustainable having the product sustainability index (PSI $_{(TLC)}$) value of 33% which lies in poor category. Similarly, according to three sustainability indicators the case company lies in poor category having low PSI values. The current practices in the FORTE tiles impact the sustainability with respect to economical, social and environmental domains. Low scores for environmental design, hazardous waste control and no recycling impact human health, increase in waste and energy utilization. Similarly very low scores for any functional improvements in product and processes and no feedback from the customers impact quality, production flexibility and customer faith in the product. Therefore, by measuring the current state and suggesting improvements in relation to the aspects of sustainability and implementing these results will increase competitive advantage for environmental friendly manufacturing processes in FORTE tiles.

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DEVELOPMENT OF CONSOLIDATED CALCIUM CHLORIDE AND ACTIVATED CARBON BLOCKS USED IN IN SORPTION REFRIGERATORS

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ABSTRACT

The choice of adsorbent/adsorbate pair has a strong influence on the practicality and performance of any solar adsorption refrigeration system. Chemisorption accompanied by physical adsorption could be the final answer to the practicality of solar refrigeration system in the remote off grid areas. The choice ammonia as adsorbate and calcium chloride ($CaCl_2$) impregnated on the surface of activated Carbon has fascinating results of high ammonia carrying capacity, high adsorption rate, low desorption temperature and no agglomeration seen after large number charge discharge cycles. Ammonia is initially charged into the cylinder at a pressure of 7.2 bars and decrease in the pressure was noted, it took 22 minutes for the consolidated block of CaCl2/Activated carbon to decrease the pressure to almost zero absolute. The cycle was repeated five times to calculate an amount of 2.6 kg ammonia adsorbed onto the surface of the blocks. Yet agglomeration effect was mitigated to zilch. Activation of carbon was carried out in the tube furnace at 700 ^{0}C. This paper covers the stepwise development of the blocks until final testing.

1. INTRODUCTION

Modern world is heavily dependent on the non-renewable fossil fuel, which is not only harmful for our environment but will be exhausted eventually. The current electricity generation by fossil fuel is about 80%, while electrical energy needed for refrigeration and air conditioning increases with every passing year. Therefore exploring solar (renewable) resources for the increasing demand of electricity is considered seriously.

Solar energy is utilized practically in two purposes i.e. Photo voltaic PV cells and solar thermal powered systems. Solar thermal cooling systems can be further categorized into Desiccant cooling systems, adsorption and absorption cooling systems. These systems directly utilize solar energy for refrigeration without involving any electrical or mechanical components and are yet environmental friendly. (Khaled, 2016)

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Research shows that PV powered cooling system is much more expensive as compared to direct thermal powered cooling systems (Kim, 2008). Furthermore PV systems converts only one third of the solar energy into cooling, while solar thermal coverts most of the energy into useful cooling load. (Otanicar, 2012)

In the light of above mentioned advantages, solar thermal systems have got much attention of today's researchers. (Sarbu, 2018)

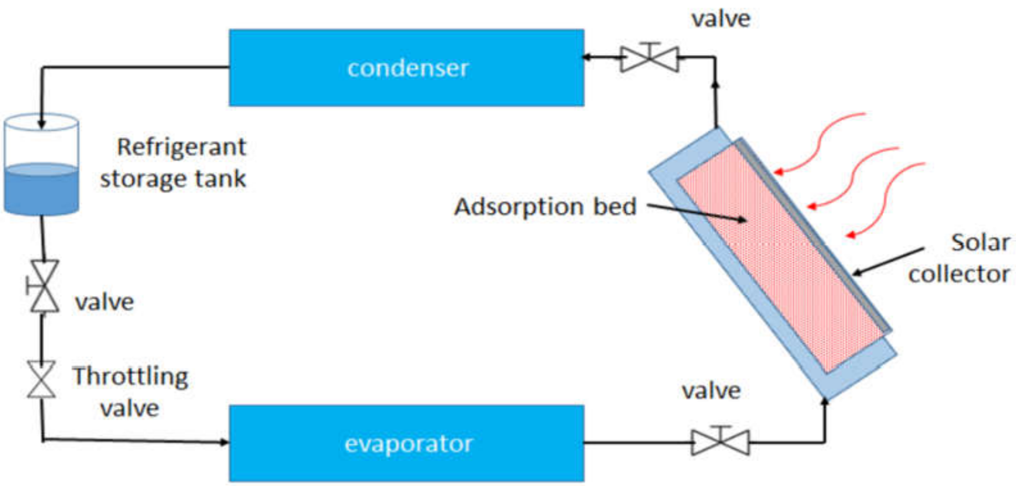

Figure 1: Solar Adsorption Refrigeration Cycle

Figure.1 shows the working of a generic solar adsorption refrigeration system.

Solar radiations falls on the solar collector containing adsorbent, adsorbate (refrigerant) pair. This energy rises the temperature of the bed which in result frees the adsorbate from its bond with the adsorbent. Further addition of heat pressurises the adsorbate till its reaches the condensation pressure. At this pressure the adsorbate passes the condenser and is liquefied, which is stored in the storage tank for the later stage of the intermittent cycle. The liquid refrigerant (adsorbate) is then allowed to pass through a throttle valve and evaporator to produce the useful cooling effect and comes back to adsorbent bed, where it is recombines with adsorbent again.

The coeffient of performance (COP) and cost of the solar powered refrigerator is highly dependent on the choice of the pair.

$\mathrm{COP} = \frac{\mathrm{Qe}}{\mathrm{Qs}}$ *Equation 1: Coefficient of Performance*

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Where Qe is the cooling effect observed at the evaporator and Qs is the solar energy that falls on the unit area of adsorbent bed.

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2. IMPORTANCE OF ADSORBENT-ADSORBATE PAIR

Selection of the adsorbent-adsorbate (refrigerant) pair is very crucial for the practicality and commercialization of the thermal powered solar refrigeration systems. Some important pairs used recently are activated charcoal-ammonia, activated carbon fibre-methanol, calcium chloride-ammonia, and silica gel-H2O etc. (Hassan, 2012)

Low toxicity, high thermal stability, high enthalpy of vaporization, low freezing temperature etc. are some of the desired attributes in a good working pair. In this research a successful attempt is made to develop a low cost methodology using the available resources to prepare a working pair of consolidated calcium chloride on activated carbon as adsorbent and ammonia as adsorbate (refrigerant) having high refrigerant carrying capacity, high thermal and chemical stability, low toxicity and high thermal conductivity.

3. A BRIEF REVIEW OF CALCIUM CHLORIDE AND ACTIVATED CARBON

Adsorption is a surface phenomenon and the amount of any gas (adsorbate) adsorbed on any solid (adsorbent) surface is a directly proportional to the surface area of the adsorbent. Adsorption is further divided into physical and chemical adsorption. In physical adsorption the governing forces responsible are the weak Vander Waal forces of attraction between the adsorbate and adsorbent surface. Activated carbon has very large surface area. A single gram of activated carbon has an area equivalent to a tennis yard area, while in chemical adsorption the adsorbate molecules interact chemically the surface molecules of adsorbent. Ammonia molecules after getting adsorbed on the surface of adsorbent do not keep their original shape. The chemical adsorption in case of ammonia (Adsorbate) and calcium chloride (adsorbent) is demonstrated below.

Adsorption:

$$CaCl2+mNH3 \longleftrightarrow CaCl2.m1NH3+ m2NH3+m1\Delta H$$

Desorption:

$$CaCl_2.m_1NH_3+m_2\Delta H \longleftrightarrow CaCl2\ (m_1-m_2).NH3+m_2NH_3$$

Where m2ΔH is the heat of desorption for “m” moles of ammonia. “m” can have values of 2, 4 or 8

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(Wang, 2009).

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This specific type of chemical adsorption of ammonia with metallic salts has the advantage, like.

High adsorption capacity usually greater than 1 kg/kg of salt.

But has got some serious drawbacks of swelling, compaction and agglomeration after successive cycles, which drastically reduces its ammonia carrying capacity and also its heat transfer coefficient is very low in longitudinal and radial direction.

Why we use solid sorbents? (Buchter, 2002)

1. Solid bed is easily implanted in solar systems.
2. It avoids heat storage
3. It also avoids the use of pump to circulate liquid refrigerant.

To avoid the phenomena of salt swelling and to improve the heat and mass transfer properties yet keeping the ammonia carrying capacity intact various researchers have studied and tested various composite materials. This paper details the research carried out on activated carbon and calcium chloride composite blocks.

Oliveira et al. (Oliveira, 2006)has reported ammonia carrying capacity of 0.8 kg/ kg salt. While Wang et al. has developed a method in which he has mixed activated carbon and $CaCl_2$ salt in the ratio of 1:4, this proportion is used in our experiment. The cycle time was 50 minutes and desorption temperature was reported as 101 ^{0}C. (Wang, 2006)

Lu et al. has worked on a two bed adsorber cooling system in which composite adsorbent was used to lessen the effects of compaction and agglomeration. He has reported cycle time of 50 min.

(Han, 2011)Hans and Lee have worked on the improvement of heat transfer, a vital issue in case of solid sorbents. They have cited 42.3 W/m k, an improved value of heat conductivity of compact activated carbon. When he impregnated calcium chloride salt on the surface of activated carbon, heat transfer value ranges from 11.1 to 48.6 W/ m k depending on the proportion of expanded graphite from 30-70%, the apparent block density varies from 110-340 kg/m3. Ammonia adsorbed in salt is in the form of CaCl2.2NH3, CaCl2.4NH3 and CaCl2.8NH3.

A bird view of preparation of consolidated blocks of calcium chloride and activated carbon has been reported by Oliveira et al. (Oliveira, 2006) But there is no detail research on how to develop consolidated blocks of calcium chloride and activated carbon.

Metallic salts are utilized for their high ammonia carrying capacity (1.05kg/kg salt) (Oliveira, 2007) but the problem of agglomeration and low thermal conductivity owing to its granular structure persists leading to increase in the cycle time. (Oliveira, 2007) The composite material is first developed then it is grinded and then compacted under pressure of 10 MPa. Ammonia carrying capacity is reported here is 0.9 kg/kg salt.

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This work is dedicated to develop a detailed method of preparation of consolidated calcium chloride and activated carbon blocks.

2. EXPERIMENTAL PROCEDURE

2.1 Activation of Carbon

The first step in the preparation of consolidated blocks is the activation of carbon. Activation of carbon is reported in many papers, Wang et al. (Wang, 2006) has reported activation of carbon at 300 ^{0}C while Hans et al. (JH, 2006) has reported that maximum expansion is noted at 700 ^{0}C, also charcoal powders activated at 700 ^{0}C has lowest mass density, twice the porosity as at 300 ^{0}C and highest surface area which ultimately leads to increase in the ammonia carrying capacity. Powders are activated in the complete absence of oxygen or else combustion takes place at such an elevated temperature.
Activation of carbon is carried out in tube furnace. Carbon powders are put inside a blind seamless stainless steel cylinder, the open end is connected to a collar, the tube rests inside the collar and it is provided with a tube which is connected to a vacuum pump through a manual valve and a purge valve.

Initially powders are poured into the tube and pressed with a rammer then the open end of tube is provided with a fine mesh wire gauze and cotton cloth to avoid powder suction yet allow gas flow that may occur because of heating inside the tube furnace.

This tube is then placed inside the tube furnace and vacuum pump is turned on while the temperature is set at 700 0C with ramp rate of 15 0C/min and dwell time of 15 min. After successful operation the powders are taken out of tube and placed in a vessel inside desiccator. About 160 grams of carbon powders are activated in single run.

Details of tube are given in the following table.

Table 1: Details of tube for tube furnace

Length	76 cm
Diameter of tube	3.8 cm
Volume of tube	376 cm3
Density of carbon	460 kg/m3
Mass of carbon	0.18 kg

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Figure 2: Tube for Tube furnace

2.2. Calcium Chloride

5 kg of Calcium chloride is taken in a steel vessel and placed in an oven at 110 0C for 2 hours to remove any moisture since it is very hygroscopic and absorbs moisture from air.

2.3 Preparation of Impregnated Powders

Calcium chloride treated above is dissolved in distilled water to make 60% solution, the activated carbon powders already obtain above are dissolved in the solution at 4:1 (salt to carbon ratio) to form a uniform suspension which is then poured into different stainless steel vessels and placed inside the oven at 110 0C for 11 hours to remove all water from it.

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Figure 3: Preparation of Impregnated powders

2.4 Calcination

Solid obtained here is placed in the same oven for another 7 hours at 270 0C in order to remove the water of hydration from it. As
$CaCl_2.nH_2O$……………. $CaCl_2+nH_2O$

Figure 4: Calcinated blocks of CaCl2 on Activated carbon

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2.5 Powder formation

After calcination the hard solid mass is removed from the vessels and crushed in a magnetic grinder to form fine powders which are carefully kept inside desiccator.

2.6 Consolidated blocks formation

For consolidated blocks formation die is made out of solid steel cylinder to cope with 11 MPa of pressure of UTM. The die is a thick walled cylindrical tube provided with a piston. The piston is provided with a hole in it as a guide for a steel rod which is necessary for making a hole inside the resulting blocks. The tube rests on a collar and the collar also has a blind hole of the same dimensions as of piston. As shown below

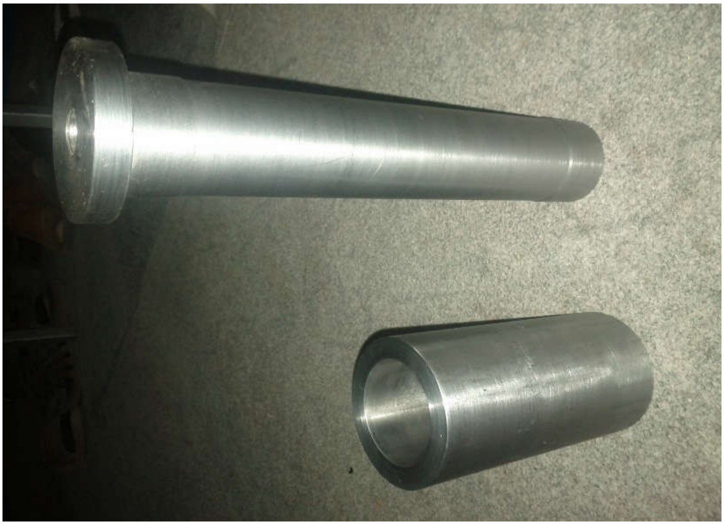

Figure 5: Die for formation of blocks

The tube is placed on collar and steel rod is placed in place, powders are poured into it and initially pressed with piston. This whole assembly is then placed on UTM and uniform pressure is applied from 0 to 11 MPa (Oliveira, 2007)

Resulting blocks are removed using the same facility. Blocks are shown below

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Figure 6: Consolidated Blocks of CaCl2-Activated carbon

These blocks are kept in a desiccator until they are finally placed inside black cast iron tube for final testing.

Tube's specifications are

- Internal diameter 49 mm
- Thickness of tube wall 4.8 mm
- Height of tube 150.5 mm
- Piston's diameter 48 mm
- Piston and collar hole diameter 14 mm

4. TESTS AND RESULTS

Prior to charging of ammonia blocks are kept inside the cast iron tube which is leak proof tube provided with a tube, pressure and temperature gauges, manual valves and a pipe is connected to it at one end which is initially connected to a vacuum pump.

Initially the tube is heated using electric heaters while keeping vacuum pump intact to degas it prior to charging. Degassing is done at 130 ^{0}C for 3 hours. As shown

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Figure 7: Measuring pressure of the system

Vacuum pump is then disconnected and the system is checked for leaks using pressure gauge to avoid air infiltration. Ammonia charging line is connected to it. The whole pipe along with charging line is placed on a digital balance. Since ammonia is very toxic, water supply is made sure so that in case of any leaks, the leak is flooded with water. Ammonia is initially charged at 7 bars and valve is closed and time is noted for the pressure to come to zero. This procedure is repeated several time in order to saturate this blocks with ammonia.

Total amount of ammonia adsorbed was noted to be 2.3kg as noted from the digital balance measurement.

Table 2: Test results of blocks for Ammonia carrying capacity

S #	Pressure at start of test	Pressure at end of test	Total time taken	Adsorbed amount
Test 1	7.0 bar	0 bar	23 min.	800 grams
Test 2	7.0 bar	0 bar	37 min.	750 grams
Test 3	8.0 bar	0 bar	38 min.	600 grams
Test 4	8.0 bar	0.5 bar	47 min.	450 grams
Total Amount of ammonia adsorbed				2.6 kg

The adsorption desorption cycle was run for over one hundred cycles to see if there is any agglomeration taken place. The agglomeration effect was not seen after hundred cycles.

5. CONCLUSIONS

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Carbon powders were expanded (activated) in a tube furnace in a complete vacuum at a temperature of 700 0C and dwell time of 14 minutes.

Aqueous solution of Calcium chloride (60%) is made, to which activated carbon are added in 1:4, to uniformly distribute calcium chloride on the surface of activated carbon.

The obtained solution is dried and subsequently calcinated to get rid of the water of hydration from calcium chloride.

The obtained calcinated powders are grounded using magnetic grinder and then pressed in a die under UTM (11MPa pressure) to obtain the desired blocks.

These blocks are then put in a tube and tested for results.

Impregnation of calcium chloride greatly enhanced blocks ammonia carrying capacity.

Swelling, disintegration and agglomeration was avoided, yet thermal conductivity is enhanced in radial and transverse direction due to compaction of powders under high pressure and activated carbon powders.

Since powders were pressed without using binder which led to increase in the compression pressure.

6. ACKNOWLEDGEMENTS

I am deeply obliged to ASHRAE for funding this research work. Also I extend my gratitude to Professor Dr Yaseen Iqbal (In charge material research laboratory university of Peshawar) for providing research facility and to UET Peshawar for their support and encouragement.

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MODELING AND SIMULATION FOR INTEGRATION OF GREEN AND SUSTAINABLE ENERGY NETWORK

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ABSTRACT

Renewable energy such as solar photovoltaic, which is available in abundance in Pakistan, is a desirable power generation source. A solar photovoltaic (PV) energy system is efficient, reliable, cost effective and environmental friendly alternative that reduces C0 2 emission as compared to the traditional energy system. Industry, government, and the local consumers are all involved keenly in cleaner and efficient energy systems. This research paper deals with the system integration and control system for renewable energy source connected to grid. The designed system combines solar photovoltaic array, generator set and utility grid using a common controller, multiple inputs DC/AC converter. Excess energy of solar Photovoltaic array after kicking load is injected into national grid while generator is used at night time. The energy generation report for the whole year is created and analyzed for Specific industry to be utilized efficiently. The simulations are performed for 130kWp solar power plant in PV System software and Matlab Simulink environment and presented and discussed in the article is satisfactory.

Keywords: Renewable energy, Solar PV, Generator, Utility Grid, Matlab

1. INTRODUCTION

The exploration of alternatives to fossil power sources is driving society towards research and development in renewable energy sources. Photovoltaic (PV) is clean and one of the many technologies that are now developed, and can contribute in residential and commercial applications. The photovoltaic system only produces DC power thus a control inverter system is needed with it to convert it into AC power for further applying to AC loads.

An electrical grid, the network for delivery electricity from suppliers to consumers, comprises of electrical power generating stations and is connected through voltage transmission lines, transmitting power from sources through distribution lines according to the demand of local costumers.
The electrical power stations may be located near the fuel source power that are generally away from heavily populated areas and thus the compatibility and the integration of renewable power generation units become an economical challenge.

“The work by (Venkata Rami et al, 2017), proposed Modeling and investigation of clean power wind energy systems by using UPQC. This technique is for wind energy system based on Unified Power Quality Conditioner (UPQC) with the usage of various Artificial Intelligent techniques. While (AI Uzeyir et al, 2017), presented Distributed Control System with fuzzy logic in wireless sensor network based on Industrial environments, in which he studied the problem of construction of mathematical model for control unit. Complex algorithms without having proper mathematical model are required traditionally to control the systems. (D. H. Babu et al, 2016), proposed Game theory and fuzzy logic based on load balancing technique for LTE networks. In LTE Networks, during load balancing, the adverse effects of

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radio link failure on the handoff performance are not considered. Further, he proposes to design a game theory and fuzzy logic based load balancing technique for LTE networks. The load balancing is triggered based on the status of each cell which is estimated using fuzzy logic Game theory and fuzzy based load balancing technique for LTE networks. (Lee Wai et al, 2016), proposes an optimal control strategy for a standalone PV system with battery-super capacitor hybrid energy storage system for a prolong battery lifespan altering the dynamic stress and peak current demand. However (Hao et al, 2017), proposed Decentralized Dynamic Optimization for power network based on voltage control. In which he study the voltage control technique for power distribution network consisting of rooftop photovoltaic panels and batteries of electric vehicle. While (S.Merlin Joys et al, 2014), presented energy management on Grid connected hybrid renewable energy sources using fuzzy logic, which describe a hybrid PV, wind and battery system.

(Byeong-Yeon Kim et al, 2015), presented Coordination and control for energy distribution in distributed grid networks, which describe coordination of power flow in a distributed grid network.

(Hyangryul Bae et al, 2015), presents supply and demand balance control of power system with Renewable energy integration by introducing congestion management, which is about frequency control method simultaneously considering the power flow management for wind and PV.

The work by (Ammar Hussein Mutlag et al,2014), presents only solar panel system for power generation however we are going to use the improved version of the said system by adding three input sources."

Most of the systems discussed above relay on battery power, batteries cause recurring cost and may not be feasible, especially in commercial applications. A model for commercial use is presented in the proceeding sections, eliminating the battery and adding three inputs i.e. solar photovoltaic, generator and utility grid as power sources with a technique to export extra energy which are more favourable and economical for commercial purposes.

2. THE MATHEMATICAL MODEL

The following is the updated version of [Ammar Hussein Mutlag et al] whose model that addresses the integration of single source, solar panel as power generation source while we have used multiple power generation units and is presented below.

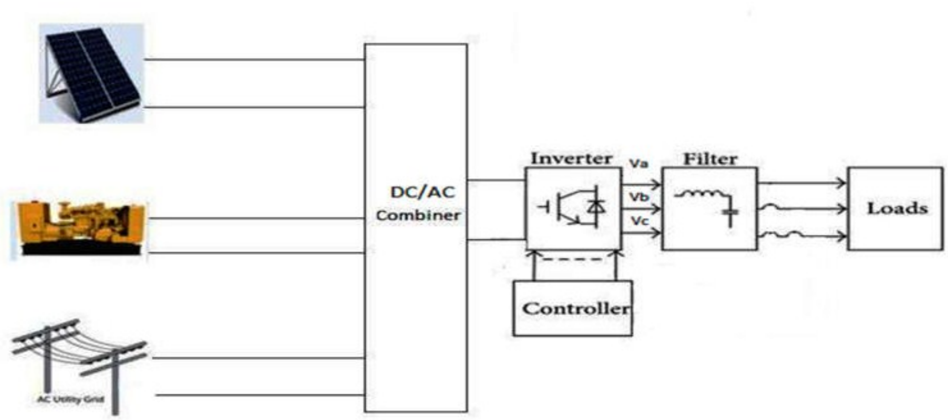

Fig 1: The Mathematical Model of Integrated Power Network

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2.1. EXPLANATION

The three-phase output voltages of the load terminal (Va, Vb, and Vc) can be represented as

$$V_a = V \sin \omega t \qquad \text{Eq:01}$$

$$V_b = V \sin\left(\omega t - \frac{2}{3}\pi\right) \qquad \text{Eq:02}$$

$$V_c = V \sin\left(\omega t + \frac{2}{3}\pi\right) \qquad \text{Eq:03}$$

These voltages (Va, Vb, and Vc) are then scaled and transformed into a reference frame to simplify the calculations for controlling the three-phase inverter.

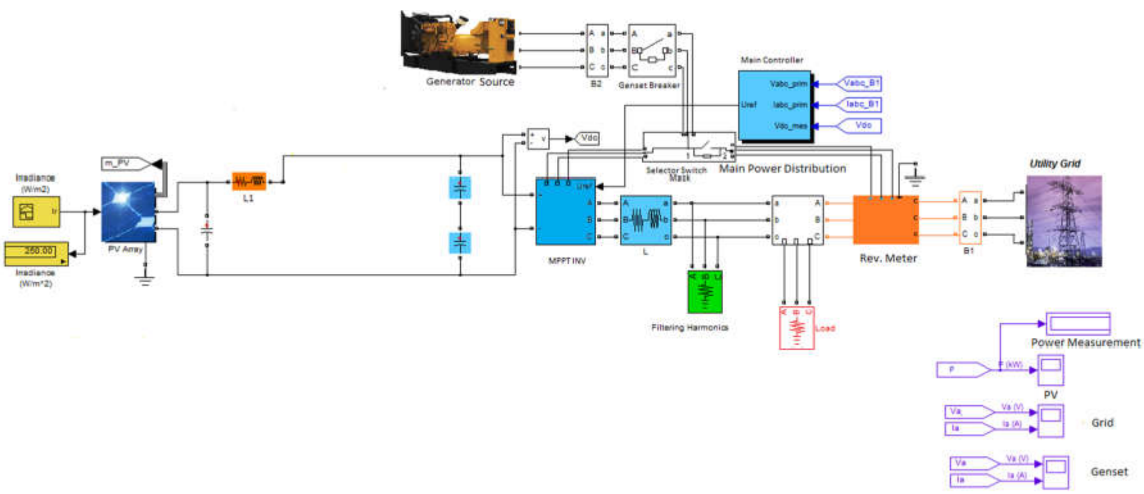

Fig 2: Simulink Model of Integrated Power Network

2.1.1 The Photovoltaic Array: The peak capacity of PV array for above model is 130kWp which consists of 20 numbers of strings each having 20 numbers of solar panels in series. The photovoltaic used for this model is Trina Solar multi crystalline (325Wp) having module efficiency of 16.8 % with cell orientation of 72.The open circuit voltage of each PV panel is 45V which comes 900V for 20 number of panels in series.
2.1.2 The Inverter: The Inverter capacity for this system is 125kW which converts the DC power into AC power. The maximum DC input voltage of inverter is 1000V.The inverter is design with DC and AC inputs which is used for photovoltaic and utility or generator respectively. The controller increases the DC voltage up to desire level using multiple power points tracking technique. A 3 phase filter is used to

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remove harmonics and link in the model after inverter in order to provide clean power supply. The inverter is capable to control the frequencies of utility and generator which connects with it through AC inputs.

2.1.3 The Generator and Utility*:* The peak capacity of Generator is 250kVA which is used in emergency purposes when Grid is not available. The inputs of Generator and utility are linked with inverter through selector switch.

2.1.4 The Irradiance Meter: The irradiance meter is installed to sense the radiation falling on the array of solar panels. The standard value for irradiance is 1000W/m2 but it may vary subject to environmental weather condition.

2.1.5 Operation:
During day time operation the power produce from solar panels with mutual coordination with utility grid to kick load and run smooth operation of industry and the generator is keep on standby mode, in case of unavailability of utility grid then the generator is used with Solar PV system.
The power produced from renewable energy source is applied to inverter system to convert it into AC power and then passed through filter to remove harmonics and deliver linear power supply to load. The controller continuously monitors the status of inverter and load.

3. SIMULATION RESULTS

The graphical results obtained from matlab simulink by using the MPPT technique which shows the peak power generated from solar photovoltaic system is 122kW when irrandiace is 1000W/m2 then it gradually decreases subject to change in irradiance.The peak load for this system is 100kW so the extra power produced exports to national grid through reverse meters.

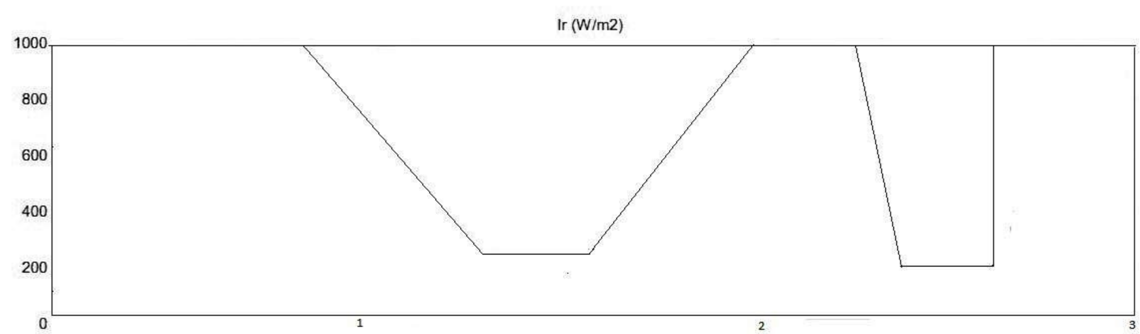

Fig 3: Irradiance

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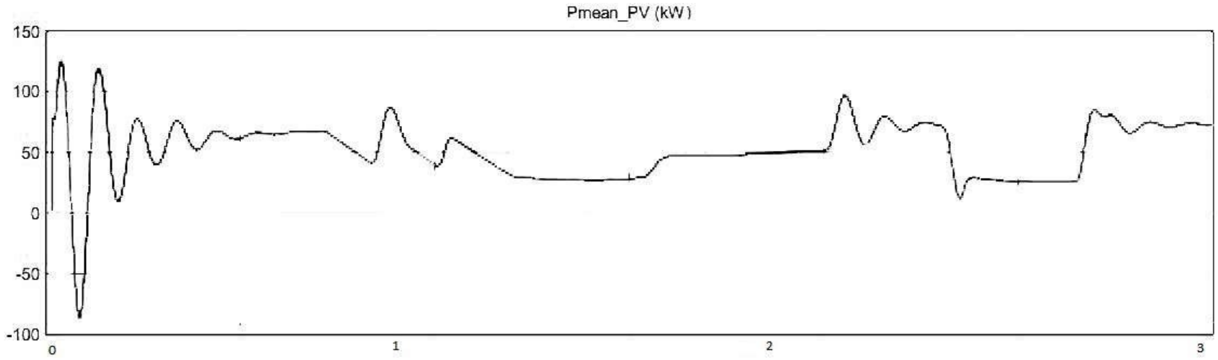

Fig 4: PV Power (kW)

4. ENERGY GENERATION REPORT

The simulation achieved for 130kWp Photovoltaic System by using PV System software, which clearly indicates the generated energy for one year. The produced energy is 211752kWh/year which is either used to kick load during routine operation or injected into National grid.

Table 1: Energy Generation Report

	Global Horizontal kWh/m2	**T Amb °C**	**Global Inc kWh/m2**	**Global Eff kWh/m2**	**Earray kWh**	**E_Grid kWh**	**EffArray R %**	**EffSysR %**
January	82.8	10.15	120	116.8	14308	14029	14.39	14.1
February	83.5	13.32	104.3	101.3	12294	12048	14.22	13.94
March	140.6	18.94	165.4	161	18620	18248	13.58	13.31
April	165.4	23.92	171.8	166.5	18947	18564	13.3	13.03
May	204	29.61	196.9	190.8	21008	20564	12.87	12.6
June	195.9	30.79	181.2	175.3	19338	18925	12.88	12.6
July	183.6	30.09	172.9	167.1	18710	18323	13.05	12.78
August	168.5	28.87	170.6	165.4	18465	18081	13.05	12.78
September	163.7	26.64	186.2	181.3	20201	19784	13.09	12.82
October	144	22.44	190.1	185.9	20925	20505	13.28	13.01
November	108.2	15.78	166.1	162.3	19041	18673	13.83	13.56
December	79.3	11.62	120.3	117.2	14288	14008	14.33	14.05
	1719.5	**21.8475**	**1945.8**	**1890.9**	**216145**	**211752**	**13.4892**	**13.215**

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5. CONCLUSION

The simulation results obtained promises high performance of the developed system. The results show that PV system is capable for feeding load with the required energy and excess power produce is injected into grid. The main findings in the above system are energy generation report for the whole year and Matlab simulation. The future work may be included to conduct a practical case study at industry premises having availability of the proposed system.

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OPTIMIZATION OF SURFACE ROUGHNESS, MATERIAL REMOVAL RATE, AND TOOL LIFE IN CNC TURNING OF ALUMINUM ALLOY.

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ABSTRACT

In the recent decade of machining and industrialization good surface finish, greater material removal rate with the best tool life is the priority for any industry in fabrication of any product. This is however the most difficult and challenging task in the metal cutting industry during the conventional and non-conventional machining processes. There is an inverse relation between the surface finish of the product and the production cost and total time. Hence, it is of most crucial to establish and develop an optimal setting of the machining parameters keeping in view the production cost and best possible surface finish. Apart from the surface finish another significant aspect to reduce production cost is to have a maximum material removal rate during machining process and to achieve an extended tool life in the harsh environments. The present study is mainly focused to explore the effects of machining and cutting parameters like spindle speed, depth of cut, feed in CNC turning of Aluminum Alloy 7075-T6 to obtain the better surface finish with highest material removal rate and better tool life. The ISO designated Tool Holder with Tungsten Carbide insert is used in the experiments. All the experiments are planned out using Taguchi's L9 Orthogonal array (3Parametrs*3Levels) technique. In accordance to evaluate the performance characteristics in turning of Al alloy, Signal-to-Noise ratio, Analysis of Means (ANOM) and Analysis of variance (ANOVA) is carried out. S/N ratio and ANOVA shall be used as statistical analyses tool to spot out the important control factors and to achieve the most favorable levels in machining respectively. It is concluded that the most significant and important factor which affects the surface roughness, material removal rate is feed rate. However, spindle speed has the inverse relation to tool life.

***Index Terms*—** Surface Finish, Material Removal Rate, Tool Life, Taguchi, ANOVA

1. INTRODUCTION

Turning is the basic machining operation in almost all the manufacturing industries. Surface roughness, material removal rate, machining time, tool life, wear and tear of tool, cutting forces can decide the productivity and the quality of the machining process. During all the machining process heat is generated near to the cutting edge of the tool. The heat dissipated in machining depends upon the Work piece material and on the cutting tool material. The heat generated also depends upon the machining parameters during high cutting spindle speeds.[1,2] This increase in temperature influences the flank and tool wear and in turn tempt to damage the surface finish ofthe final product.

Increase in temperature and all the other conditions guide to low material removal rate and reduced surface finish. In real time domain, there are many factors that affect the surface roughness, material removal rate like cutting environment (speed, feed and depth of cut) tool variables(nose radius, rake angle, cutting edge geometry ,etc.) and also the work piece variables like (material composition, hardness, and other mechanical properties etc.).Therefore, to attain good surface finish and good product quality, it is of prime importance to select the optimal cutting parameters to enhance the cutting efficiency.[3-6]

Mostly, the optimum parameters selection is based on machine operator‟s experience or by the design and manufacturing data books. But this condition sometimes leads to decrease in productivity, increase in the machining cost and decrease in the final product quality. Hence, the statistical design of experiments and their numerical models are used as for decreasing the machining time and product cost. [7-10]

Statistical design of experiments and tools helps in process planning of experiments and for appropriate data analysis for the valid and productive conclusions. [11] Taguchi‟s techniques are widely used engineering design, and can be applied to most of the optimization design, parameter design, model prediction and many other statistical designs. Taguchi‟s design

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differs from the conventional design of experiments as it incorporates simultaneous modeling of the mean and variance both at the same time.[12] Taguchi based optimization method is unique from the traditional practices as the traditional methods is relatively complex and time consuming, whereas, Taguchi has developed highly precise and fractionated factorial design

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called orthogonal array which covers the complete region of interest for the experimental personnel with fewer number of experiments. This technique cut down the cost and time of the experiments.[13-15]

Generally the information from the experiments is used to investigate the means response. However, in Taguchi technique, mean and variance of the response at each of the parameter setting in orthogonal array is combined into distinct performance measure that is Signal-to-Noise(S/N) ratio. Depending on the criteria for the quality feature to optimize, various S/N ratios can be selected:

(a) Larger-is–better: to be used when the larger value of the response is requisite.

S N ratio -log1 [—]

(b) Smaller-is–better: to be used when the smaller value of response is requisite.

S N ratio -log1 [ ]

(c) Nominal-is–better: to be used when the nominal value of response is requisite.

S N ratio -log1 [ ]

Where Yi is the observed response and S is the standard deviation.

In the current research, Taguchi method [11] and ANOVA is useful to optimize cutting parameters in turning operation of Al7075 work piece to attain better surface finish, highest material removal rate and less machining time.

2. EXPERIMENTAL DETAILS

2.1. Work piece Material

The work piece used in the study is Aluminum alloy Al-7075 as shown in Figure 1. Taken as form of cylindrical bars of Dia 35mm and length of 65mm each. Al-7075 has got a wide range of applications in the field of almost every aerospace and production industries. The chemical composition of the Al-7075 and its mechanical properties are shown in Tables 1 & Table 2.

Figure1. Aluminum-7075-T6 Work piece

Table 1. Chemical Composition of Al-7075

Element	Al	Cu	Cr	Fe	Mg	Mn
Wt %	87.1-91.4	3.9-5.0	0.1max	0.5Max	2.1-2.9	0.4Max

Table 2. Mechanical Properties of Aluminum-7075-T6

Parameter	Tensile Strength (MPa)	Yield Strength (MPa)	Brinell (BHN)	Rockwell	Density(kg/m³)
Value	510	480	135	50	2700

2.2. Cutting Insert

Cutting insert used during the all experimental work was (Tungsten Carbide with ISO designation DNMG110408. The cutting insert was clamped to the tool holder having ISO designation PDJNR1616H11 as shown in Figure 2. TRIMSOLF

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UK IP68N2 was used as a coolant during machining process.

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Figure 2. Tool Holder with Insert

2.3. Experimental Procedure

The experiments on the work piece were carried out under wet condition on CNC (Computer Numerical Control) Lathe (COLECHESTER, ALPHA 1330U). Before the carrying out of experiments, rust layer from the work piece was detached by 0.5 mm depth of cut to reduce the effect of homogeneity on the end results. Machined parts are shown in Figure 3.

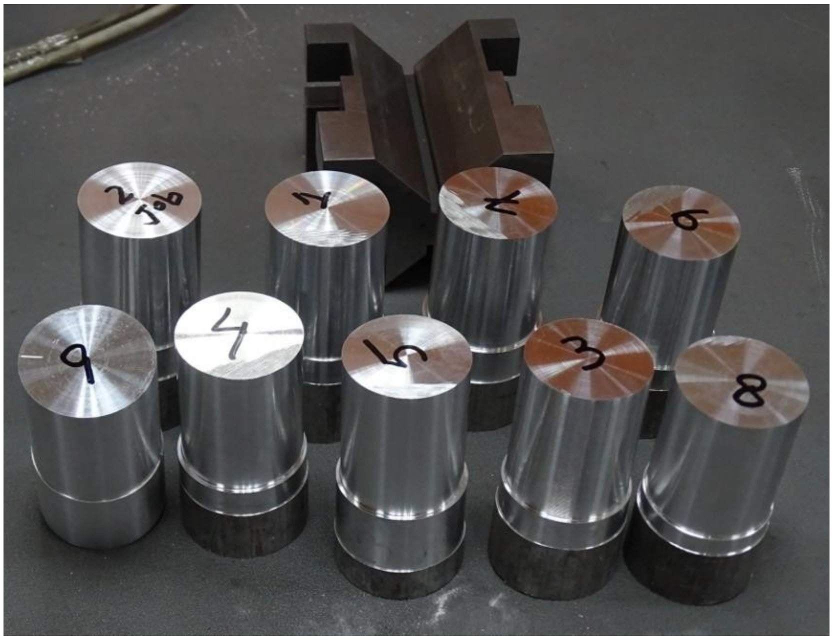

Figure 3. Machined Parts of Aluminum-7075-T6

2.4. Measurement of Surface Roughness

The surface roughness of the machined parts were calculated by using Mitutoyo SJ-210 as shown in Figure 4.

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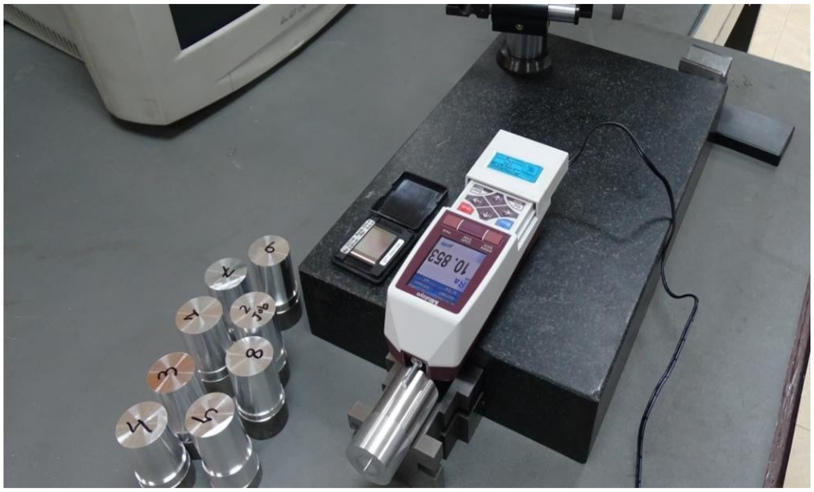

Figure 4. Experimental Setup for measuring Surface Roughness

2.5. Design of Experiments

In the current study, three cutting parameters were selected, namely, cutting speed ( ), feed rate (, depth of cut ( ) were considered. The machining parameters ranges were selected through machining guidelines given by work piece and tool manufacture recommendation and through previous researches. The experiments were arranged as per Taguchi‟s L9 orthogonal array as shown in Table 3. The real meaning of Taguchi‟s design lies in that with limited number of experiments, person can see the whole design space. Through Taguchi‟s design of experiment cutting speed, feed rate and depth of cut were kept at three different levels. The control parameters and their respective levels during the experiments are shown in Table 4.

Table 3. Taguchi L9 Array

S.No	Speed (rpm)	Speed	Feed (mm/rev)	Feed	Depth of Cut (mm)	Depth of Cut
1	1000	1	0.1	1	0.4	1
2	1000	1	0.2	2	0.8	2
3	1000	1	0.4	3	1.2	3
4	1500	2	0.1	1	0.8	2
5	1500	2	0.2	2	1.2	3
6	1500	2	0.4	3	0.4	1
7	2000	3	0.1	1	1.2	3
8	2000	3	0.2	2	0.4	1
9	2000	3	0.4	3	0.8	2

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Table 4. Parameters with Levels

Parameter	Units	Levels		
		1	2	3
Speed, V	rpm	1000	1500	2000
Feed, f	mm/rev	0.1	0.2	0.4
Depth of Cut, d	mm	0.4	0.8	1.2

3. RESULTS AND DISCUSSION

A number of experiments were conducted on Aluminum-7075-T6 with Tungsten carbide insert and designed as per Taguchi‟s L9 orthogonal array. S N ratio for surface roughness, material removal rate and machining time as proposed by Taguchi are given in Table 5-7.

Table 5. Experimental Results of Surface Roughness

S.No		S/N Value
1	3.25	-10.23
2	5.56	-14.99
3	12.72	-22.08
4	3.78	-11.54
5	6.62	-16.41
6	12.6	-22.00
7	3.15	-9.96
8	5.98	-15.53
9	12.38	-21.85

Table 6. Experimental Results of Material Removal Rate

S.No	___	S/N Value
1	6.817	16.67
2	22.759	27.14
3	43.555	32.75
4	18.483	25.33
5	31.202	29.87
6	55.650	34.94
7	28.320	29.03
8	47.325	33.46
9	71.353	36.98

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Table 7. Experimental Results of Tool Life

S.No		S/N Value
1	750	57.50
2	666	56.46
3	580	55.26
4	435	52.76
5	428	52.62
6	450	53.06
7	269	48.59
8	288	49.18
9	301	49.57

3.1 Analysis of Variance (ANOVA)

The main purpose of the analysis of variance is to carry out research that which cutting parameters significantly affect the surface roughness, machining time and material removal rate. The results for the experiments of surface roughness, material removal rate and tool life were analyzed with ANOVA. The results for ANOVA are shown below

Table 8. ANOVA Results of Surface Roughness

Source	DOF	SS	MS	F	P Value
Speed	2	0.088	0.0441	0.45	0.69
Feed	2	128.41	64.2048	653.43	0.002
DOC	2	0.012	0.0062	0.06	0.941
Error	2	0.197	0.0983		
Total	8	128.707			

S = 0.3962 R-sq = 99.85% R-sq(Adj)=99.39%

Table 9. ANOVA Results of Material Removal Rate

Source	DOF	SS	MS	F	P Value
Speed	2	914.36	457.18	591.03	0.075
Feed	2	2305.02	1152.51	1489.94	0.001
DOC	2	15.95	7.97	10.31	0.088
Error	2	1.55	0.77		
Total	8	3236.87			

S = 0.8795 R-sq = 99.95% R-sq(Adj)=99.81%

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Table 10. ANOVA Results of Tool Life

Source	DOF	SS	MS	F	P Value
Speed	2	2051.2	1258.22	1584.23	0.0020
Feed	2	850.65	323.28	758.55	0.0092
DOC	2	12.22	6.89	16.55	0.1558
Error	2	1.87	0.66		
Total	8	2914.07			

S = 0.8795 R-sq = 99.95% R-sq(Adj)=99.81%

3.2 Optimum Levels

Table1 12. Optimum Levels for Surface Roughness

Parameter	**Level**	**Value**
Speed,rpm	3	2000
Feed,mm/rev	1	0.1
Depth of Cut,mm	3	1.2

Table1 13. Optimum Levels for Material Removal Rate

Parameter	**Level**	**Value**
Speed,rpm	3	2000
Feed,mm/rev	3	0.4
Depth of Cut,mm	2	0.8

Table1 14. Optimum Levels for Tool Life

Parameter	**Level**	**Value**
Speed,rpm	1	1000
Feed,mm/rev	2	0.2
Depth of Cut,mm	3	1.2

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4. CONCLUSIONS

- The optimal machining performance for surface roughness is obtained by keeping the speed at level 3, feed at level 1 and depth of cut at level 3. i.e. speed at 2000 rpm, feed at 0.1mm and depth of cut at 1.2mm
- The optimal machining performance for material removal rate is obtained by keeping the speed at level 3, feed at level 3 and depth of cut at level 2. i.e. speed at 2000 rpm, feed at 0.4mm and depth of cut at 0.8mm.
- The optimal machining performance for tool life is obtained by keeping the speed at level 1, feed at level 2 and depth of cut at level 3. i.e. speed at 1000 rpm, feed at 0.2mm and depth of cut at 1.2mm.
- According to ANOVA analysis, it is established that the feed has the maximum influence on Surface roughness and Material removal rate.
- Spindle speed has the inverse influence on the tool life.

5. FUTURE RECOMMENDATIONS

- The Present work can be widen further for different conditions of process parameters at different levels.
- The Present work can be spread further for different industrial materials and for various machining operations.
- The Present can be carried out with different cutting tool material and spindle speed.

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HYBRID MODELING OF SOLAR PVS TO STUDY THE EFFECTS OF DYNAMIC ATMOSPHERIC CONDITIONS AND IDEALITY FACTOR

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ABSTRACT

With the limited energy resources globally, the research trend is focused on renewable energy resources. Harvesting solar energy with the Photovoltaic (PV) technology is the third largest renewable resource of electricity in the world. The electric power generated by PV modules depends on parameters such as Solar Irradiance (G), leakage current in the depletion region represented by Shunt Resistance (Rp), Resistance across the path current (Rs), Dark saturation current (Is) and shading conditions etc. Minute changes in the input parameters of PV cells results in significant changes in the output. The performance of PV modules under different operation conditions must be determined before installation forreliable performance. This can be done either through extensive testing using hardware simulators, or by development of prediction models which are low cost, robust and accurate. Many PV circuit models have been proposed by different researchers. This paper details development of a Hybrid PV cell Single diode Rp model in Simscape™ with masked user interface. Various modules can be developed in the interface by inter connection of these cells. Effect of varying diode Ideality factor in a single cell as well as in a module of four cells connected in series is also reported.

Keywords: Diode Ideality factor, Contact Resistance (Rs), Shunt Resistance (Rp), Single diode Rp model, Photovoltaic Cell, Irradiance, User interface, Dark saturation current, Simscape™.

1. INTRODUCTION

With the energy crisis in the present technological word the researcher's focus is diverted towards renewable energy resources (Fay et al.,2002; Ventre and Messenger, 2000). Solar energy is eco-friendly, everlasting and easily available source to be utilized as an alternative to conventional energy resources (Ventre and Messenger, 2000; Ming, 2012). To maximize the power output from solar photovoltaic module is one of the most emphasized research area. Reason is the dependence of PV module characteristics on the vibrant irradiance temperature conditions (Cubas and Pindado, 2014). To increase the maximum power point (MPPT) of the solar modules a PV simulator is necessary requirement.

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PV simulator provide control environment and replicated solar energy source for the repeated testing of solar modules under the same irradiance and temperature conditions; to estimate the efficiency and current-voltage (I-V) characteristics under the fluctuating environmental conditions. But in the initial development phase software based PV simulator is one of the pre-hardware requirement for the prediction of output characteristics. Circuit based Software PV simulator provide user friendly, economical and least cost facility to the manufacturer as well as the researchers (Park and Choi, 2016).

Two different approaches are adopted for computer software modeling of solar PV cells or modules. Mathematical approach and physical electronic components circuit modelling (Agarwal, 2008). Mathematical modelling is applied in simulink® using complicated implicit non-homogenous equations. One parameter of one equation serve as the input parameter for several equations. Such mathematical models possess higher cost in comparison to circuit modeling technique. Furthermore, circuit modelling enables to interface the model with other electronic components or circuits like dc to dc power convertors. The electronic component-based modelling is however unable to integrate dynamically fluctuating environmental conditions such as irradiance and surrounding temperature (Jiang and Qahouq, 2016). Simscape™ module of Matlab® provide a hybrid approach towards modeling of dynamic systems. It provides the capability of converting the output of mathematical modeling to a physical signal which can be used as the input signal such as current or voltage source, to physical electronic based model (https://www.mathworks.com/products/simscape.html).

There are two basic models; single diode and double diode solar PV model, which consider losses and their results are closer to the actual PV cells. Single diode models are subdivided into single diode Rs model and single diode Rp model. In this paper our hybrid modeling is based on single diode Rp model.

Fig. 1 shows single diode Rp model of solar PV cell.

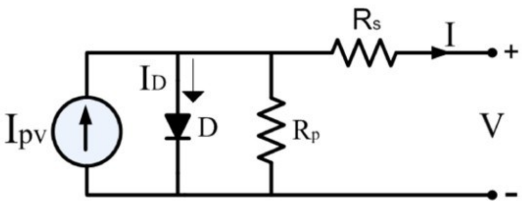

Figure 1 Single Diode Rp Model

In this equivalent circuit model Rp considers the leakage current in the depletion region of the diode and Rs takes into account the contact resistance which come across in the path of current flow (Jordehi, 2016). From nodal analysis of the circuit output current I is given as:

$$I = Ipv - I_D - I_{Rp} \quad (1)$$

Whereas Ipv is function of temperature and irradiance and I represented by the following equation (Chenni and Makhlouf et al., 2007):

$$Ipv\ (T, G) = (I_{pv,STC} + K_I(T - T_{STC}))\frac{G}{G_{STC}} \quad (2)$$

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Where $I_{pv,STC}$, T_{STC} and G_{STC} are photocurrent, temperature and irradiance at Standard test conditions (STC). At STC, the temperature is 25℃, irradiation is 1000 W/m^2 and air mass is 1.5. T and G represent temperature and Irradiance at which the photocurrent is evaluated. K_I represents temperature coefficient of photocurrent. Diode current I_D is given by Shockley equation as follows (Solanki, 2015):

$$I_D = I_s\,[e^{(\frac{qV_D}{aKT})} - 1] \qquad (3)$$

Where $\boldsymbol{I_D}$ and $\boldsymbol{V_D}$ are the current and voltage of diode respectively, $\boldsymbol{I_s}$ is the saturation current or dark current of diode, a is the ideality factor of diode, q is the absolute value of electric charge of an electron, T is temperature in Kalvin and K is Boltzmann constant. Inserting equations (2) and (3) the equation of output current is as follows:

$$I = Ipv - Is\,[e^{(\frac{q(V+IRs)}{aN_sKT})} - 1] - \frac{V+IRs}{Rp} \qquad (4)$$

N_s is the number of cell connected in series whereas I and V are the output current and voltage respectively. Fig. 2 (Villalva and Gazoli, 2009) shows three noteworthy points of I-V curve of PV cells that are published by PV manufacturers. These points Open circuit voltage (Voc), Open circuit current (Isc), voltage (Vmp) and current (Imp) at maximum power point, Temperature coefficient of current and voltage respectively i.e. KI and KV (Rasool et al. 2017).

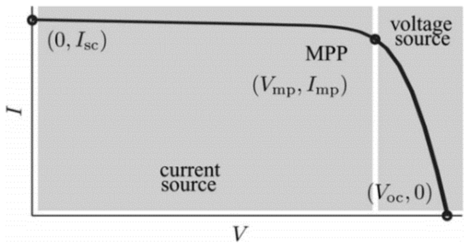

Figure 2 I-V Characteristic PV cell

This paper presents the methodology for the development of hybrid single diode Rp solar PV cell model using manufacturer provided data. Further applying this hybrid model to investigate the effects of ideality factor on the power output of individual cell and module.

2. HYBRID SIMSCAPE™ MODEL

Before modeling Single diode Rp equivalent circuit in Simulink® Simscape™ module the first step is to determine five unknown parameters i.e. Rs, Rp, Is, a and Ipv. All these five parameters are function of solar irradiance level and surrounding atmospheric temperature.

The manufacturer data need to be tuned as they are also function of stated conditions. This dynamic tuning increases the accuracy of the proposed model. The output current of PV cell is linearly dependent on irradiance level whereas output voltage is logarithmic function of irradiance level. However, KI and Kv identifies how output current and voltage vary with the

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surrounding temperature (Soto et al. 2007; Celik and Acikgoz, 2007). Figure 3 shows the steps that are carried out to get the resulting single diode model parameters. These equations are

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presented by De Soto et. al, 2007. *DS_Update.m* Matlab® function updates the data sheet parameters for varying Irradiance (G), temperature (T) and ideality factor (a) of PV cell.

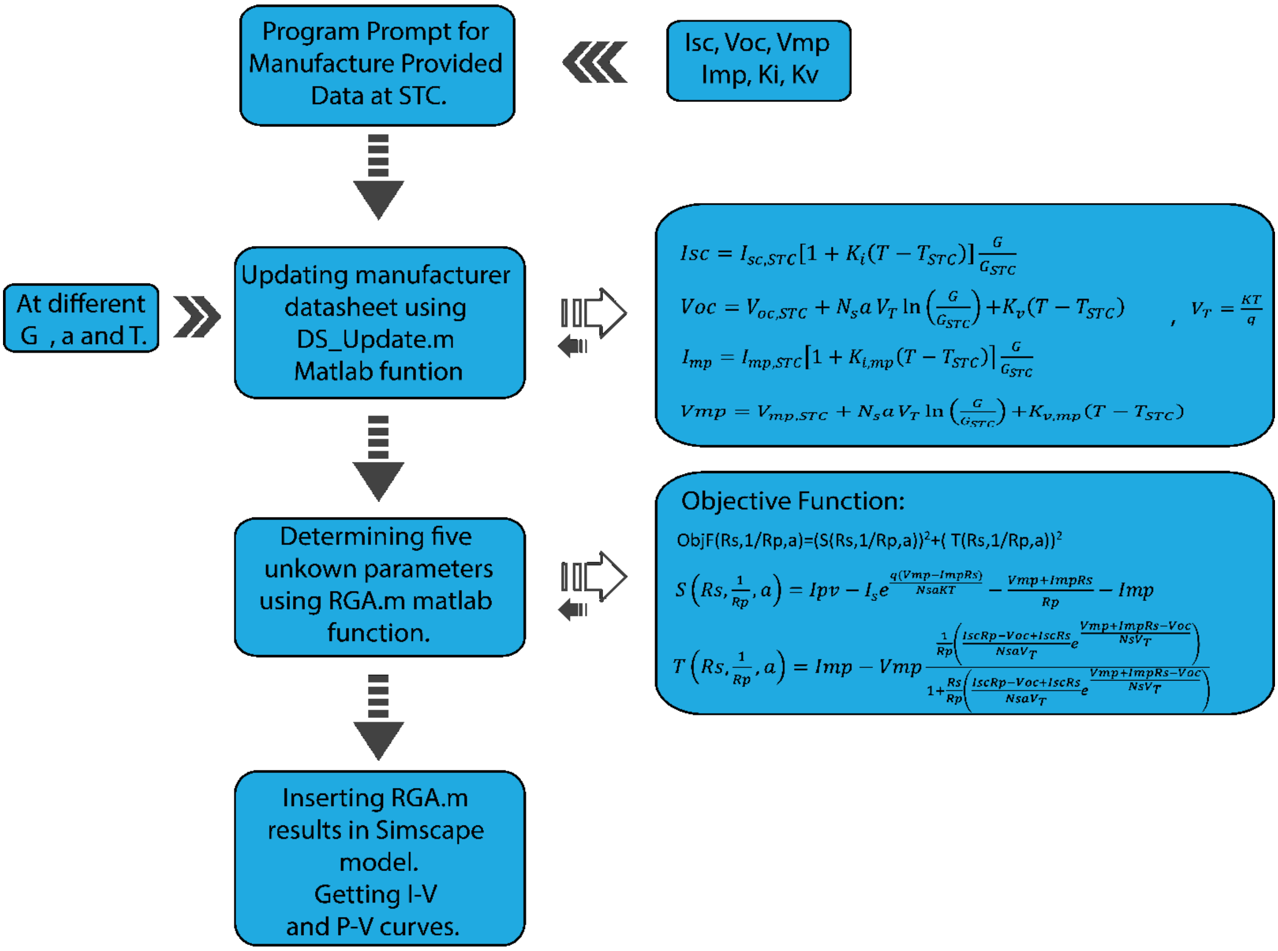

Figure 3. Flow Chart of Matlab Coding

Where *RGA.m* Matlab® function minimizes the objective function given by Park and Choi, 2016.

One Solar PV cell connected with data logger is shown in figure 4. Data logger consist of variable load resistor with a ramp function that gradually increase the load resistance during

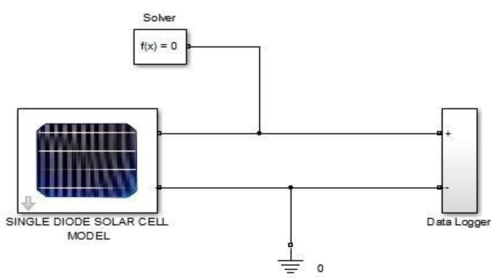

Figure 4. Simscape Single Diode Model with Data Logger

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the simulation period. Data logger uses actual physical electrical ammeter and voltmeter that record output current and voltage. Data logger circuit is shown in figure 5.

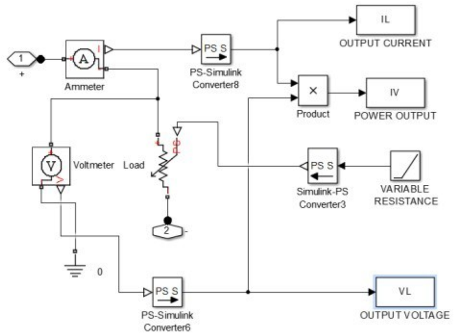

Figure 5. Data Logger Circuit

Figure 6. shows the inner Simscape™ hybrid model. Block A is the mathematical modelling of equation 1. Block B is Electronic components based modelling. Block A and Block B are connected through Simulink® to Physical signal convertor. This physical signal act as a constant current source.

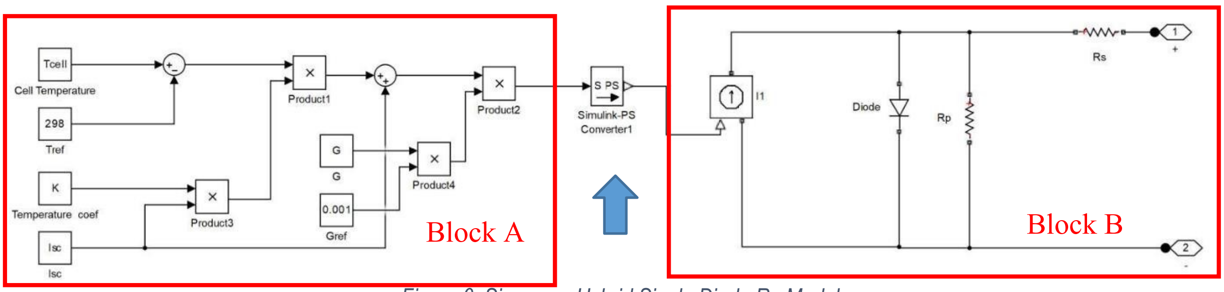

Figure 6. Simscape Hybrid Single Diode Rp Model

The hybrid cell model is masked to give user friendly interface shown in figure 7.

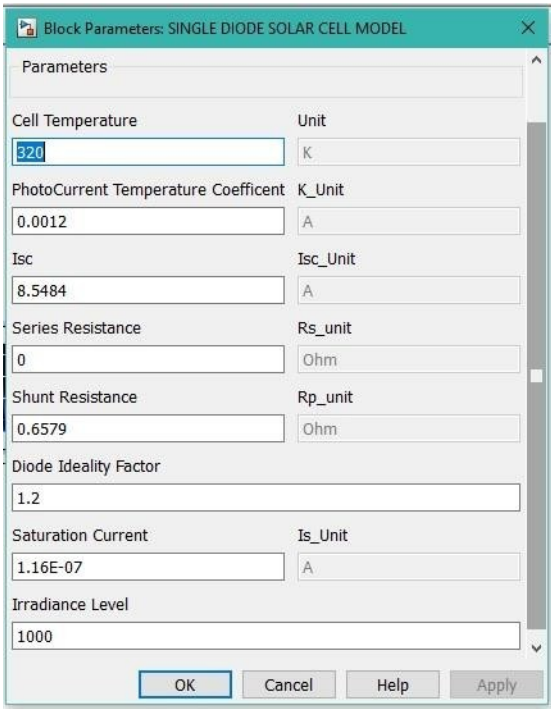

Figure 7. Masked User Interface for Single PV Cell

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3. SIMULATION RESULTS

Output current (I) and output power (P) versus output voltage (V) at varying Irradiance levels ranging from 1000 W/m2 to 200 W/m2 at standard temperature i.e. 298.15K of single PV cell is shown in figure 8 and figure 9 respectively. It is obvious that short circuit current Isc and open circuit voltage Voc are decreasing with the decrease in the irradiance level.

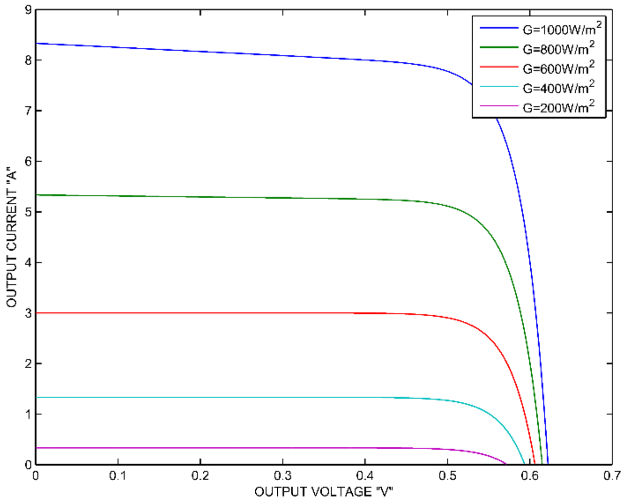

Figure 8. I-V Characteristic Curve for the Model at Standard Temperature.

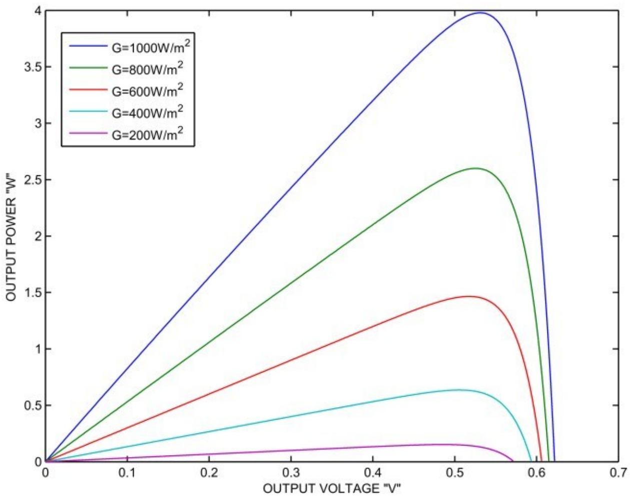

Figure 9. P-V Characteristic Curve for the Model at Standard Temperature.

Current-Voltage (I-V) and Power-Voltage (P-V) characteristic curves at irradiance level of 1000W/m^2 with varying temperature ranging from 298.15K to 320K are presented in figure 10 and 11 respectively. Isc is shifting upwards on y-axis i.e. increasing whereas Voc is shifting leftwards i.e. decreasing with increasing temperature.

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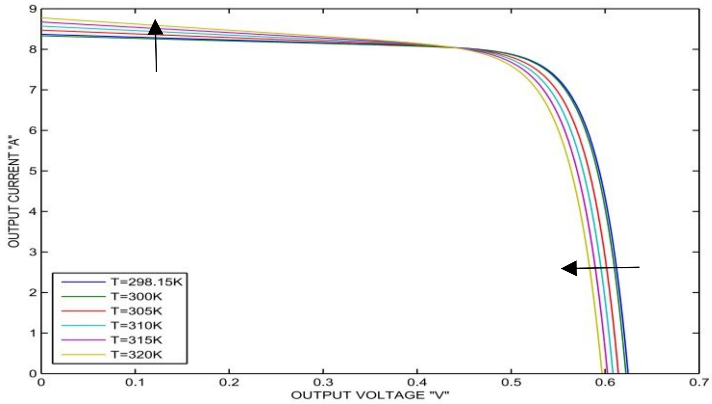

Figure 10. I-V curve at G=1000w/m^2 with varying Temperatures

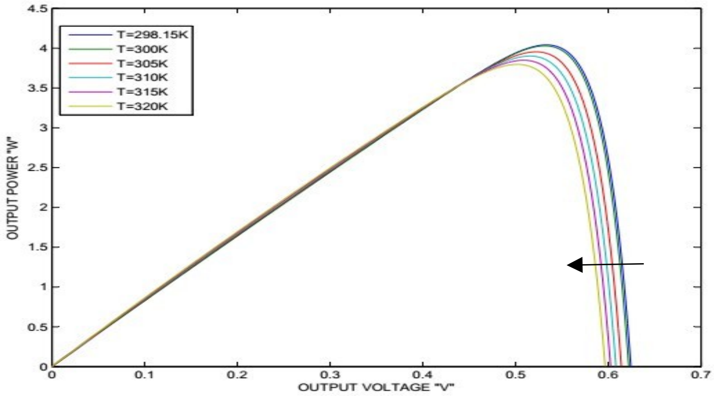

Figure 11. P-V curve at G=1000w/m^2 with varying Temperatures

With variation in the Ideality factor (a) of solar PV diode the curvature of the I-V and P-V curve decreases as shown in figure 12 and 13 respectively. This means that the maximum power point (MPPT) decrease with increasing Ideality factor. With the increase in the Ideality factor, the dark saturation current Is of the PV cell increases. Which means that the leakage current increases in the diode of equivalent circuit, hence resulting in the shift of MPPT towards left i.e. dropping.

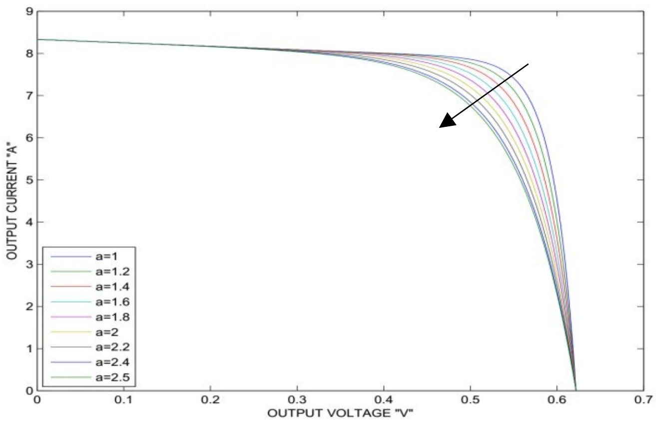

Figure 12. I-V Curve with varying Ideality Factor at STC

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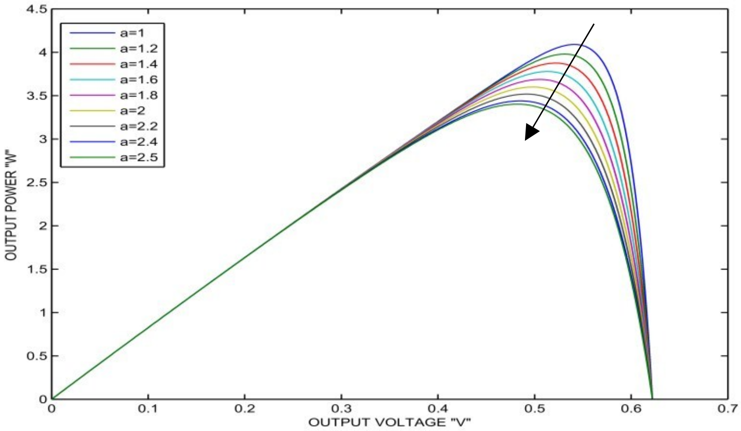

Figure 13. P-V Curve with varying Ideality Factor at STC

4. Module of Four Cells connected in Series

The model developed in the work reported here is capable of connecting any number of cells in series or parallel configurations. Such modules can then be investigated for determining the output under any given condition. Four similar single PV cells were connected in series to determine the I-V and P-V characteristics of four cell module through the developed hybrid model (Figure 14).

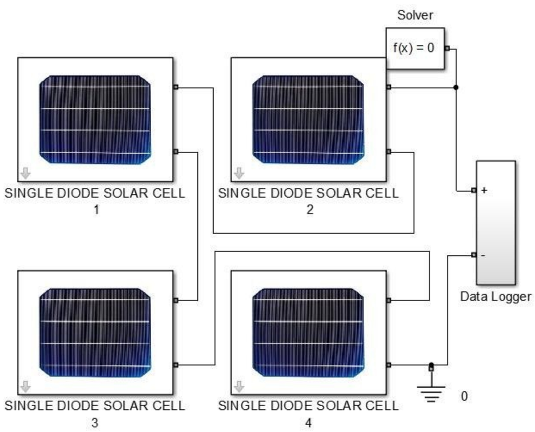

Figure 14. Four number of cells Connected in series

Connecting four cells in series increased the open circuit voltage and hence the power output from 4W to 16W. The same is represented by the I-V and P-V curve in figure 15 and 16 respectively. The module Voc is four times the Voc of individual cell.

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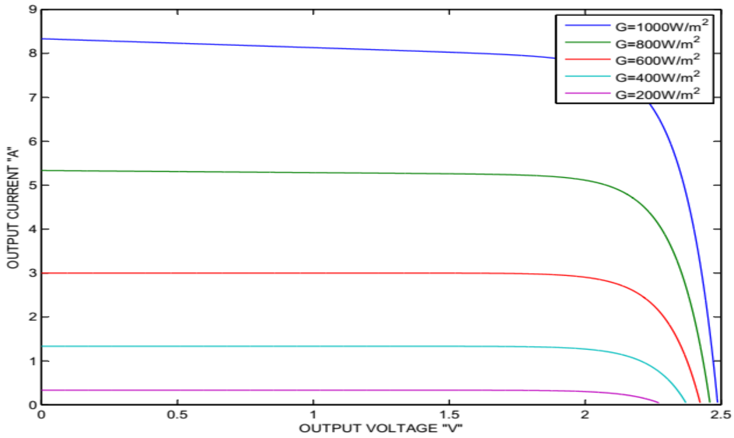

Figure 15. I-V Characteristic Curve for the four cell Module at Standard Temperature.

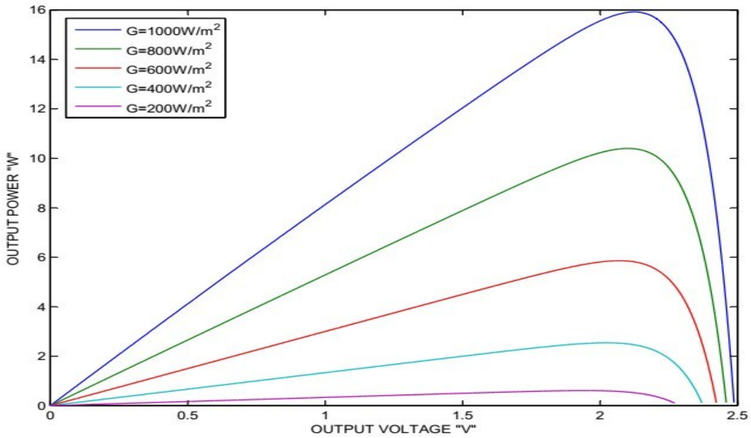

Figure 16. P-V Characteristic Curve for the four cell Module at Standard Temperature.

Figure 17 and 18 show the influence of ideality factor on the output voltage and power respectively. With the increase in the ideality factor the MPPT of the module is decreasing due to the current loss in the diode.

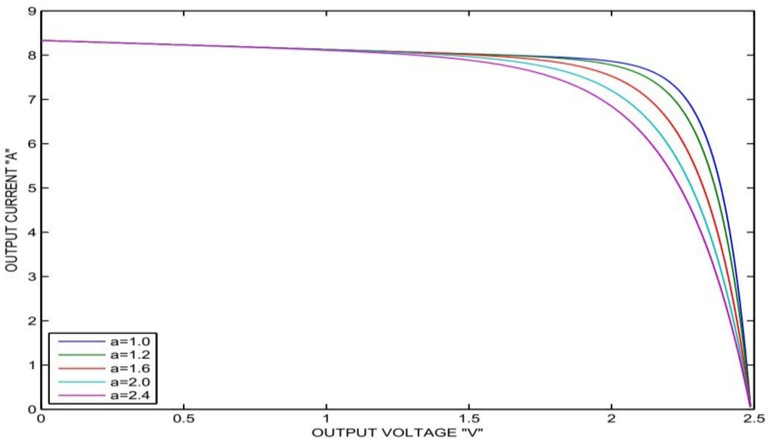

Figure 17. I-V Curve of module with varying Ideality Factor at STC

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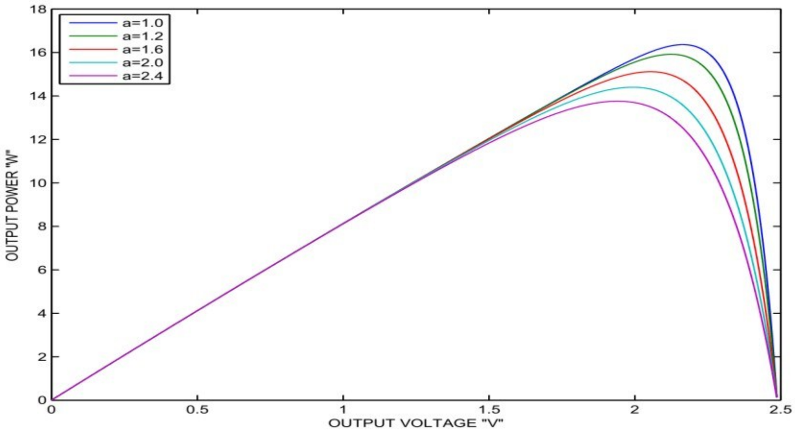

Figure 18. P-V Curve of module with varying Ideality Factor at STC

5. CONCLUSION

This paper presents a hybrid approach towards modelling of solar PV cells to predict their performance under varying conditions experienced during operations. The entire model has been developed in Simscape^{TM} module of Simulink Matlab®. The model tunes the manufacturer provided data for varying irradiance and temperature conditions; it then uses the tuned conditions for determining the optimum combination of Rs, Rp, Is, a and Ipv. These parameters are then used to develop the I-V and P-V curves for the cells under given operating conditions. The model was then used to predict the performance of a single cell as well as a module of four cells in series. The developed model was able to predict the performance of PV cells effectively under varying atmospheric condition and ideality factor of the diode. The model can further be extended to investigate the effects of partial shading on individual cells of any module, since it has a capability to fix the operating conditions on individual cells.

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MANUFACTURING PRODUCTIVITY IMPROVEMENT BY APPLYING EQUIPMENT EFFECTIVENESS METRICS IN A TEXTILE INDUSTRY

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ABSTRACT

Manufacturing companies are striving to improve and optimize their productivity. This would be possible if the companies identify their production losses, improve quality of their products and introduce these products to the market at low cost. In this paper, Metrics of Overall Equipment Effectiveness (OEE) and Total Effective Equipment Performance (TEEP) are applied in a manufacturing set up for the quantitative measurement of equipment and system productivity. These metrics identify the losses in manufacturing process by measuring the availability, performance and quality of production process. These results enable us to identify the manufacturing losses due to breakdowns, stoppages, and defects etc. Analysis of these results is used to suggest and minimize production losses.

Index Terms— Overall equipment effectiveness, total effective equipment performance, production losses.

1. INTRODUCTION

Manufacturing companies are trying to increase their sales by improving production and provide high quality products to customers. According to Fleischer *et al* (2006), the competitiveness of manufacturing companies depends on the availability and productivity of their production facilities. Huang *et al* (2003) argue that due to global competition and in order to remain competitive, companies are striving to improve and optimize their productivity. This would be possible if the companies identify their production losses, improve quality of their products and introduce lean concepts to improve performance (Andersson, 2011; Belekoukias, 2014). This situation requires defining performance measures and using different elements of productivity in a manufacturing process. Nakajima (1988) introduce the total productive maintenance (TPM) concepts, which provide a quantitative metric called Overall Equipment Effectiveness (OEE). This metric is used for measuring productivity of individual equipment in a factory. It identifies and measures losses of important aspects of manufacturing such as availability, performance and quality rate. OEE is used to find and trace improvements or decline in equipment effectiveness over a period of time (Panagiotis et al 2012).

Losses due to availability (i.e. breakdowns, changeovers), performance (i.e. stoppages, reduced speed) and quality (i.e. defects, scrap) are the major concern in manufacturing industry. Local Textile industry is not using the lean approaches to identify the big losses that impact their production. These results enable us to identify the manufacturing losses due to breakdowns, stoppages, and defects etc.

Breakdown loss is one of major issue in manufacturing industry. Industries are searching for effective approaches for optimization of quality and cost. This research is based on lean manufacturing implementation which will play a fundamental role in the company improvement. To minimize the losses and wastes and bringing the industry at a sustainable level, a study must be made first to identify the losses in production and to identify maintenance issues in the propylene floor making company.

This study is about total productive maintenance approaches such as overall equipment effectiveness metrics that measures the production losses by taking into account the availability, performance and quality losses. This metrics will help to identify the manufacturing losses and the analysis of these results is used to suggest and minimize production losses. This study contribute by applying TPM and OEE approaches to the local industry for improving their overall production processes.

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1.1. Literature Review

With the industrialization in the early 20th century and rapid advancements in the industrial sector, many organizations strive to reduce the cost and become more responsive to the market demands. In this backdrop, lean manufacturing approaches have been widely accepted by the industry to address these challenges because these approaches reduce waste without additional requirements for resources.

Lean production is an integrated socio-technical system its main objective is to eliminate waste by concurrently reducing or minimizing supplier, customer, and internal variability (Shah et al. (2007). Piercy and Rich (2009) discussed the evidences of successful lean implementation in service environment; to achieve reducing costs and improving quality. Meier and Forrester (2002) found that lean production practices can be successfully applied to craft manufacturing. Melton et al (2005) applied LM approaches to process industries. Sullivan et al. (2002) discussed an equipment replacement decision problem within the context of lean manufacturing for inventory saving, floor space reduction, and high quality.

Panagiotis (2012) investigates the relationship between production line and the factory management using the failure and fair data analysis to identify the important points of the production process that need improvement in the operation of the process. Pradeep et al (2016) study reveals that implementing OEE reduced production cost that results in increase in the sales revenue and profit. So the industry achieved benefits with the TPM implementation. Nur et al. (2015) investigates the managerial issues related to OEE with descriptive statistics. This study support organizations and mangers to understand the factors that impact the successful implementation of OEE practices in the industry.

2. METHODOLOGY

Initially, we have studied the production process in local Textile industry making mats. We observed that local textile industries are based on traditional manufacturing processes without considering how to improve their production processes. After literature review we collected data in the mats production process related to pipes manufacturing, weaving and sewing processes. We analyzed this data using overall equipment effectiveness and TEEP metrics. Analysis of these results is used to suggest and minimize production losses.

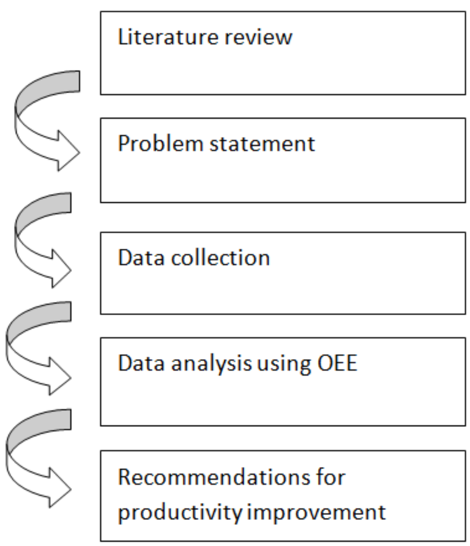

Figure 1. Research methodology

3. INTRODUCTION TO CASE COMPANY

MKB Group is group of Companies that are being the largest manufacturer of Polypropylene Woven Floor Mats in Pakistan.The factories is located in Gadoon Amazai, Peshawar and Risalpur Industrial Estates of KPK. Main products of the

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MKB group are Polypropylene Woven Floor Mats, Polyethylene Film bags, Un-Plasticized Polyvinyl Chloride Leisure Furniture for outdoor use etc.

For this study the MKP manufacturing facility in Peshawar is selected as they are involved in the production of floor mats made of Polypropylene. The following type of machines are used in the production process,

- Extrude machines (poly propylene pipes making machines)
- Weaving machines (pipes binding machines by threads)
- Sewing machines(mates sewing machines to make required piece)
- Recycling machines (Scrap melting machines to make raw material

Figure.2 Weaving machines for mats production.

Figure.3 Extrusion machines Pipes production

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Figure.4 Sewing machines for mats production

3.1. Flow Chart of Mats production:

Initially, extrusion process is used to manufacture pipes and scrap is removed, then these pipes are woven in weaving machines to make mats with further elimination of scrap, and finally the mats are brought into the sewing process where sewing machines are used to make the final product.

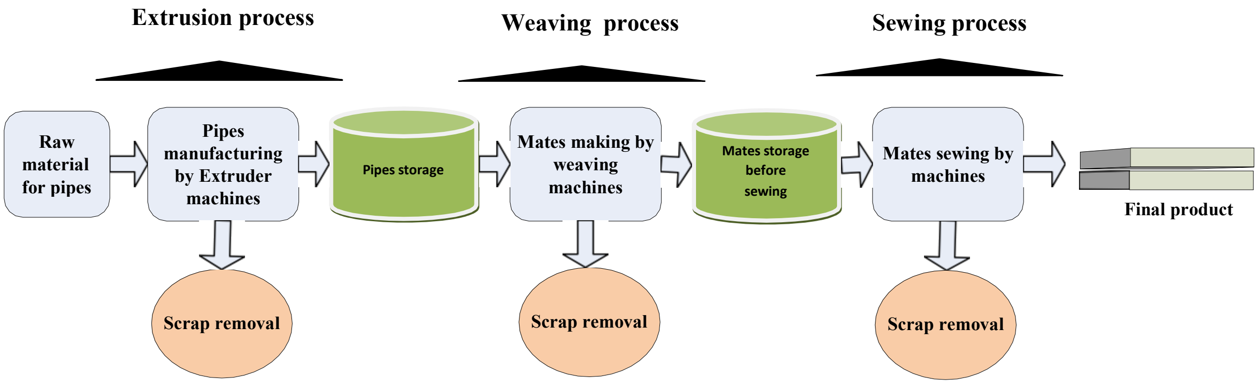

Figure.5. Flow chart of the mats production

4. PRODUCTION ANALYSIS-USING TOTAL PRODUCTIVE MAINTENANCE APPROACH

There are six equipment losses identified within TPM that are used to calculate OEE in manufacturing facilities, these are

Availability
- Breakdowns
- Changeovers

Performance
- Minor Stoppages
- Reduced Speed

Quality
- Defects
- Setup Scrap

4.1. Overall Equipment Effectiveness (OEE)

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Overall equipment electiveness (OEE) is a useful measure of the efficiency and electiveness of the manufacturing processes (i.e. machines, assembly lines, cells, processes, etc.). OEE is a metric that is used to identify the percentage of planned production for tracking and improving plant efficiency. Measuring OEE is best practice in manufacturing systems. By measuring OEE and the production losses, industry can achieve important insights on how to systematically improve manufacturing process. OEE is best for identifying losses, improving the productivity of manufacturing equipment (i.e., eliminating waste). This metric is equal to:

OEE = Availability x Performance x Quality.

$$\text{Availability loss} = \_\ \frac{\text{Production Time}}{\text{Total Available Time - Scheduled Downtime}}$$

$$\text{Performance loss} = \_\ \frac{\text{(Total Production / Production Time)}}{\text{Ideal Run Rate}}$$

$$\text{Quality loss} = \_\ \frac{\text{(Total Production - Total Scrap)}}{\text{Total Production}}$$

Where, Production time = Total available time – (Scheduled downtime + unscheduled downtime)
Ideal run rate = number of parts per minute or hour.
Scarp= is the number of parts wasted or lost
Scheduled downtime = planned stops that could be changeovers
Unscheduled downtime= Unplanned stops due to breakdown etc

4.2. Data Collection and Analysis

To measure the overall equipment effectiveness, data of the different sections in the mats production process is collected and analyzed in the following sections.

4.2.1. Pipe Section

Initially, the data about the pipes section is taken for a single shift, explained in the following section.

Data Collection for single shift that's 12 hours.
Production= 544 kg/ machine/12 hours. 12*544=6528 kg
Scrap= 1.36 kg/machine/12 hours. 12*1.36=16.32 kg.

Table 1.Data for Pipes production by extruder machines

S/nr	Extruder Machine	Batch or Product	Scrap (kg)	Total Production	Total Available Time in minutes	Scheduled Downtime	Unscheduled Downtime	Production Time	Ideal Run Rate
1	12	Impure	16.32	6528	720	60	30	630	9 kg/min
2	24	Impure	32.64	13056	720	60	30	630	18 kg/min
3	24	Impure	32.64	13056	720	60	30	630	18 kg/min
4	24	Impure	32.64	13050	720	60	30	630	18 kg/min

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5	15	Pure	20.4	8160	720	60	30	630	11 kg/min
Total	99		134.6	53856	3600	300	150	3150	74 kg/min

Performance = 53856/3150/74= 0.23
Availability= 3150/ 3600-300= 0.95
Quality = 0.98
OEE = 0.21 = 21%

4.2.2. Weaving Section

In the weaving section, there is approximately 11 % of waste. Weights are in kilograms and time is measured in minutes.

Table 2.Mats production be weaving machines

S/nr	Weaving machines	Batch or Product	Scrap (kg)	Total Production of mats	Total Available Time	Scheduled Downtime	Unscheduled Downtime	Production Time	Ideal Run Rate
1	69	Impure	380	3450	720	80	100	540	4.8 kg/min
2	64	Pure	350	3200	720	80	100	540	4.5 kg/min
Total	133		730	6650	1440	160	200	1080	9.3 kg/min

Performance: 6650/1080/9.3 = 0.66
Availability: 1080/1440-160 = 0.84
Quality: 6650-700/6650 = 0.89
OEE = 0.66 x 0.84 x 0.89 = 0.49 = 49 %.

4.2.3. Sewing Section

In the sewing section, two types of machines are used at MKB. Over lock machines are used for sewing two or more mates with each other. Joki machines are used for sewing the borders of the mates.

Table 3. Mats production by sewing machines

S/nr	Sewing machines	Batch or Product	Scrap	Total Production number	Total Available Time	Scheduled Downtime	Unscheduled Downtime	Production Time	Ideal Run Rate
1	2	Over lock machine	25	2100	8*60 =480 minutes	20	30 -35	425	4.375 per minute
2	3	Border Making machine	20	2256	8*60 =480	20	30-35	425	4.70 Per minute
Total	5		45	4356	960	40	70	850	9.07

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Availability = 850 / 960-40 = 0.92

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Performance = 4356/850/9 = 0.57
Quality = 4356 - 45/4356 = 0.98
OEE = 0.51 = 51 %

4.3. Total Effective Equipment Performance (TEEP)

TEEP (Total Effective Equipment Performance) is a performance measure of production, and it takes into account both equipment losses measured by OEE and schedule losses measured by utilization. This metric is equal to

TEEP= Availability x Reliability x Quality x Utilization
TEEP= OEE x Utilization

Where, Utilization= Planned production time/ Total production time
OEE = 0.21 + 0.49+ 0.51 = 0.40 = 40 %
Planned Time = 12 hours x 2 shifts x 5 days = 120 hours
All time = 24x7 = 168 hours
Utilization= 120 / 168 = 0.71 = 71 %
TEEP = 0.71 x .40 = 0.28 = 28 %

5. RECOMMENDATION FOR PRODUCTIVITY IMPROVEMENT

In the pipe production section, OEE is 21 % that is very low, because the performance loss is too much as compared to availability of the machines and the quality of the product. In the weaving section, OEE is 49 % that is low, because the performance loss is more as compared to availability of the machines and the quality of the product. In the sewing section, OEE is 51 % that is still low, because the performance is low as compared to availability of the machines and the quality of the product. From the analysis, the total equipment performance is also very low due to small value of OEE, however the machine utilization is 71% that is much better than the other factors.

In MKB textile mill, quality is impacted by poorly maintained equipment, system misalignment, and inconsistent raw materials. Performance can be improved by equipment overhaul, replacements, preventive maintenance scheduling, improving quality of the raw materials and include employee training. Furthermore, the availability of the machines can be improved by having the maintenance plan. In the MKB textile mill, there is only breakdown maintenance that must be replaced by preventive maintenance to increase the availability time that is usually lost due to unscheduled downtime. Once the availability, performance and quality of the production system are enhanced, that will improve the total effective equipment performance.

6. CONCLUSION AND FUTURE WORK

The analysis of the production system reveals that the overall equipment effectiveness at MKB is 40 % that is much less than the worldwide practice of high OEE values. The utilization of the machines is 70 % on weekly basis, however small OEE results in lowering the value of total effective equipment performance. These results enable us to identify the manufacturing losses due to breakdowns, stoppages, and defects etc. Results show that most of the time is lost at breakdown maintenance that impacts the availability and quality of the products. Based on the results some recommendations are suggested in this study such as implementing maintenance program and management commitment to get better results.

Through this study, for the first time OEE metrics are applied to assess the production losses in the MKB group of companies. These results enable us to identify the manufacturing losses. Further investigations will be conducted to identify the reasons of these losses and their cost estimation. From the preliminary result it is evident that the total equipment performance is just 28 % that is much lower and need further work to improve the overall productivity.

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APPLYING MODEL BASED SYSTEMS ENGINEERING (MBSE) TO AIRCRAFT HYDRAULIC SYSTEM

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Abstract

The paper presents Model based Systems Modeling (MBSE) approach to build an aircraft hydraulic system. While building such complex systems in which many interdependent variables are involved it is wise to get support from MBSE in order to address all erros well before the system enters into the realization phase. The legacy approach for system modeling was document based and includes all the life cycle activates as mentioned in Systems Engineering Handbook (INCOSE stands for International Council on Systems Engineering). The problem with legacy document based approach is that it presents disjoint sets of artifacts using textual and some graphical methods such as concept of operations (ConOps) documents, requirements specifications, requirement trace-ability and verification matrices (RTVMs), interface definition documents (IDDs), N2 charts (also known as N-squared charts—matrices of structural interfaces), architecture description documents (ADDs), system design specifications, test case specifications, and specialty engineering analyses (e.g., analyses of reliability, availability, schedulability, throughput, and response time), which not only adds cost to the project but is also difficult to manage and analyze. In this regard the proposed approach of MBSE takes a leap in terms of time and cost efficiency. Further MBSE provides the provision of early opportunity of conflict resolution and proves its efficiency in cross cutting phase where if the System engineer (SE) desires to incorporate changes/amendments, the same is implemented across all the system models. The tool utilized to build aircraft hydraulic system architecture is **Modelio 3.7** utilizing system modeling language **(SysML)** architect **3.7.01**.

Index Terms: System Engineer (SE), Modelio, Model Based System Engineering (MBSE),

[1] Assistant Professor,

[2] Graduate Student,

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1. Introduction

Systems engineering (SE) is an interdisciplinary field that develops complex systems through intelligent and innovative solutions, focusing on ways to handle projects from idea generation till disposal. It aims at ensuring that “customer and stakeholder’s needs are satisfied in a high quality, trustworthy, cost efficient and schedule compliant manner throughout a system’s entire life cycle”. [1]

The system engineering (SE) approach has been revamped by the introduction of Model Based system engineering (MBSE). It takes the life cycle from the textual canvas to the graphical representation of same textual content to enhance the efficiency of the product design and operational team. MBSE includes system requirements, design, analysis, verification and validation events. “The greatest benefit of a model-driven process is improved communication between engineering disciplines, between technical and non-technical parties, using different levels of abstraction, and avoids information overload” [2]. Further to that another advantage MBSE has over textual model, is the traceability, by using stereotypes one can define the function in one diagram and then that specific function can be called upon in subsequent diagrams. This crosscutting feature put MBSE in forefront for resolving the conflicts in complex system apart from developing a sound foundation for systems thinking.

In order to support the design process of complex systems, the design team needs to build several diagrams which include block diagrams and functional flow diagrams. There are different modeling languages that support such types of diagrams, Unified modeling language (UML) being one of them. UML was targeted mainly for software engineering. In 2001 system engineering felt a need to develop their own language which address SE contents in a more elaborated manner and easy to consume by customers and stakeholders. SysML extends a subset for UML and is in use by SE since then. SysML was developed by the Object Management Group (OMG), International Council on Systems Engineering (INCOSE), and International Organization for Standardization (ISO), using UML’s profile that represents a subset of UML 2 with extensions. It is designed to support development stages, including the specification, analysis, design, and validation of SE applications. “In particular, the language provides graphical representations with a semantic basis for modeling system requirements, behavior, structure, and parametrics, which is used to adapt with other engineering analysis models” [3]

The aim of this paper is to encourage the designer and operational team to use MBSE to express their needs and communicate with different tiers of life cycle management of a certain system more effectively than ever before. The aim is elaborated by taking an example of aircraft hydraulic system. The hydraulic system modeled in this paper is if of generic aircraft hydraulic system. The hydraulic system supplies power for operation of the primary flight control surfaces and utility systems. This is done by two engine-driven hydraulic pumps, an emergency hydraulic pump, and two hydraulic power distribution and control subsystems. The engine-driven hydraulic pump supplies pressurized hydraulic fluid to the pressure filter manifold (hydraulic filter pressure manifold). The manifold interfaces with the hydraulic low-

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pressure switch and divides hydraulic fluid to the flight control units as required. It also supplies hydraulic fluid to the hydraulic reservoir service manifold, which divides fluid to the hydraulic reservoir and to aircraft utility functions. Return fluid is filtered through the return filter manifold and then routed to the heat exchanger bypass valve (cooler thermal bypass valve). At normal temperatures, fluid will bypass the fuel/oil heat exchanger and flow directly to the reservoir. At higher temperatures, the heat exchanger bypass valve routes flow through the heat exchanger and then to the reservoir.

2. Related work

There has been notable research work on MBSE and SysML application and improvements. The application of SysML is widespread, however the reluctance in conversion of legacy designers and practitioner's methodology to this new approach is evident. In this regards INCOSE and its other associated chapters are making substantial efforts to bring about the awareness and advantages of SysML application. A SysML based process for the high-level development of mechatronic systems is applied in a paper, reaching from requirements specification to the detailed modeling of the element-connections. The subject paper approach shows how the information from the different levels of abstraction and the different development phases can be connected, including a functional modularization of the mechatronic system. In this way, developers can trace variations amicably [4].

Another work carried out in SysML application is management in the discipline of requirement engineering. Requirements engineering plays a pivotal role in a system's life cycle. Model-based engineering, in which models are the main object during system development, is an developing approach that tries to address system intricateness by the intense use of models. The article proposes a model-driven approach to requirements engineering based on SysML Requirements and Use Case Diagrams. The main advantages are that user requirements and relations are explicitly modeled and mapped, and system decomposition is considered in the early system development activities. The proposed approach by researcher as mentioned in Figure 1 is that SysML diagrams are used to provide a structured approach to the legacy methodology of representing the requirements in an informal diagrams and natural language. However, the researcher specifies on the subject is that SysML doesn't replace the legacy method completely as natural language-based requirements are kept for further requirement engineering activities as they provide the primary communication medium with the stakeholders. [5]

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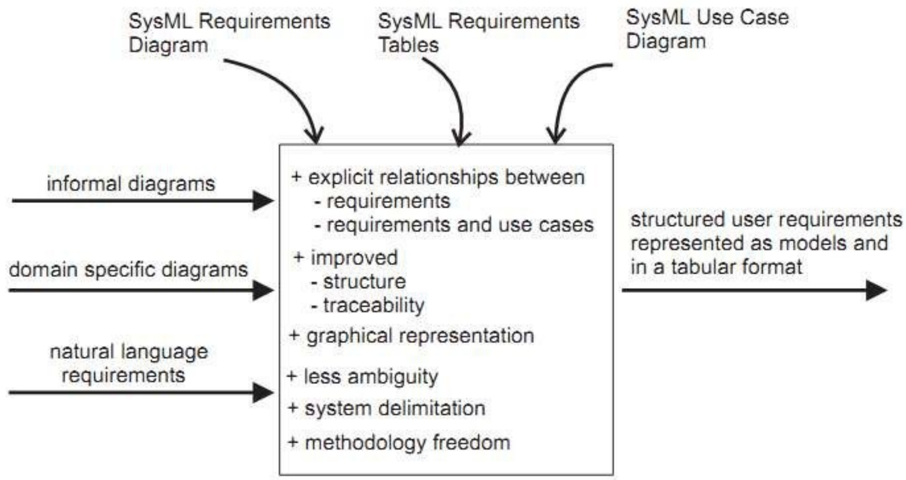

Figure 1: Model driven Requirements engineering approach with SysML

Another researcher proposed the utilization of SysML in an integrated systems and software development process known as Harmony. This process follows the classic development scheme that starts with requirements and functional analysis and progresses to the phases of design synthesis and implementation, till end system acceptance. [6]

A researcher proposes a practical application of SysML at a sub system level of a submarine design. A diesel generator as the powerplant for submarine is taken as a sub system and SysML diagrams are applied for better design synthesis at the early stages of submarine design. The methodology discusses a number of important topics associated with building a system model that is intended to advances from a preliminary design over the lifespan of the submarine. [7]

Another interesting use of SysML is also seen in design optimization area. The focus is on improving a designer's capability to determine near-optimal sizes of components for a given architecture. Component sizing is a difficult problem to tackle because of the presence of stringent objectives, requirements from multiple disciplines, and the need for finding a solution promptly for the architecture being considered. [8]

3. Methodology and Case study work

The methodology followed in this paper is using SysML approach to model aircraft hydraulic system at different levels of abstractions and from black box to white box specifications. It is to be noted that intentionally an existing example is used to elaborate on the uses and understanding of SysML approach. The tool utilized to build aircraft hydraulic system architecture is **Modelio 3.7** utilizing system modeling language **(SysML)** architect **3.7.01**. The software Modelio is an opensource software developed by modeliosoft. There are basically three broad categories of SysML diagrams behavior, requirement and structure diagram, further they are divided subsequent categories as shown in Figure 2. Requirement and Parametric diagrams are unique to SysML as compare to UML. [9]

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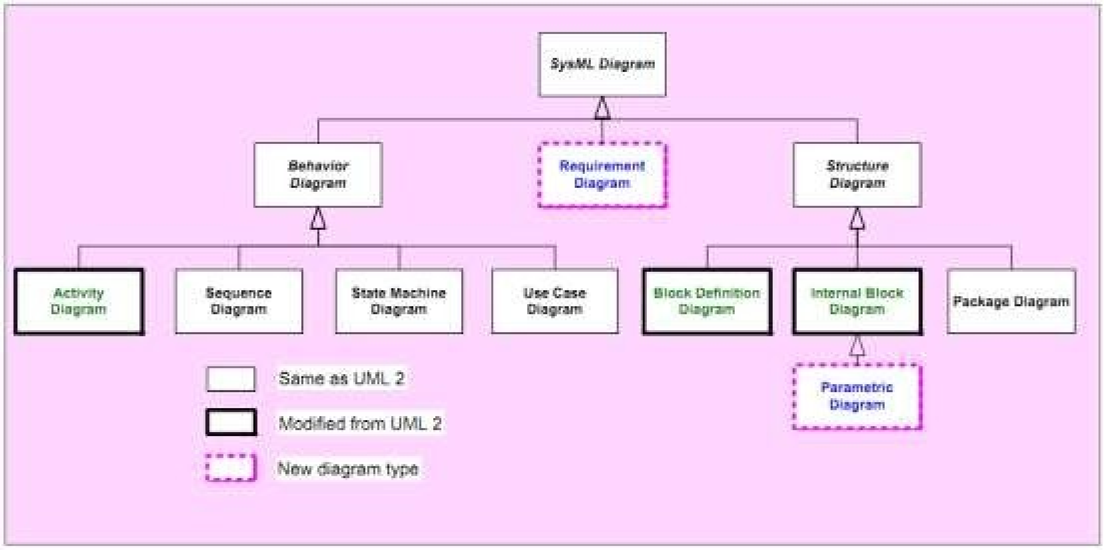

Figure 2: SysML diagram Taxonomy

Activity diagrams are used to represent the behavior of a system, highlighting the flow of control and transformation of inputs to outputs. **Sequence diagram** are used to highlight the detail design sequence of an operation of a system. They are usually helpful in the development cycle of a system for better visualization and analysis [10]. It also specifies the interaction of individual blocks with each other. **State machine diagram** is used to specify the behavior with focus on the states of the block and interaction between these states in which the system transitions. **Use Case diagram** is used to specify the interaction of human with the system. **Block definition diagram** specify the system hierarchy and classification tree. **Internal block definition** is use to explore the white box specifications of the system. **Package diagram** is used to display the way a model is organized in the form of a package containment hierarchy [11]. **Parametric diagram** is a unique diagram and is exclusive to SysML which displays the constraints in the form and equations or inequalities. Further the help in performing engineering analyses, including performance, reliability, availability, power, mass, and cost. **Requirements diagram** is used to display text-based requirements and the interaction among the requirements (it is also exclusive to SysML) [12].

The diagrams utilized to build aircraft hydraulic system are Use case, block definition, sequence and package diagrams. It is to be kept in mind that the modeling is done with Block-box specification in context with fewer diagrams using white-box specification depending upon the availability of data.

3.1 Package Diagram

As shown in Figure 3, the Aircraft hydraulic system is a package that represents the user model. The SysML Profile must be applied to this package in order to include stereotypes from the profile. The Aircraft hydraulic system may also require model libraries, such as the SI Units Types model library. The model libraries must be imported into the user model as indicated.

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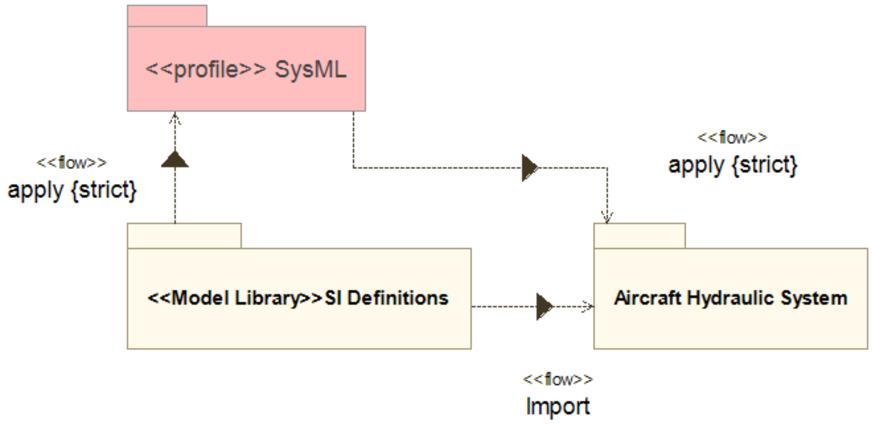

Figure 3: Package Diagram for Aircraft Hydraulic system

3.2 Block Definition Diagram

The most common kind of SysML diagram type offering modeling of model elements and relationships on a BDD to express information about a system's structure. Aircraft hydraulic system constitute of system A and B for redundancy in the event of failure of one system. Each system consists of main, return and case hydraulic subsystems. Main system is pressurized from main hydraulic pump with pressure maintained at 3100 psi for operation of aircraft hydraulic dependent utilities such as flight controls. After the operation the fluid is return via return filter to same system reservoir. Case system fluid is use for lubricating of hydraulic pump during operation and is fitted with a filter to avoid any contaminants from entering into reservoir. Further the fluid is also passed through fuel oil cooler so that cooler fluid is allowed to enter back to reservoir after operation. It is to be noted that only system hierarchy is highlighted in BDD's, for operation view sequence diagram is used which offers a detail operational view of the system.

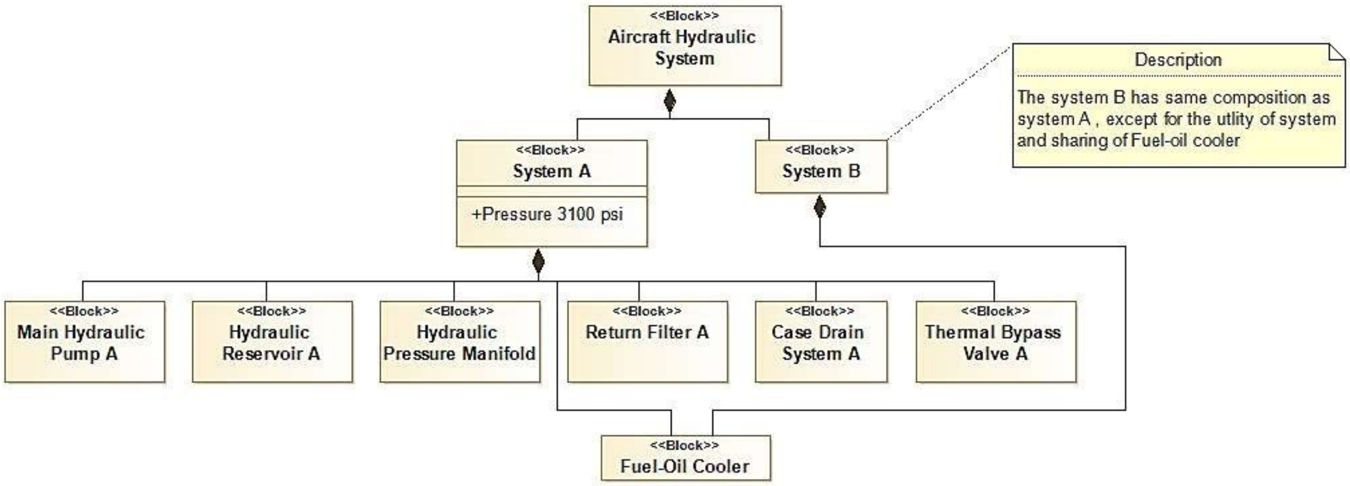

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Figure 4: Block Definition Diagram of Aircraft Hydraulic system

3.3 Sequence Diagram

Sequence diagrams provides designers to express information about a system's dynamic behavior. The sequence diagram for aircraft hydraulic system is shown at Figure 5. The engine driven hydraulic pump supplies pressurized hydraulic fluid to the pressure filter manifold (hydraulic filter pressure manifold). The manifold interfaces with the hydraulic low-pressure switch and divides hydraulic fluid to the flight control units and other systems as required. Return fluid is filtered through the return filter manifold and then routed to the heat exchanger bypass valve (cooler thermal bypass valve). At normal temperatures, fluid will bypass the fuel/oil heat exchanger and flow directly to the reservoir. At higher temperatures, the heat exchanger bypass valve routes flow through the heat exchanger and then to the reservoir. Case drain (cooling and lubricating) fluid from the pump flows directly to the return filter manifold where it unites with return fluid. This fluid is then routed to the heat exchanger bypass valve.

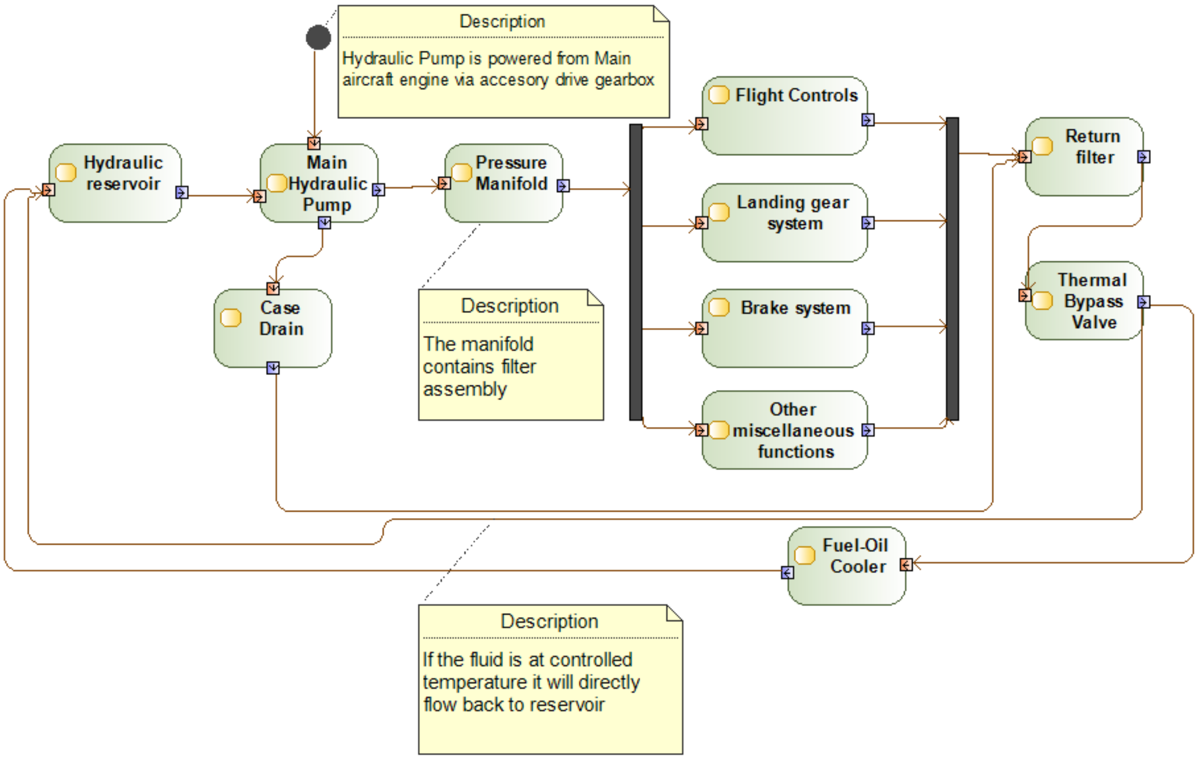

Figure 5: Sequence Diagram of Aircraft Hydraulic system

3.4 Use Case Diagram

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The use case diagram presents a black box view as to what all actors are involved with the system. Further it specifies each actor with its particular interaction area in the system. In the case of aircraft hydraulic system, there are three actors involved. Pilot, ground operator and maintenance system specialist, they all interact with the system differently in order to keep the system functioning. Aircraft hydraulic system energizes as soon as the main engine is lit up, so the pilot interaction with this system is passive as if the system malfunctions in air (with the indication in cockpit), the pilot will command the auxiliary system to power up and provide adequate power to flight control system for emergency landing. Ground operators interacts with the system for charging of hydraulic system as a final ground check before releasing the aircraft for pilots. Whereas maintenance system specialist interact with system in a more concise way, they troubleshot the system and replace the components such as reservoirs, pumps and filters. The use case of aircraft hydraulic system is shown in Figure 6.

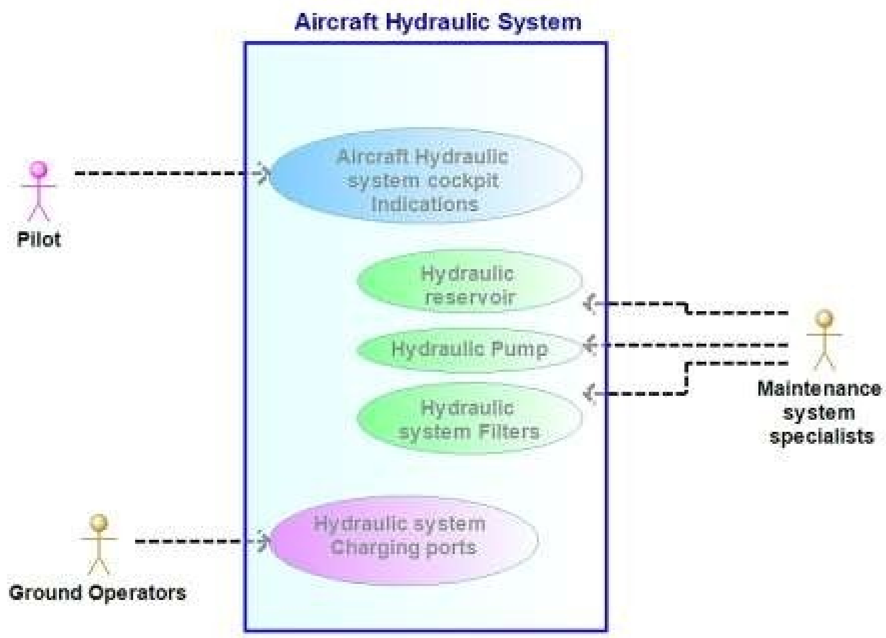

Figure 6: Use case Diagram of Aircraft Hydraulic system

4. Limitations

The limitation observed during application of SysML on aircraft hydraulic system using Modelio software is missing of conventional diagram header. The software although fully developed lacks the option of importing the diagrams with conventional header format of SysML which indicate the diagram type and its title. The Header helps in diagram identification and is easy for navigation during cross cutting of different diagrams. For the fulfillment of said issue, the other commercial software's such as Rhapsody and enterprise architect may be looked into while developing a real-world case.

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5. Future Work

SysML is an emerging area in Systems Engineering and is in under continuous evolution. However, the use of SysML in Pakistan is fewer to none. The scarcity of use has many explanations, awareness being the most prominent of them. Future extensions to this paper is applying SysML to other systems with addition to other diagrams that are not included in this research due to the non-availability of certain designer data. Further the diagrams specified in this paper can be improved by adding more data to it. SysML use is to be emphasized in designer communities of Pakistan so that detection of system flaws and improvements may be incorporated in early development phase.

6. Conclusion

The approach presented in this paper provide a staging ground for designers and practitioners to model their respective systems using SysML, in order to better communicate with the core team and stakeholders, traceability, sub system modeling and cross cutting by using stereotypes and links. SysML must be available at all tiers of system development so as to establish a better understanding of systems thinking and rapid incorporation of design/operational modifications.

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MATERIALS SELECTION FOR PLAQUE OF RADIANT GAS HEATERS USING GRANTA'S DESIGN CES EDUPACKSOFTWARE

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ABSTRACT

Materials Selection is very important in modern engineering design process due to great diversity in the properties of modern materials. Today thousands of materials are available for engineers to select the best required material for their design. One may use either online materials data base like MatWeb or may use the Granta's Design CES selector software for materials selection. In this paper, research is conducted for the selection of materials for plaques of radiant gas heaters by using the Granta's Design CES Edupack software package. Radiant (Infrared) gas heaters are generally used for the purpose of cooking food and warming rooms, halls etc. to the humans comfort. The plaques used in these heaters are usually made of ceramics like glasses, cordierite, alumina etc. In this work, suitable candidates for the material of plaque are selected using the Granta's Design CES Edupack software and among these materials cordierite is selected as material of choice for the plaque of radiant gas heaters. Cordierite is an insulator with good thermal shock resistance, higher melting point, good fracture toughness, lower price, higher specific strength, easy processibility, appreciable porosity and light weight.

Index Terms— Material Selection, Granta's Design CES Edupack software, Plaques, Radiant gas heater.

1. INTRODUCTION

Importance of material in the engineering design process is well known. Designing an engineering product without proper material identification and selection increases the risk of its failure either at the manufacturing stage or duting its operation. Therefore appropriate material has to be selected while designing an enginee ring product.

Each and every design has its required set of attributes i.e. its properties like the yield strength, stiffness, fracture toughness, maximum and minimum service temperatures etc. Similarly every material has its own set of properties, often called the "attributes profile". Materials selection is the process of finding the best possible match between the required set of design properties and the material attributes profile. This is not an easy task for a designer to select the appropriate material among more than 120,000 known materials. It is difficult, boring and time consuming job. Moreover the risk of selecting wrong material among such largr number of materials is always at its highest level. These types of difficulties can be tackled with the use of modern software technologies such as the Granta's Design CES software. The strategy and approch of materials selection has been explained by Ashby in his work (Ashby et al., 2002)

The Granta's Design CES (Cambridge Engineering Selector) package is used to compare various aspects of the design with one another, considering the environmental credentials of materials and shortlist those materials that meet the design requirements. All materials can generally be classified into six families i.e. Metals, Ceramics, Polymers, Glasses, Elastomers and Hybrids. Different colors envelops in the CES Edupack selector show various material families and the small bubbles inside these envelops represent the members of families. The software has 3 levels. Level 1 has bulk materials only; level 2 has relatively higher number of materials than level 1; level 3 contains almost all the materials. The properties charts where one property is compared against the other property and limits provided to software play very crucial role in material selection. However, the final choice of material among final candidates also depends on

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various others factors such as in-house expertise, the geo-political situations, availability of the material and taxation etc.(Ashby et al., 2003).

Gas heaters are used in almost every part of the world for cooking food, warming rooms, hall etc. Fuels used in these heaters are either LPG (Liquid Propane Gas) or Natural gas (Methane is the major cons tituent) or both. These heaters can be classified into two main categories i.e. blue flame (convection) heaters and radiant (infrared) heaters. Blue flame heaters heat air in the surroundings through convection and there is no need of plaques as the convec tion occurs from open flames of the heater to the surrounding air. These types of heaters are used in rooms that are well insulated and a person sitting near heater will not feel heat at the beginning because the air in the room is heated though convection and the hot air being lighter moves upward and thus leaving the dense cold air below at human level sitting in front of the heate r. Therefore, these heaters are not suitable for instant heating of the room and the room must be well insulated as fresh air entering the room will drop their efficiency. On the other hand **,** radiant gas heaters emit infrared radiations and heat opaque objects (humans are also opaque) coming in their way rather than just heating the air. In ra diant gas heaters, the combustion of gas heats plaques that in turn radiate to the surrounding objects. The infrared radiations move in straight line and heat all opaque objects that come in their way. Therefore, plaques are essential part of radiant gas h eaters. An appropriate material has to be selected for the plaques as the performance of radiant gas heaters depends upon these plaques. In this work, material selection for the plaque of infrared gas heaters is done by using Granta's design CES Edupack se lector package (Chen and Energy, 2007).

2. PROPERTIES CONSIDERED IN SELECTING MATERIALS FOR PLAQUE OF RADIANT GAS HEATERS

Plaques used in radiant gas heater allow infrared radiations to emit from their heated surfaces. The following properties must be considered during materials selection for these plaques.

2.1. Temperature

Plaque material to be selected must be of a high refractory to be able to withstand high operating temperatures.

2.2. Thermal Shock Resistance

Thermal shock resistance (TSR) is the measure of material's resistance to fracture under sudden maximum change in the temperature i.e. the response of material for large changes that occurs over short period of time. TSR is found to be dependent upon various properties like the thermal conductivity, thermal expansion coefficient, maximum service temperature, fracture toughness, yield strength and elastic modulus of the material etc. (Lu and Fleck, 1998).

The material to be considered must have high thermal shock resistance to withstand without failure the greater difference between the maximu m operating temperature and the minimum temperatures.

2.3. Thermal Conductivity

Thermal conductivity is a material property that measures its ability to cond uct heat ($^{W}/_{m.K}$) . Thermal conductivity of the material must be lower to minimize the heat t ransfer though conduction from the heated surface of the plate where flames burn to its back side (Bergman et al., 2011).

2.4. Thermal Expansion

The change in shape, length or volume of a material due to the change in temperature at constant pressure is called thermal expansion. Thermal expansion of the selected material must be lower so that there are negligible thermal strains in plaques (Ho and Taylor, 1998).

2.5. Fracture Toughness

The ability of a material to resist the propagation of cracks is called its fracture toughness. The material selected must have comparatively good fracture toughness so that the plaque don't get damaged durinng operation.

2.6. Density

The mass per unit volume of substance is called its density ($^{kg}/_{m^3}$). Here low density material should be preferred to reduce the overall weight of the product.

2.7. Flamablity

The chosen material must not be flammable i.e. it should not burn out during the combustion of fuel.

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3. METHODOLOGY

Level 3 of Granta's design Cambridge Engineering Selector (CES) Edupack software was used to select the suitable candidate materials for plaques of radiant gas heaters. This was achieved by considering the *function*, *objective(s)* and *constraints* for the plaques of radiant gas heaters.

- The basic function of these plaques is to emit infrared radiations at elevated temperature, when fuel (Natural gas or LPG) is burnt at their surfaces.
- The objectives of these plates are to withstand high temperature, resist thermal shocks, light weighted, maximized fracture toughness, lower thermal expansion and lower cost.
- The constraints considered for plaques materials are; higher melting point, maximum service temperature, non-flammable, minimum thermal conductivity, good mechanical and thermal stability.
- Material choice and dimensions are the free variables.

Material properties charts were developed using CES Edupack software and suitable candidate materials were selected on the basis of material requirements given in Table 1. After the shortlisting of maerials, furhter screening is done on analytical as well as on material rating chart. The material with maximum raitng value will the preferred selected material for plaques of radiant gas heaters.

Table 1. Material Requirements

Function	Plaque of Radiant gas heaters
Constraints	• Non-flammable • Higher Melting Point i.e. ≥ 1300 °C • Max. Service Temperature i.e. 300°C < MST < 1500°C • Stiff and strong • Fracture Toughness ≥ 1 MPa.m^0.5 • Thermal Conductivity ≤ 5 W/m. °C • Thermal Expansion Coefficient ≤ 5 µstrain/°C • Price ≤ 50 USD/kg
Objectives	• Maximize Fracture Toughness • Maximize Thermal Shock Resistance • Minimize Thermal Conductivity • Minimize Thermal Expansion • Minimize Mass • Minimize Cost
Free variables	• Choice of material • Plaque dimensions

4. RESULTS AND DISCUSSIONS

The candidate materials selected for the plaque of radiant gas heaters were; cordierite, ceramic tile, graphite (perpendicular to plane), limestone (2.66), marble (2.7), steatite (general) (920) and steatite (low loss) (908).

Initially various properties limits are applied to the material selection process as given in Table 1. The application of these limits result in the shortlisting of 7 materials among 3087 materials. It would never be easy if done manually. Further screening is done on the basis of comparison of various properties of these materials. Again this is done with the help of the CES selector software. In Fig 1. to Fig 7. various properties are compared to each other and ranking is done for the material selection of plaques of the radiant gas heaters after detailed analysis of the results.

In Fig 1. the thermal conductivity (TC) and maximum service temperature (MST) is compared with each o ther. As per requirements for the application, a material with low thermal conductivity and higher maximum service temperature should be selected. The two envelopes show Technical and Non -Technical ceramics. Ceramic tile and Limestone (2.66) have minimum TC but its MST is not higher. Graphite (perpendicular to plane) has both TC and MST higher. Steatites and cordierite have relatively lower TC and also higher MST, which make them good choice of materials for plaques of radiant gas heaters.

The comparison of Thermal Expansion Coefficient (TEC) and Maximum Service Temperature (MST) is shown in Fig 2. Material with least TEC and higher MST will be the choice of material. It can be seen from the graph that graphite has relatively lower TEC and also the higher MST which makes it the material of choice for the plaques. Cordierite stands second in this regards.

The graph between young's modulus (YM) and MST in Fig 3. shows that the cordierite is the choice of material for plaques of radiant gas heaters with highest YM and appreciable MST. Steatites also lie in the close range and can be preferred.

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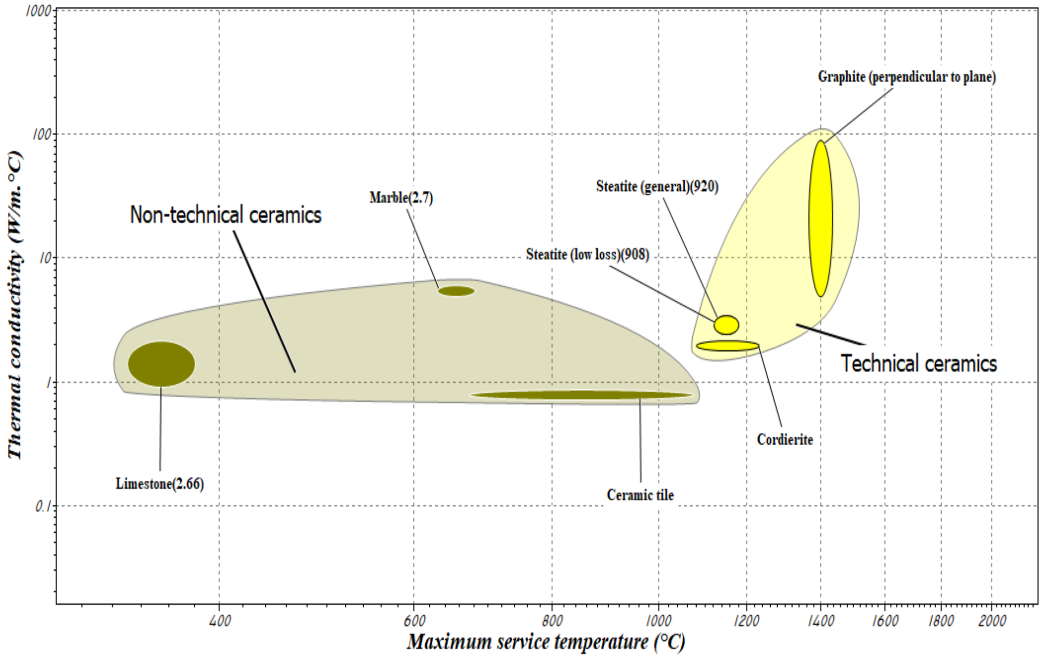

Fig 1. Thermal Conductivity (W/m.°C) vs. Maximum Service Temperature (°C)

Fracture Toughness (FT) vs. Yield strength (YS) in Fig 4. shows that cordierite and steatites have good fracture toughness and YS ratio among the seven candidates. Steatite (low loss)(908) shows better YS than cordierite and steatite (general)(920) with almost same FT. In Fig. 5, price is compared to the density of the materials. Graphite (perpendicular to plane) has minimum density but maximum price thus not giving optimized result. Ceramic tile is observed to be the cheapest. Fig 6. shows the graph of compressive strength (CS) vs. FT (MPa.m^0.5). Steatite (low loss)(908) s hows highest CS and FT as per material requirements. In Fig 7. cordierite and steatites show maximum stiffness and FT which are the requirements of the material for heater plaques.

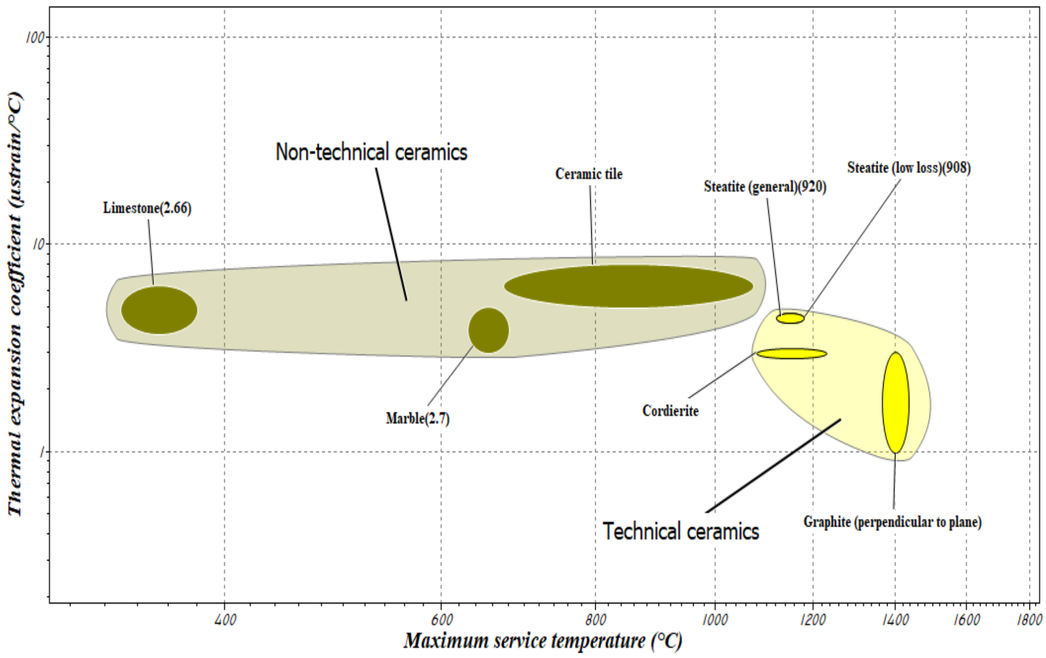

Fig 2. Thermal Expansion Coefficient (1/°C) vs. Maximum Service Temperature (°C)

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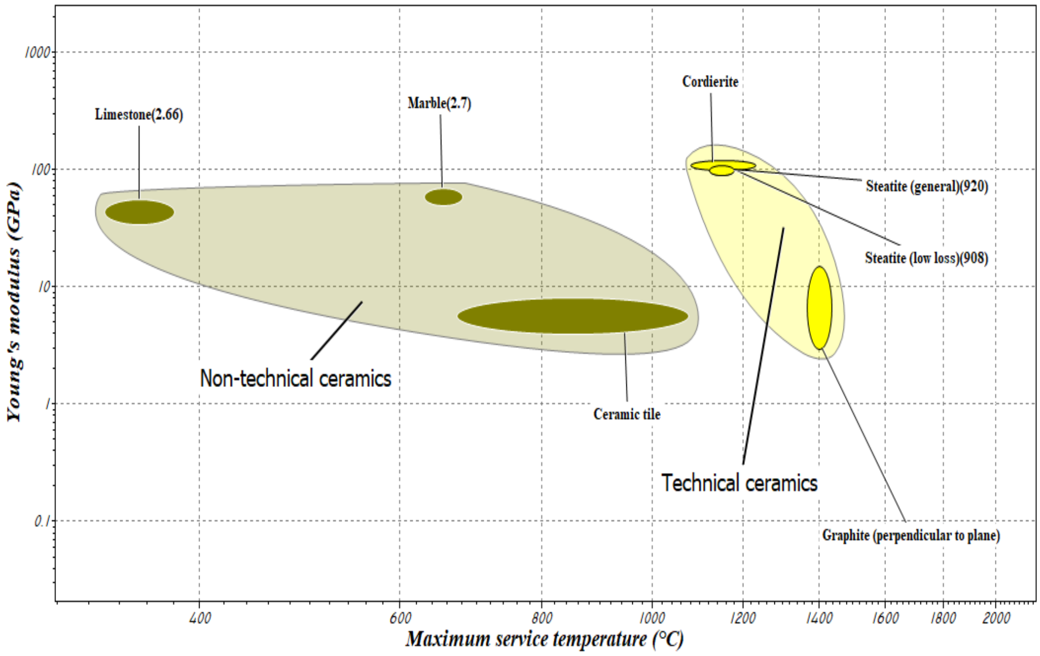

Fig 3. Young's Modulus (GPa) vs. Maximum Service Temperature (°C)

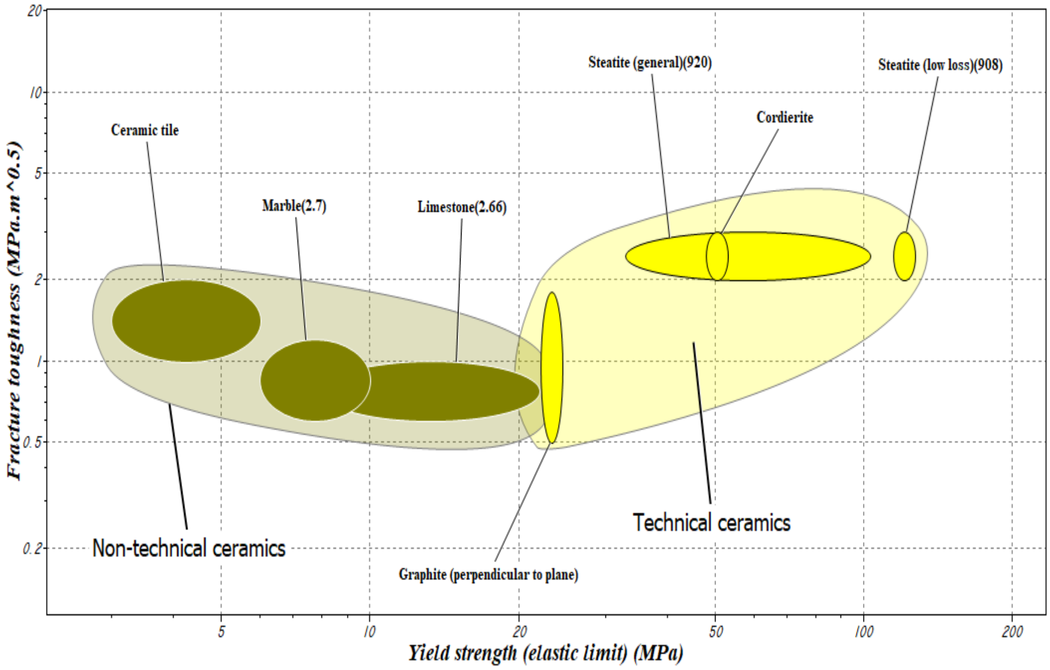

Fig 4. Fracture Toughness (MPa.m^0.5) vs. Yield Strength (MPa)

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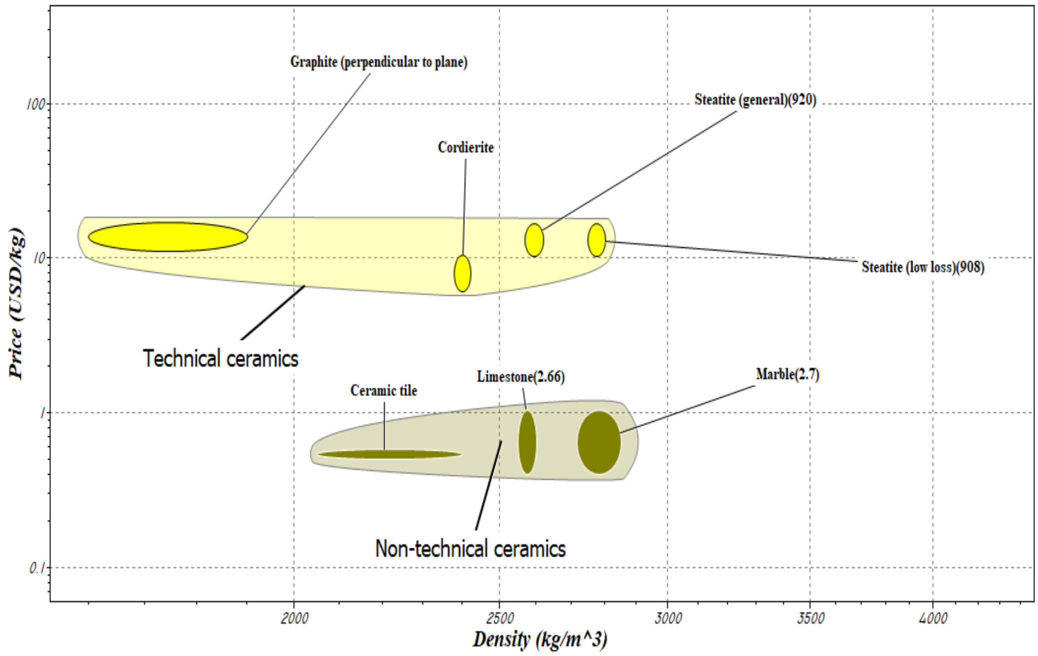

Fig 5. Price (USD/kg) vs. Density (Kg/m^3)

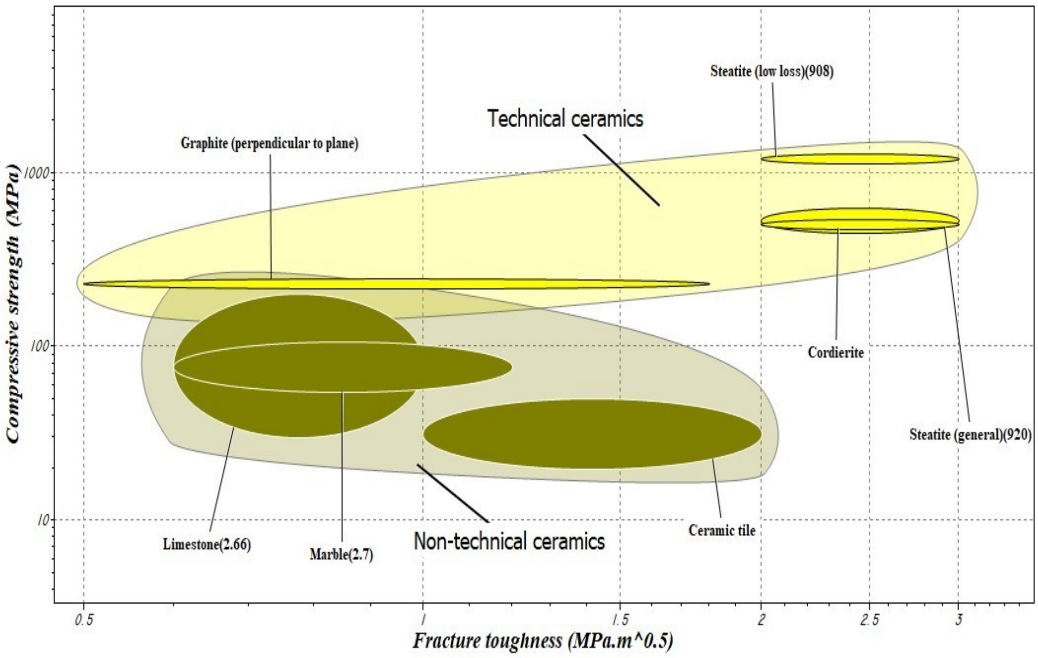

Fig 6. Compressive Strength (MPa) vs. Fracture Toughness (MPa.m^0.5)

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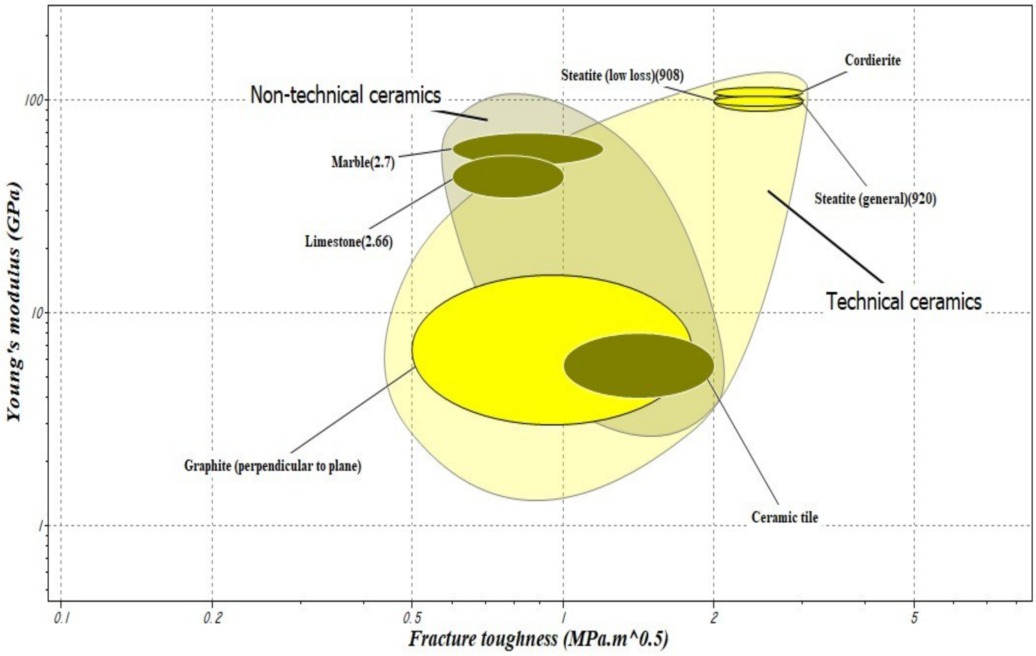

Fig 7. Young's Modulus (Gpa) vs. Fracture Toughness (Mpa.m^0.5)

4.1. Materials Rating Chart

As it can be seen from Fig 1. to Fig 7. that there is a general idea that among seven candidate materials, the technical ceramics are more likely to meet the requirements of the material to be selected for the plaques of the radiant gas heaters. Moreover, cordierite and steatites are more favorable to be used for the plaques of the radiant gas heaters. But to be surer further screening is done on the basis of materials rating chart given in Table 4.

All required properties were given weighting factor, **r** (1 to 5) according to their importance in the application, Table 2. Property rating number, **R** (1 to 5) shows that what the material response against each property is, Table 3. The material should be non-flammable and that is the Go-No-Go property as shown in Table 4.

Table 2. Weight factor of each property

Property	Weighting Factor, r
Thermal Shock Resistance	5
Maximum Service Temperature	5
Thermal Expansion Coefficient	5
Thermal Conductivity	4
Fracture Toughness	4
Compressive Strength	4
Yield Strength	4
Stiffness	4
Density	4
Price	4

Table 3. Property rating number

Grade	Property rating number, R
Excellent	5
V. Good	4
Good	3
Fair	2
Poor	1

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Table 4. Property Rating Chart for Candidate Materials

Material	Go-No-Go	Relative Rating Number, R = property rating number * weighing factor										$\sum R$	$\sum r$	$\frac{\sum R}{\sum r}$
	Flamm-ability	MST	TSR	TEC	FT	TC	CS	YS	Stiffness	ρ	Price			
Ceramic Tile	Satisfactory	3x5	4x5	3x5	4x4	5x4	1x4	1x4	1x4	4x4	5x4	134	43	3.1
Cordierite	S	4x5	5x5	3x5	5x4	4x4	4x4	3x4	5x4	3x4	3x4	168	43	3.9
Steatite (general)920	S	4x5	3x5	3x5	5x4	3x4	4x4	3x4	5x4	3x4	3x4	154	43	3.6
Steatite (low loss)908	S	4x5	3x5	3x5	5x4	3x4	5x4	5x4	5x4	3x4	3x4	166	43	3.9
Graphite (perpendicular to plane)	S	5x5	2x5	5x5	2x4	1x4	2x4	2x4	1x4	5x4	3x4	124	43	2.9
Limestone (2.66)	S	2x5	2x5	3x5	2x4	4x4	2x4	1x4	3x4	3x4	5x4	115	43	2.7
Marble (2.7)	S	3x5	2x5	4 x5	2x4	2x4	2x4	1x4	4x4	2x4	5x4	117	43	2.7

From Table 4. it can be obsereved that the Cordierite and Steatite (low loss) (908) has rating value of 3.9 out of 5, whcih is the maimum rating value among the seven candidate mateials. Limestone (2.66) and Marble (2.7) has t he minumum rating value of 2.7. Graphite (perpendicular to plane), Ceramic Tile and Steatite (general)(920) has rating values of 2.9, 3.1 and 3.6 respectively.

5. CONCLUSION

Plaque material for radiant gas heaters is selected by using Level 3 of Granta Design CES Edupack selector package. The shortlisted materials are cordierite, ceramic tile, graphite (perpendicular to plane), limestone (2.66), marble (2.7), steatite (general) (920) and steatite (low loss) (908). All of them meet the demand of the required material for th e plaque of radiant gas heaters, but for better results further screening was carried out through the comparison of differnt properties of these material with each other using property charts of CES Edupack software. Property Rating Chart methodology is also used for the verification of the results.

It is concluded that Cordierite and Steatite (low loss) (908) are the materials selected for the plaques of the radiant gas heaters. The property charts show the optimum values of Maximum Service Temperature, Melting point, Thermal conductivity, Thermal Expansion Coefficient, Thermal Shock Resistance, Density and Price for both the materials. Moreover, the Property Rating Chart also endose the findings with highest rating value of 3.9 for both Cordierite and Steatite (low loss) (908). The results further reveal that Limestone (2.66) and Marble (2.7) are not preferred and reliable choices for the plaques material.

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ELIMINATION OF UNECESSARY TIME AND MOTION AT PAK MATCH FACTORY PESHAWAR:

TO INCREASE PRODUCTIVITY

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"ABSTRACT"

In the present era of industrialization and competition, the industries struggle to boost their efficiency and sustain their market capitalization and to improve the production rate and reduce its cost. For enhancing efficiency of such system, Time and Motion study is one of the most excellent tool. One may be able to eliminate all the non-value-added activities (over production, excessive motion, underutilized people, waiting, transportation etc.) and accomplish the task within standard time following standardized procedures. Due to manual work in PAK Match factory, mostly in 2 sections having four operations (Packing, tray discharging, tray filling and Dozen Packing), that is needed to be optimized to maintain and increase its market share, which cover almost Pakistan and some other countries. SIMO charts, Therbligs and principles of motion economy are being used for analysis. These techniques applied to achieve goals and results, while standard time for operations for the standardizing jobs, operations, equipment's, methods, and materials and working condition, assessing manpower requirements correctly and cost control through proper planning. The result which is obtained from the factory including performance of 2 sections having 4 operations after applying time and motion study techniques, productivity improved in each section of operation by 30% ,37%, 32 % and 35 % respectively and cost improved as a profit of Rs.10 million per year. Moreover, it provides methods of measuring work for determining the performance index or productivity index for an individual or group of workers, a department or entire plant.

Index Terms
Time and motion study, Standard time, SIMO Chart, Principles of motion economy and Therbligs.

"1. INTRODUCTION"

In the today competitive environment, every organization struggle to maintain its market share and gain more of it by improving its production rate, reduction of production cost. To sustain the positive growth, it is necessary to ensure the proper utilization of resources financial development of any industry to a great extent

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relies upon minimizing abundance work and productivity enhancement. To minimize abundance work and enhancing productivity at first, we ought to understand the production term. Production is any process or

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methodology created to exchange an arrangement of contribution to a predefined set of yield in legitimate quality and amount, therefore accomplishing the targets of an industry.(Moktadir, Ahmed, et.al Fatema-Tuj-Zohra, 2017) For obtaining for better results after applying the time and motion study tool, that must be implemented in manual and semi manual work in the factory. so that's why the PAK match factory is the proposed research target, after detailed study of process it has been concluded that there is a very certain and a big chance of enhancing productivity of the system, mostly in four operations which follow this research upon time and motion study i-e method engineering. It is observed that there are a lot of unnecessary and unwanted activities. Using time and motion study techniques to eliminate all these problems will yield productivity. Like others organization match factory also wants to maintain its production. It's seems like local factory but they produce eight famous brands now a day's i-e shine, fine, fifa, Mashal, fighter etc., and produce daily five hundred cartons of match. All these distributed to country wide and also export to middle and Far East. In this project some the very famous and common techniques of time and motion study has being used i-e Therbligs Calculation and simultaneous motion (SIMO) chart to solve problems. These techniques have helped us to break the complex work into their respective elements for understanding the task better and understandable. Also, there are factors related to work place that also effects the productivity i-e lighting, standing work station, foot rest. As work place affect the working pace of the worker. To reduce the effect of poor workplace design some of the factor might be considered.

1.1. Goals of the Research

The primary objective of this project is to eliminate all the non-value-added activities and excessive motions. Doing so it will ultimately enhance the productivity of individual combining these will result overall efficiency enhancement,

- Elimination of non-value-added activities.
- Elimination of unnecessary motions.
- Developing of standard time and preferred method for a task

1.2. Problem statement

Time and motion study is the important side for production rate in production which leads the business. there are other factors that affect it like inventory, raw materials, tools etc. the time also influence production rate greatly, although the motion time is the factor that take care of very transaction of it. Pak match factory is a newly established factory, and faces different problems related to methods of performing tasks. The study has been conducted in four operations which involve both man and machine means manual work this project is ideal for such situation. There was no standard method and time for performing the tasks, also poor workplace design which contributes a lot to maintain pace of the worker. When there is no standard time the production going to be out of plan Therefore it was of great importance to establish standard time and method for those operations which leads to maximum profitable production.

1.3. Literature Review

The time and motion study are a vast field deals with determination of preferred method for work methods

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along with determination of o standard for human and machine to do a job in a proper method. To perform a project that is to analyse and interpret one need to have a complete command over each and every aspect of

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that particular area. According to Ralpha M. Barnes (R. M. R. M. Barnes, 1980) Frank and Lillian M. Gilbreth are known as the parents of motion study. Gilbreth begin investigation to find the "best way" of performing a given task trough analysing the motions used by his workmen and he easily saw how to make improvements. He also possessed for analysing work motion situations to enhance their ability for shorter or less fatiguing motions to improve the work environment. The research included the elimination of all useless motions and the reduction of those remaining motions. The elimination of this unwanted waste known as work simplification. (Bon & Ariffin, 2010)

According to Fred E. Mayers (Meyers, 1992) time study was developed by Frederick W. Taylor in about 1880 which he is the first person to use a stopwatch to study and measure work content with his purpose to define "a fair day's work." He called as Father of Time Study. Among his study is 'Taylor Shoveling Experiment' which he studied between 400 and 600 men that using his own shovel from home to moving material from mountains of coal, coke and iron ore in around two-mile-long yards. The Time and Motion study will examine the work process and eliminate non-productive process, which can reduce number of process, space utilization and production and operation time. Time is important in production industry because according Fred (1992) time is money and time tells us exactly how much money was used.(Bon & Ariffin, 2010) Work and time study techniques is raising the efficiency of utilization of the factors of production have been used for all manufacturing and service sectors as a scientific approach. In the content of study, a firm that produces tea glass is analysed in terms work/time during the process of model production. In order to measure efficiency of tea glass models, time survey is made and by the help of that method standardized time is calculated. Actual time and standardized time is compared and as a result it is aimed that measuring inevitable times and take necessary precautions against them. As a result of the study, waiting time cause inefficiency in the work of moulder and in the content of work/time, efficiency is increased 53 percent and model production capacity is reached at 237.(Duran, Cetindere, & Aksu, 2015) T&M is generally regarded as the most reliable approach for assessing the impact of health IT implementation on clinical work. However, there exist considerable inconsistencies in how previous T&M studies were conducted and/or how their results were reported, many of which do not seem necessary yet can have a significant impact on quality of research and general is ability of results. Therefore, we deem it is time to call for standards that can help improve the consistency of T&M research in health informatics. This study represents an initial attempt .(Kai Zheng, 2011) Work Study is management technique that agrees on standard time requisite to complete a task and ascertains the best methodology to bring about the task in the easiest and cheapest manner. As manual work abounds in the apparel industry of Bangladesh, work study may be the main methodology to stipulate a time period to finish each task. Work study likewise indicates the exact technique for doing the task. Along these lines, work study contemplate improves efficiency to the preferred level as a principal strategy obviously. More or less, this is a study of setting up standard time of an job (work measurement) and finding the best and the most straightforward method for playing out the assignment in a production floor of an apparel industry like Bangladesh since work study may be the main systematic method for looking at existing methods for completing an task in order to enhance profitability up to the mark and to set up standard time to maximize production efficiency. (Tanvir & Ahmed, 2013). Work study was widely known for years as "time and motion study", but with the development of the technique and its application to a very wide range of activities it was felt by many people that the older title was both too narrow and insufficiently descriptive. (Dr. M. P. Sing, June

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2016).

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1.4. Time study definition

According to Barnes

Time study is a work measurement technique for recording the time of performing a certain specific job or its elements carried out under specified conditions, and for analysing the data so as to obtain the time necessary for an operator to carry out at a defined rate of performance.(R. M. R. M. Barnes, 1980)

According to Meyers (2002), time standards can be defined as "the time required to produce a product at a work station with the following three conditions: (1) a qualified, well-trained operator, (2) working at a normal pace, and (3) doing a specific task." The three conditions are discussed below.(Nor Diana, 2008)

1.5. Motion and Time study and Productivity

There is a body of knowledge which has evolved over the years that is designed to increase the productivity of an organization and of individual who make up the organization.

Motion and time study has its objective of the elimination of unnecessary work, the design of methods and procedures which are most effective, which require the least effort, which are suited to the person uses them. Moreover, it provides methods of measuring work for determining the performance index or productivity index for an individual or group of workers, a department or entire plant.

"2. RESEARCH METHODOLOGY"

Sep wise method is important for enhancing productivity through time and motion and study to overcome and reduce the non-value-added activities from a certain working job. We are Try to make a helpful framework which can help to the ongoing research in proper way.

In this research we have to the select the job, which is in match factory. Then going towards manual sections, packing involving sections are manual or semi manual mostly. First, start from the observation of tray filling while taking the stop watch for noting and recording the data. After keen observation of all operations to identify existence problems while applying different techniques. After identification and solving problems we made a new method, the new method will give improvement after implementation in the factory.

2.1. Production Process

In The continuous match dipping machine, the splints are placed in holes in the bars, which are assembled to and endless chain. In this machine, the splints are par affined, dipped in a bath to get their heads and at last dried. At the end the matches

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are automatically pushed out from the bars and filled in the inner box in the filling machine. After closing, the boxes are conveyed further to a wrapping machine and other packing machines.

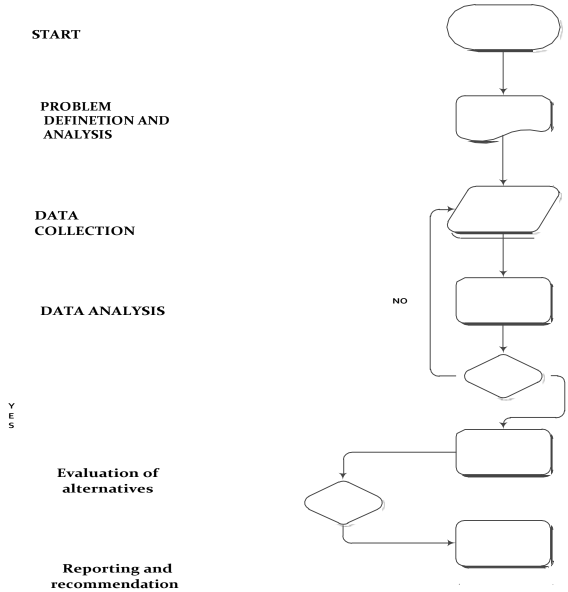

Fig.2.1. Step wise methodology

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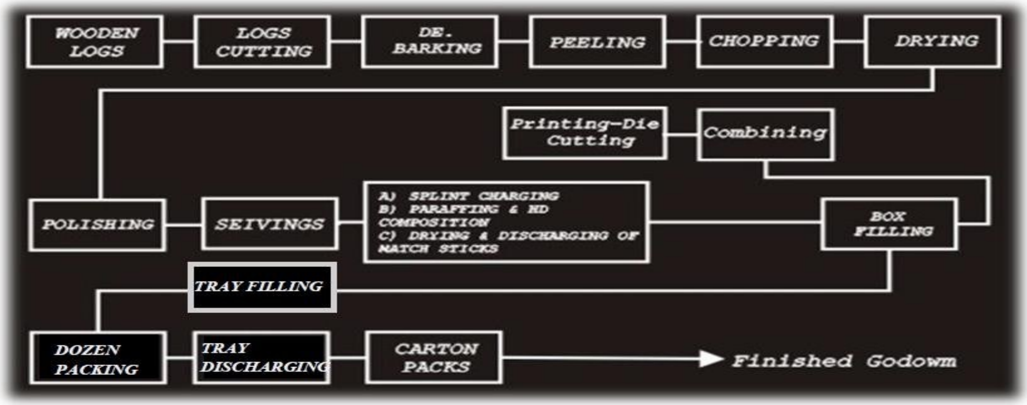

Fig.2.2 Production Process

2.2. Selecting the job

The first step in time study is selection of the job which is going to be studied. Generally, there are few situations when a work study expert can go into a working area or a department and select a job at random. There is nearly always a reason, why a particular job requires attention some possible reasons are:(R. M. R. M. Barnes, 1980; Kanawaty, 1992)

- The job in question is a particular operation appears to be a bottle neck holding up subsequent operations.
- Standard times are required before an incentive scheme is introduced.
- A piece of equipment appears to be idle for an excessive time or its output is low, and it therefore necessary to investigate the methods of its use.

"3. DATA COLLECTION AND ANALYSIS"

Data collection is going to determine data needed to develop a process. The collected data explains how the operations of process, how, where, and when each job is executed. Data collected as much as possible of 2 times a day for 6 weeks based on systematic observation. Stop watch has been used for the study. Data is included

- Data sheet for each process
- Information operations in detail for each process
- Analysis sheet for each operations process
- Fundamental hand motions for each operation process
- Improved analysis sheet for each operations process
- Simo chart and its Improved Simo chart for each process
- Production Normal time calculate standard time

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- Movement from one process to another process

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3.1. Steps in making a time study

When the work to be measured has been selected, the making of a time study usually consist of the following steps. (R. M. R. M. Barnes, 1980)

- Obtaining and recording all the information available about the job, the operative and the surrounding conditions, which is likely to affect the carrying out of the work.
- Recording a complete description of the method, breaking down the operation into "elements"
- Examining the detailed breakdown to ensure that the most effective method and motions are being used and determining the sample size.

3.2. Time study equipment

Certain items of equipment are essential if time studies are to be made. Basic time study equipment consists of:

- A stop watch
- A study board and
- Time study form

3.4. Number of observation

An operation having cycle time less than or equal to 2 minutes, we took N=10. (R. M. Barnes, 1968)Confidence interval 95% and ±5% precision is used in most of time and motion study

Formula of determining number of observation:

$$N' = (40 \text{ SQRT } (N \sum X^2 - (\sum X)^2) / \sum X)^2$$

A decision must be made as to confidence level and the desired accuracy that are to be used in determining the observation to make. A 95 percent confidence level and (+5, -5) % precision is commonly used in time study. This means that chances are at least 95 out of 100 that the sample mean or the average value for the element will be in error more than ± 5 %of the element time.

Estimating the number of observation to make

Take the readings as:

Ten good readings for a cycle of 2 minutes or less

For value of k: K=N/n (www.wikipedia.com)   where n=N'

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S.NO	Carton Packing	Tray filling	Tray Discharging	Dozen Packing
1	12.05	37.79	21.84	19.08
2	12.25	38.31	21.6	19.22
3	12.90	39.19	21.60	18.93
4	12.89	38.70	21.54	18.30
5	12.40	37.85	22.09	18.83
6	12.24	38.13	21.98	18.18
7	12.03	37.98	22.28	19.36
8	12.72	37.61	22.43	19.27
9	12.60	37.57	21.74	19.01
10	12.82	38.94	21.89	19.16

Table.3.1. k values for observations

S.NO	Carton Packing	Tray filling	Tray Discharging	Dozen Packing
1	12.85	37.92	21.62	19.28
2	12.70	38.42	21.43	19.11
3	12.65	39.25	21.57	18.28
4	12.04	38.54	21.85	18.95
5	12.51	38.96	22.07	19.20
6	12.13	37.87	21.95	18.17
7	12.47	38.19	22.25	18.81
8	12.28	37.92	22.42	19.07
9	12.79	37.49	21.73	18.53
10	12.63	37.45	21.91	19.35
11	12.97	37.95	22.36	18.93
Total	∑X = 138.02 Sec	∑X =420.55 Sec	∑X =241.16 Sec	∑X =207.68 Sec

Allowances

Personal 5%
Fatigue 4%
Others 0%

Worker Physical condition: **Good**
Physical fitness: **Good**
Eye sight : **Good**

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Table.3.2. Number of Observation

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3.5. Standard time

Standard time is derived by adding allowance to normal time. Allowance is frequently added, which will force the worker to stop the work, and do other things. (HARTANTI, 2016).

3.5.1. Standard Time Calculations

The Standard Time (ST) is a unit time value for completion of a work task as determined by the proper application of the appropriate work-measurement techniques (BNET, 2010). Standard time must include time for all elements in the operation, and in addition it must contain all necessary allowances. Standard time=Normal Time*100/100-Allowance Factor %. However, it is not expected that a person will work all day without any rest. For the purpose of this study the standard time was calculated for each repair process using the following formula: (Hassanali, 2011)
ST = Observed Time x (1 + PFD) X rating factor

3.6. Normal time

Observed time is not the actual time required to accomplish the work for operator. It is normalized using the performance rating factor. Performance rating is an evaluation method that considers the effectiveness operator doing work. Then it will be applied to obtain the normal time. The performance rating of the worker is important because it helps to quantify the worker during the operation.(HARTANTI, 2016) It is merely the time that a qualified operator would need to perform the job if he or she worked at a normal tempo. Rating factor included in normal time.

3.7. Rating factor

According to H.B the term rating describes the measurement of efficiency of an employee. The operators rating is quantification of his performance and calculated by comparing his speed of work with standard performance. The rating standard of an operator employee is decided by the work study man as directed by his supervisor. Various rating methods used are speed rating, synthetic rating and objective rating. It is next step after the execution of time study through monitoring and successive watch readings in measuring the time for each element, wherein, the central and most challenging part of time study is to evaluate the speed or tempo at which the employee is operating "The rating factor is defined as the process in which the analyst conducting time study, compared the performance (speed) of the operator observed with the observer's (analyst) own concept of normal performance".

3.8. Allowances for personal needs

This allowance provides for the necessity to leave the workplace to attend to personal needs such as washing, going to the lavatory or fetching a drink. Common figures applied by many enterprises range from 2 to 5 per cent.

3.8.1. Allowances for basic fatigue

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This allowance, always a constant, is given to take account of the energy expended while carrying out work and to alleviate monotony. A common figure is 4 per cent of basic time. This is considered to be adequate for

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a worker who carries out the job while seated, who is engaged on light work in good working conditions and who is called upon to make only normal use of hands, legs and senses

3.9 Simultaneous Motion chart (SIMO)

The time for each therbligs recorded on the analysis sheet may be shown by means of simultaneous motion cycle chart commonly called simultaneous motion chart. Either the analysis sheet or simultaneous motion chart may be made independently, or the simultaneous motion chart may be constructed from the data on the analysis sheet. When a full simultaneous motion chart showing every moving member of the body is made, it is customary to use a sheet of cross-section paper 22 inches wide with lines ruled 10 to the inch. For operation longer than half minute some analyst use paper with lines ruled 10 to the half inch, or paper ruled in millimetres in order to condense the chart. For many operations, however, it is not necessary to construct a complete chart of all the moving members of the body. The vertical scale shown in the centre of the chart represents time in 2000th of a minute. The therblig description, symbol, colour, and relative position in the cycle all appear on the chart. The time required for each motion is drawn to scale in the vertical column and coloured to represent the particular motion. The sheet is arranged much like the analysis sheet.

4.9.1 Fundamental Hand Motion

The term therbligs is more convenient to use than "hand motion" or motion element and perhaps carries a more precise meaning than motion although the word therblig is familiar to industrial engineer, the term motion or hand motion is preferred when discussing the subject of micro motion study with factory and office personnel. (R. M. Barnes, 1968)

The fundamental hand motions together with their letter symbol, mnemonic symbols, and colour designation, which is shown in fig .the definition of these are the following(FERGUSON, 2000)

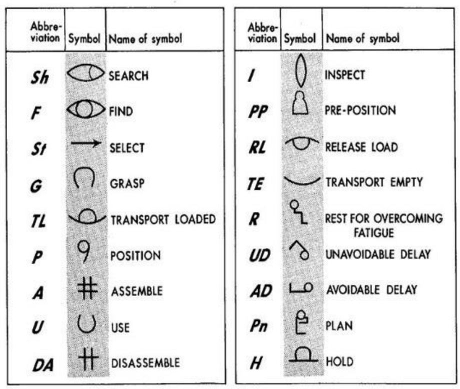

Fig.4.1. Therbligs (Crandall, 1963)

4.9.2. Analysis sheets for SIMO chart of different operations

The analysis sheets are important step while Calculating SIMO chart. For Analysis sheet first to make a frames from videos and then calculate the therbligs see fig 4.1. It is also explaining in 3.9 SIMO chart. The preceding's tables involve full details for SIMO chars which has been drawn for each operation of both right and left hand motion. The tables show standard time of old (existence) method, new method and its improvement in time of different therbligs in each operation.

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Carton Packing Operation

	Left Hand					Right Hand				
s. no	Activity	Activity Description	Old method	New method	Remarks	Activity	Activity Description	Old method	New method	Remarks
1	TL	Pick the carton	0.49	0.24	Improved	TL	Pick the carton	0.49	0.24	Improved
2	P	Position the carton for boxes	1.63	1.13	Improved	P	Position the carton for boxes	1.63	1.13	Improved
3	TE	Movement of hands toward s boxes	0.69	0.69	Nil	TE	Movement of hands toward s boxes	0.69	0.69	Nil
4	TL	Putting the boxes in the carton	0.94	0.84	Improved	TL	Putting the boxes in the carton	0.94	0.84	Improved
5	TE	Movement back for boxes	0.37	0.25	Improved	TE	Movement back for boxes	0.37	0.25	Improved
6	P	Position the boxes to put into			0.69	o.19	Im pr ov			Position the boxes to put into carton

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Improved

0.69 0.19

7	TL	Movement of boxes towards	0.94	0.94	Nil	TL	Movement of boxes towards	0.94	0.94	Nil

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		carton by hands					carton by hands			
8	A	Put the boxes into the carton	0.37	0.50	Improved	A	Put the boxes into the carton	0.55	0.50	Improved
9	A	Assemble and close the carton	0.75	0.56	Improved	A	Assemble and close the carton	0.56	0.56	Improved
10	AD	Twisting for the using of tap	0.48	0.57	Improved	AD	Twisting for the using of tap	1.95	0.57	Improved
11	U	Using of tap on the carton	2.96	2.21	Improved	U	Using of tap on the carton	2.96	2.21	Improved
12	RL	Releasing of carton	1.32	0.32	Improved	RL	Releasing of carton	1.32	0.32	Improved

Table.4.1. Analysis sheet of SIMO for carton Packing Section

Tray Filling Operation	
Left Hand	**Right Hand**

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s. no	Activity	Activity Description	Old method	New method	Remarks	Activity	Activity Description	Old method	New method	Remarks

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1	TL	Pick the tray to load the boxes	1.49	0.84	Improved	TL	Pick the tray to load the boxes	1.49	0.84	Improved
2	TE	Movement of hands and twisting from tray to boxes	0.71	0.39	Improved	TE	Movement of hands and twisting from tray to boxes	0.71	0.39	Improved
3	P	Position the boxes for tray while using left hand	3.96	1.36	Improved					
4	TL	Put the box dozen box in the tray by hands	1.88	1.30	Improved	TL	Put the box dozen box in the tray by hands	1.88	1.30	Improved
5	E	Movement of hands and twisting from tray to boxes	0.78	0.78	Nil	TE	Movement of hands and twisting from tray to boxes	0.78	0.78	Nil
6	P	Position the boxes for tray	5.85	4.41	Improved	P	Position the boxes for tray	5.85	4.41	Improved

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7	TL	Put the box dozen box in the tray by hands	1.56	0.98	Improved	TL	Put the box dozen box in the tray by hands	1.56	0.98	Improved

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8	TE	Movement of hands and twisting from tray to boxes	1.36	1.10	Improved	TE	Movement of hands and twisting from tray to boxes	1.36	1.10	Improved
9	P	Position the boxes for tray	6.82	4.61	Improved	P	Position the boxes for tray	6.82	4.61	Improved
10	TL	Put the box dozen in the tray By hands	1.38	0.78	Improved	TL	Put the box dozen in the tray By hands	1.38	0.78	Improved
11	TE	Movement of hands from tray to boxes	1.43	0.85	Improved	TE	Movement of hands from tray to boxes	1.43	0.85	Improved
12	P	Position the boxes for tray	7.34	4.68	Improved	P	Position the boxes for tray	7.34	4.68	Improved
13	TL	Put the 11-box dozen in the tray	2.86	2.21	Improved	TL	Put the 11-box dozen in the tray	2.86	2.21	Improved
14	AD	Wait for tray	4.74		Eliminated	AD	Wait for tray	4.74		Eliminated
15	TL	Movement for another tray	0.26		Eliminated	TL	Movement for another tray	0.26		Eliminated

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Table.4.2. Analysis sheet of SIMO for Tray Lifting Section

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Tray Discharging Operation

	Left Hand					Right Hand				
s. no	Activity	Activity Description	Old method	New method	Remarks	Activity	Activity Description	Old method	New method	Remarks
1	G	Select the tray and just grasp in both hands movement	0.72	0.34	Improved	G	Select the tray and just grasp in both hands movement	0.72	0.34	Improved
2	TL	Pick the dozen boxes from the tray and feed into wrapping m/c	1.87	0.29	Improved	TL	Pick the dozen boxes from the tray and feed into wrapping m/c	1.87	0.29	Improved
3	TE	Movement and twisting towards tray to pick boxes	0.57	0.38	Improve	TE	Movement and twisting towards tray to pick boxes	0.57	0.38	
4	TL	Pick the dozen boxes from the tray and feed into wrapping m/c	1.58	0.62	Improved	TL	Pick the dozen boxes from the tray and feed into wrapping m/c	1.58	0.62	Improved
5	TE	Movement and twisting	0.57	0.38	Nil	TE	Movement and twisting	0.57	0.38	Nil

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		towards tray to pick boxes					towards tray to pick boxes			
6	TL	Pick the dozen boxes from the tray and feed into wrapping m/c	0.76	0.38	Improved	TL	Pick the dozen boxes from the tray and feed into wrapping m/c	0.76	0.38	Improved
7	TE	Movement and twisting towards tray to pick boxes	1.15	1.07	Improved	TE	Movement and twisting towards tray to pick boxes	1.15	1.07	Improved
8	TL	Pick the dozen boxes from the tray and feed into wrapping m/c	0.57	0.33	Improved	TL	Pick the dozen boxes from the tray and feed into wrapping m/c	0.57	0.33	Improved
9	TE	Movement and twisting towards tray to pick boxes	0.81	0.33	Improved	TE	Movement and twisting towards tray to pick boxes	0.81	0.33	Improved
10		Pick the			Improve		Pick the			Improv

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TL	dozen boxes from the tray and feed into wrapping m/c	1.10	0.58	d	TL	dozen boxes from the tray and feed into wrapping m/c	1.10	0.58	ed

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11	AD	Wait for picking boxes	1.96	1.96	Improved	AD	Wait for picking boxes	1.96	1.96	Improved
12	TL	Pick the dozen boxes from the tray and feed into wrapping m/c	1.20	0.48	Improved	TL	Pick the dozen boxes from the tray and feed into wrapping m/c	1.20	0.48	Improved
13	TE	Movement and twisting towards tray	0.96	0.15	Improved	TE	Movement and twisting towards tray	0.96	0.15	Improved
14	TL	Pick the empty tray	0.96	0.48	Improved	TL	Pick the empty tray	0.96	0.48	Improved
15	RL	Release the tray	4.12	0.68	Improved	RL	Release the tray	4.12	0.68	Improved

Table.4.3. Analysis sheet of SIMO for Tray discharging Section

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Dozen Packing Operation

	Left Hand					**Right Hand**				
s. no	Activity	Activity Description	Old method	New method	Remarks	Activity	Activity Description	Old method	New method	Remarks
1	TL	Pick the boxes from tray and fed into machine	0.70		Eliminated	TL	Pick the boxes from tray and fed into machine	0.70		Eliminated
2	TE	Movement of hand from m/c back to tray	0.67		Eliminated	TE	Movement of hand from m/c back to tray	0.67		Eliminated
3	AD	Wait to pick the boxes	2.72	1.22	Improved	AD	Wait to pick the boxes	2.72	1.22	Improved
4	G	Grasp the boxes from tray for loading	0.38	0.38	Improved	G	Grasp the boxes from tray for loading	0.38	0.38	Improved
5	L	Pick the boxes from tray and fed into machine	0.83	o.57	Improved	TL	Pick the boxes from tray and fed into machine	0.83	o.57	Improved
6		Movement			Improve		Movement			Improv

TE	of hand from m/c	0.96	0.61	d	TE	of hand from m/c	0.96	0.61	ed

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		back to tray					back to tray			
7	TL	Pick the boxes from tray and fed into machine	1.05	0.73	Improved	TL	Pick the boxes from tray and fed into machine	1.05	0.73	Improved
8	TE	Movement of hand from m/c back to tray	0.86	0.58	Improved	TE	Movement of hand from m/c back to tray	0.86	0.58	Improved
9	TL	Pick the boxes from tray and fed into machine	0.32	0.20	Improved	TL	Pick the boxes from tray and fed into machine	0.32	0.20	Improved
10	TE	Movement of hand from m/c back to tray	0.83	0.48	Improved	TE	Movement of hand from m/c back to tray	0.83	0.48	Improved
11	TL	Pick the boxes from tray and fed into machine	1.05	0.70	Improved	TL	Pick the boxes from tray and fed into machine	1.05	0.70	Improved
12	TE	Movement of hand from m/c back to tray	1.67	1.45	Improved	TE	Movement of hand from m/c back to tray	1.67	1.45	Improved
13		Wait to			Improve		Wait to			Improv

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AD	pick the boxes	1.12	0.71	d	AD	pick the boxes	1.12	0.71	ed

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14	TL	Pick the boxes from tray and fed into machine	1.69	1.28	Improved	TL	Pick the boxes from tray and fed into machine	1.69	1.28	Improved
15	TE	Movement of hand from m/c back to tray	1.12	0.71	Improved	TE	Movement of hand from m/c back to tray	1.12	0.71	Improved
16	TL	Pick the boxes from tray and fed into machine	0.89	0.54	Improved	TL	Pick the boxes from tray and fed into machine	0.89	0.54	Improved
17	TE	Movement of hand from m/c back to tray	1.79	1.22	Improved	TE	Movement of hand from m/c back to tray	1.79	1.22	Improved
18	TL	Pick the boxes from tray and fed into machine	1.60	0.68	Improved	TL	Pick the boxes from tray and fed into machine	1.60	0.68	Improved
19	TE	Movement of hand from m/c back to tray	1.28	0.68	Improved	TE	Movement of hand from m/c back to tray	1.28	0.68	Improved
20		Disposing			Improve		Disposing			Improv

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DIS	the empty tray	1.08	0.60	d	DIS	the empty tray	1.08	0.60	ed

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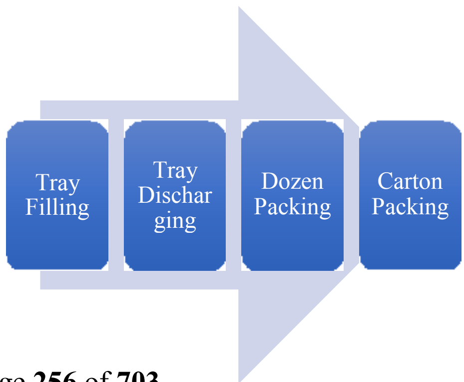
21	UD	Machine working so wait for another one	0.8	0.8	Nil	UD	Machine working so wait for another one	0.8	0.8	Nil

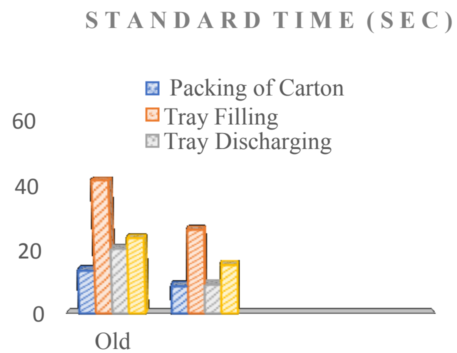
Table.4.4. Analysis sheet of SIMO for Dozen Packing Operation

"5. Results and Discussion"

In the following bar the productivity enhancement of each station is shown. The old (existing) and improved (suggested) method, their time old and new and percentage of improvement is shown against each other.

The first operation comes to perform is tray filling which involves, the picking of match boxes in different numbers into tray by worker, it's a totally manually operated section. This match boxes in tray moved for dozen making. Before enter to machine the match, boxes discharging from tray which is important manual operation. Here one worker for each machine available. after getting the dozen packed match box then again come to fill it in tray and then discharge packing of cotton section .in this a lot of improvement occurred expresses in tables. When a worker packs a carton, it will first confirm the dozen packed boxes which is comes from other section are available or not, packing required enough amount of previous storage that worker work smoothly.





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hod

New
Method

Fig.5.1. Operations

Fig.5.2. Standard of both method for each operation

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Then collect the data and after analysis with help of SIMO chart and other tools we get the time for old and new method which shows the difference b/w these method shows below in fig 5.2. And gives us percentage improvement.

The following are the total improvement from filling to packing by average, obtained after analysing the recorded observation data.

Standard Time comparisons

Operations	**Existence method(old)**	**New method**	**Improvement**
Packing Of carton	13.66	8.67	36.53%
Tray filling	41.67	26.47	36.47%
Tray discharging	20.57	9.21	55.22%
Dozen Packing	23.89	15.41	35.49%

Table.5.1. Standard Time comparisons

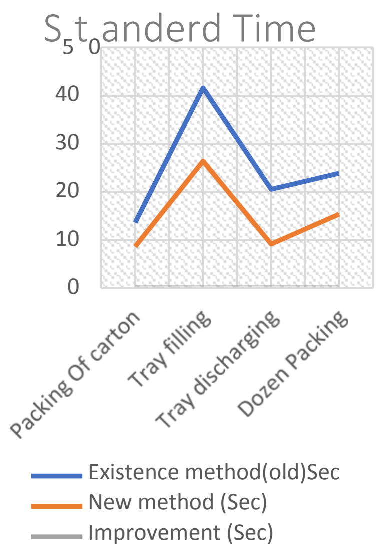

Fig.5.1. Standard Time comparisons

5.1. Suggestions and Recommendation

As illustrated in the previous chapters, enormous amount of improvements has been brought in the productivity by simply eliminating the wasteful activities, combining the operations or by eliminating the unnecessary time. Following are some very general suggestions that we recommend to the industry.

- Improve the methods or procedures adopted in performance of various jobs.
- Develop suitable working conditions
- The task must be oriented to achieve target i-e number of cartons packed per day, number of trays filled and disposed etc.…
- To implement the recommended standard method, the worker must be trained properly.
- Gravity roller conveyor

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- For releasing load by twisting and reaching beyond the maximum working area it takes a lot time. Instead of doing so it would be better to install a gravity roller conveyor to eliminate all these unnecessary motions.

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- The buffer of cotton
- It is found more convenient that the momentum of the body in the right direction could be easily controlled. Keep the materials which are frequently used, to the right of the body just in between the normal and maximum working area.
- Standing work station
- There must be a chair for sitting during starvation for relaxing of the worker. The chair must be designed ergonomically.
- Foot rest
- With the table there must be foot rest such that the worker can fit their feet alternatively, such that the fatigue caused by standing may be overcome.
- Specifications
- The footrest must be adjustable in height, angle and position. The angle must be from 8 - 10◦.

5.2. Conclusions

The above investigation demonstrates that there are numerous advantages to be acquired by actualizing productivity change exertion. The main reason for the usage of motion and time consider by respondent are increment productivity, work productivity, quality improvement, diminish operation time per part, contend in local market and satisfying business sector demand. The accomplishment of the of execution motion and time study had been contributed by several achievement factors, for example, top administration capability, interdepartmental participation, great planning and control framework, organization technique capability, experienced work powers, consistent budget inflow and clear product procedure. Tragically, the organizations executing motion and time study face various difficulties, for example, collaboration from specialists, trailed by inexperienced project team, inaccessibility of relevant expert, staff training and absence of inter departmental participation.

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PID CONTROL SYSTEM FOR AN UNMANNED AERIAL TRI-COPTER

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ABSTRACT

This study is directed to design and implement a PID controller for a T-shaped tri-rotor unmanned aerial vehicle. The design features are selected in order to find an optimized balance between stability and agility. In order to provide high scalability, T-shaped tri-rotor vehicle is selected. In this context, to stabilize and balance the tri-rotor vehicle the rotational speed of each of the motor is controlled independently by making use of the PID controller. The PID was tuned using a combination of Ziegler-Nichols and Trail and Error Method. Combining the trial and error with the Ziegler-Nichols Method greatly reduced the number of trials. The implementation of this research work is carried out by controlling the motors of a prototype T-shaped tri-copter using a microcontroller such as Arduino.

Index Terms— Unmanned aerial vehicle, PID Controller, Tri-copter, Direction Cosine Matrix (DCM) Filter, Control System, Inertial Measurement Unit (IMU)

1. INTRODUCTION

The recent trend and advancement in the field of unmanned vehicles had pushed the boundaries from ground vehicles to aerial vehicles. The Unmanned Aerial Vehicles (UAVs) has gained popularity due to its wide range of application in many fields (Ta et al., 2012). These application ranges from military purposes to the use of drones for first aid in highly crowded areas. The UAVs are also very helpful in difficult terrains, small indoor places, disaster sites, and for firefighting, where manual labor cannot reach and work properly (Papachristos and Tzes, 2012). In order to facilitate work in such difficult situations, Unmanned Aerial Vehicles (UAVs) have been regarded as the best solution as compared to their counterpart Unmanned Ground Vehicles (UGVs) due to their fast response and rapid maneuverability. The different designs of these UAVs have been designed keeping in view the specific set of requirements by the users. However, there are some general set of requirements that UAVs should possess are the following:

- Firstly, the UAVs must be small enough in size so that it can accommodate its free motion under challenging circumstances.
- Secondly, the most important feature, which gives an edge to UAVs over UGVs is its rapid motion in every possible direction for evasive manoeuvres.
- Thirdly, Cost-benefit ratio must be maintained during the development of UAV.
- And finally, the most important and basic requirement is the Vertical take-off and landing.

To satisfy all the above requirements, a multi-rotor thrust UAV is considered to be the best solution. However, these UAVs have its own set of problems, the most important of them is to design an efficient and robust control system for them that can maintain the vehicle stability under all circumstances. Aiming for more efficiency in term of size, autonomy and maneuverability, various conventional and non-conventional structure designs, configurations and control techniques for UAV systems have been adopted. Each approach provides its own strengths and weaknesses; hence it is essential that the design choice should be made keeping the concerned application in mind.

This research paper aims to discuss two important aspects of the design process of the UAVs. The first is the mechanical design of the T-shape tri-copter and different design constraints considered during the process. And second aspect is the design of an autonomous control system with help of PID for the UAV that enables it to keep itself balanced and stable under undesirable conditions.

The rest of the paper is structured as follows. Section 2, presents the structural design of the UAV. Section 3, discusses different operational modes of the UAV specific to this research work. Section 4 gives a detail description of different

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equipment's and components used in the design process. Section 5 describes the use of Direction Cosine Matrix (DCM) Filter used for filtering the sensors data. Section 6 illustrates the implementation of control system in terms of PID control and

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presents the results obtained from the implementation and different tests performed. And finally, Section 7 concludes the work done in this research article and presents the future prospects in the respective field.

2. STRUCTURAL DESIGN

To fulfill one of the major requirement of efficiency of these UAVs, as discussed in previous section this research article focus is study on Tri-rotors. These Tri-rotors are considered to be more cost efficient, small in size, flight time, and in terms of power consumption due to less motors as compared to the traditional quad-rotors (Salazar-Cruz and Lozano, 2005). However, this efficiency comes at a huge cost of control and stability. There is a tradeoff between the power consumption and the stability of the vehicle. Furthermore, these tri-rotors vehicles are divided in to two different arrangements. One being the Y shaped vehicles in which all three motors are placed at 120 degrees from each other at same distance from the center (Mohamed and Lanzon, 2012). The other is the T-shape configuration which gives more flexibility and great agility. The length of the arms of different motors are in certain proportion which is shown in figure 1. The three force generating units of each motor are identical and consists of a fixed pitch propeller driven by a Brushless DC (BLDC) motor to generate thrust. The propeller motor assembly is attached to the body arm via a servo motor that can rotate in a vertical plane to tilt the propeller-motor assembly in order to produce a horizontal component of the generated force. All three propellers can be tilted independently to give full authority of thrust vectoring. This configuration enables the vehicle body to stay aligned in the required direction regardless of the movement it makes. To encounter the most common yawing moment problem associated with these tri-rotor UAVs different designs and solutions has been presented. This yawing moment is induced by the reaction torque from the unpaired rotor.

2.1. Single Rotor

A single tri-rotor consist of three rotors in which the tail rotor as shown in figure 2 is slightly tilted so that to vanish the effect of the reaction torque (Yoo et al., 2010). A single tri-rotor enables the generation of rapid motion from its tilt rotor. Yaw control is achieved using the tilt angle of the third motor in the rear along with non-stable torque. However, tilting the motor would decrease the thrust of the motor. Furthermore, inaccurate compensatory increase in thrust can change the

2.2. Co-Axial Tri-Rotor

A coaxial tri-rotor UAV in comparison to the single rotor has two rotors installed on each axis of rotation. These rotors not only nullify the yaw moment of each other but also counters the effect of reaction torque on the entire system. Yawing control is achieved using the tilt angle of the third motor in the rear through a servo motor. As a result, better stability is achieved; however, more power is required in order to operate six rotors.

2.3. Fixed Wings

Fixed winged UAVs fly like an aircraft. They have propellers placed horizontally for forward flight. The lift is provided by the wings and the yaw is provided by the ailerons. The pitch and roll of the flight is controlled by different motion of flaps on the wings. Mimicking flight of an aircraft they can manage fast speeds, but it comes with inherent cost of limited maneuverability. For our application we combine the Single Axis Tri rotor with the Fixed Wings to achieve fast speed and vertical takeoff simultaneously. Fig 1 provides the calculation for the T-copter's frame design that was taken into consideration. Based on the individual part's weight and size, the Motor –to- Motor (M2M) distance was suited to be 32 inches and the corresponding front arm to the Rear Motor (RM) was set to be 27.7 inches. The Centre of Gravity (CG at 9.24 in) and Motor to CG (M2CG at 18.48in) was obtained with the expressions shown in the figure. The appropriate lengths are essential towards the final stability of the Tri-copter. The physical model of the Tri-copter is shown in Figure 2.

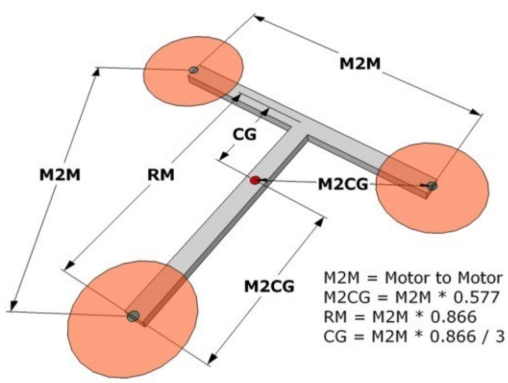

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Figure 1: Frame design implemented for Tri-Copter

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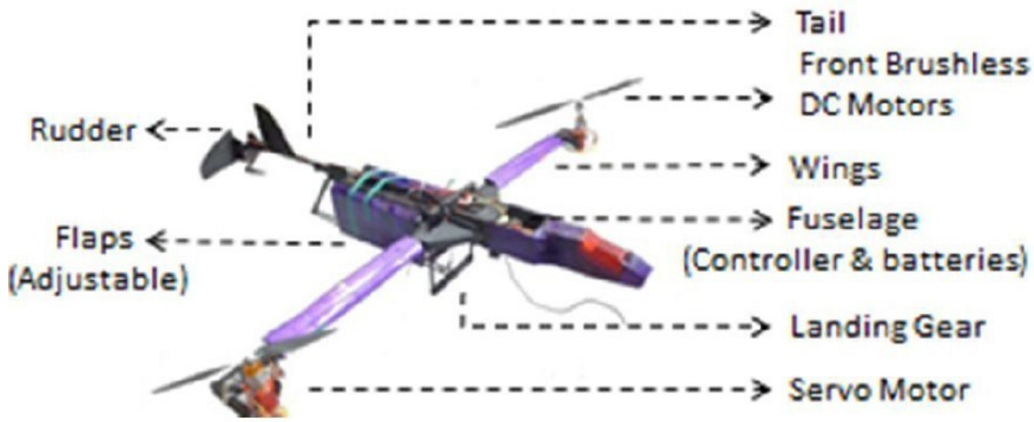

Figure 2: Final implemented design of the Tri-copter.

3. OPERATIONAL MODES

This section of the paper explains the different modes in which the Tri-copter can operate. There are two basic modes of operation for this UAV i.e., multi rotor mode and airplane mode below is the detailed explanation of each one of them.

3.1 Multi-rotor Mode

In this mode front motors tilt vertically upwards.

1. *Thrust:* The thrust is produced by the front motors by providing equal force to them. When both the motors are moving at the same speed an upward lift is created.
2. *Roll:* The same front motors are used for roll mechanism, but the forces are applied differentially to them. So that the torques created do not cancel each other and the net force creates the roll effect.
3. *Pitch:* This is controlled by changing the speed of rear motor. When speed is increased, reaction force is in upward direction which moves the tail up and the whole UAV is pitched downwards. Similarly decreasing the speed of rear motor will result in net upwards pitch of the UAV.
4. *Yaw:* Angles of front motors are changed to produce the yaw mechanism. The angles are altered using servo motors. Initially when the motors are in vertical position they do not have any vertical component of force, when the angles of these motors are changed differentially a vertical component is also introduced which provides for yaw mechanism.

3.2 Airplane Mode

We tilt the front motors forward. The wings come into play as it provides extra lift with increasing speed.

1. *Lift:* The lift is provided by the flaps in the wings of this UAV. Flaps are control surfaces attached at the wings of the airplane. In this UAV the wings are acting as the flaps and their movement is controlled by the servo motors. When they are moved downwards the direction of reaction force is upwards so it produces a lift on the UAV. Both the flaps are always moved simultaneously. They are used to increase the lift at low speed.
2. *Roll: The* roll mechanism in the airplane mode is controlled by the ailerons which are control surfaces attached at the end of the wings of this UAV. The force is applied differentially to both the ailerons. They always move in pair and produce a couple. They are not attached near the main body of the UAV because then they will be near the centre of gravity and moment arm will be quite less, so a very large force will be required to produce the same amount of torque than when it is attached at the end.
3. *Pitch:* Pitch in aerial vehicles is described as the rotation around the side to side axis of the vehicle. The pitch balance of aircrafts is usually controlled by elevators, which are flight control surfaces that are commonly installed at the rear end of an aircraft. The different orientation of the elevators changes the lift of the vehicle's wings and specifically tail. These elevators move up and down in a pair simultaneously, just like flaps.
4. *Yaw:* Yaw on the airplane is defined the rotation around the vertical axis of the vehicle. Rudders on an aircraft are responsible for controlling the yaw. Usually rudder is a flat plane or sheet of material attached to the vehicles tail that move from one side to the other to minimize aerodynamic drag. In this UAV the yaw mechanism is controlled using the front motors attached at the end of both wings, and not by a usual rudder. By controlling the speed of front motors the yaw movement will be provided. The speeds of the motors are changed differentially.

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4. COMPONENTS

4.1 Model Propeller Parameter

The propellers which were used in the prototype are the EPP-1045 model with a diameter of 25.1 cm. For the mathematical model used, the main propeller parameter is the thrust coefficient (C_T) that relates the thrust with the rotation speed and the propeller's diameter. This coefficient is described by equation (1) obtained in [10].

$$C_T = \frac{T}{\rho \,.\, n^2 \,.\, D^4} \tag{1}$$

Where T [N] is the thrust, the density of air is represented with ρ [kg m -3], n [s-1] revolutions per second, and D [m] is the diameter of the propeller. To calculate this coefficient, the propeller's thrust is measured for many different rotational speeds by trials. There is minimum thrust that each rotor must sustain in for the flight. The total mass of the UAV in this research work was 2 Kgs (19.6 N), which implies that each of the three motor engines must support a thrust of at least 667 grams (6.53 N) to support the weight of the aircraft. Thus, the rotational speed measured at this point was 1450 s-1 and C_T coefficient calculated was of 0.0098.

4.2 Model ESC-Motor-Propeller

Brush-less electric motors (Turnigy) were used in the prototype due to its higher energy efficiency and durability compared to other brushed motors (Sanca et al., 2008). However, there is a tradeoff with the level of complexity of its control system as compared to brushed motors. These BLDC comes with a specific device, an electronic module dedicated to control of these motors, called ESC (Electronic Speed Controller). This device controls the flow of current to the motors, it provides a sequence of current pulses to the motor windings to produce a rotating field. By varying the duty cycle of the PWM signal to the ESC input the rotational speed and electrical power provided to the motors can be changed. Most of the ESCs modules have a commercial 8-bit microprocessor (ATMEGA8), which performs functions of speed control of the motors and also some special functions, such as the process of braking and acceleration curve. The resolution of the PWM modulator which performs the control of the rotation speed is around 7 bits (0.8%), with update rate of 50 Hz. This is the reason our microcontroller (Arduino) is sampling at 50Hz.

The combination of motor-ESC-Propeller gives us a simple system which can be substituted for a virtual Black Box with the input being pulse from the microcontroller and the output being the motor speed and thus the position. The overall system of the Tri-copter has been broken down into subsystems for easier analysis as shown in Figure 3. The system is divided into devices namely device1, device2, and device 3 being motor 1, motor2 and motor3 respectively. We treat each device as an individual system. Initially, segregated PID control for each subsystem is developed followed by joining of device 1 and device 2 to form a new subsystem (device 4). The PID control for this new system is developed and appropriately tuned. Finally, the same process is followed to obtain device 5, comprising of all the motors. This step by step process facilitates continuous tuning of the PID during experimentation phase.

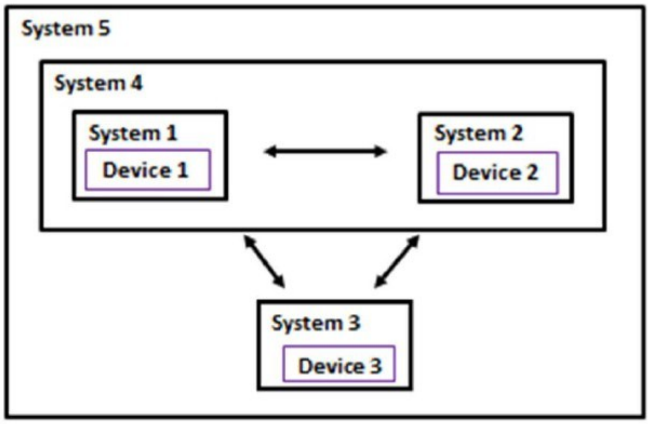

Figure 3: System divided into subsystems

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4.3 SENSORS

The sensor which is used in this UAV is a 10 DOF (Degree of Freedom) inertial measurement Unit (IMU). The IMU consist of a set of accelerometers, gyros and barometers. The data obtained from these three sensors is fused and filtered together to obtain the position of the UAVs. The IMU enable us in deriving the position as well pitch, yaw and roll of the vehicle, which allow better performance for dynamic orientation calculation (Zhang et al., 2005). The final reading of IMU is a weighted sum of the readings of these three sensors plus a barometer is also in place to determine the height thus giving it a 10 DOF (Degree of Freedom) measurement. 50 readings per second are taken from the IMU used in this UAV. The final equation which it implements is:

$$\text{IMU} = \text{Gyroscope} + \text{Accelerometer} + \text{Magnetomter}$$

In this UAV magnetometer readings are taken just for the sake of accuracy of the roll and pitch readings the yaw readings are redundant to us because our yaw mechanism is controlled manually and PID algorithm is not implemented on it.

i. Gyroscope

A gyroscope is a device for measuring or maintaining orientation, based on the principles of angular momentum. Equation (2) shows the fundamental equation describing the behavior of the gyroscope.

$$\tau = \frac{\partial L}{\partial t} = \frac{\partial (Iw)}{\partial t} = I\alpha \qquad (2)$$

where τ and L are, respectively, the torque on the gyroscope and its angular momentum, the scalar I is its moment of inertia, the vector ω is its angular velocity, and the vector α is its angular acceleration.

ii. Accelerometer

The accelerometer gives the rotational acceleration of the sensing object, form which the position is calculated. Hence, the angular acceleration changes very abruptly even with little change so its values are fused and filtered along with that of gyro to obtain better results (Kang and Su, 2008). It is also capable of detecting rotation and motion gestures such as swinging or shaking. Accelerometer is reliable under static conditions and as well in long term as it does not involve any integral terms to accumulate the error.

In dynamic conditions the gyroscope readings are very reliable, so their weight is increased in the final equation. In static conditions error is accumulated in its readings so its weight is minimized in the final equation. The specification of the elements used for the Tri-copter has also been tabulated (Table I).

Table 1: COMPILES THE GENERAL SPECIFICATIONS OF THE EQUIPMENT USED

Sensors		**Motors**	
IMU	10 DOF	Brushless DC Motors	Front 900W Rear 300W
Rate	50Hz	ESC	10A max
3 axis compasses	LSM303	**Batteries**	
3 axis accelerometers	LSM303	Current	6.6 AH
3 axis MEMS gyroscope	L3GD20H	Voltage	11.2 V
On-boards Controller		**RC controller**	
Arduino Mega 2560 Microcontroller		Transmitter & Receiver	4 Channels

5. DIRECTION COSINE MATRIX (DCM) FILTER

Direction Cosine Matrix filter is used to obtain the orientation of the tri-copter. Since, accelerometer and gyroscope provide data in axes and rotation per second respectively and in a sudden jerk, these drifts unstably, DCM filter is used to get stable data from IMU (inertial measurement unit). The filter operates in the following fashion:

1. The gyros are used as the primary source of orientation information. We integrate the nonlinear differential kinematic equation that relates the time rate of change in the orientation of the aircraft to its rotation rate, and its present orientation.
2. Recognizing that numerical errors in the integration will gradually violate the orthogonally constraints that the DCM must

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satisfy, we make regular, small adjustments to the elements of the matrix to satisfy the constraints.

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3. Recognizing that numerical errors, gyro drift, and gyro offset will gradually accumulate errors in the DCM elements, we use reference vectors to detect the errors, and a proportional plus integral (PI) negative feedback controller between the detected errors and the gyro inputs used in step 1, to dissipate the errors faster than they can build up. Magnetometer is used to detect yaw error, accelerometers are used to detect pitch and roll. The process is shown schematically in Figure 4.

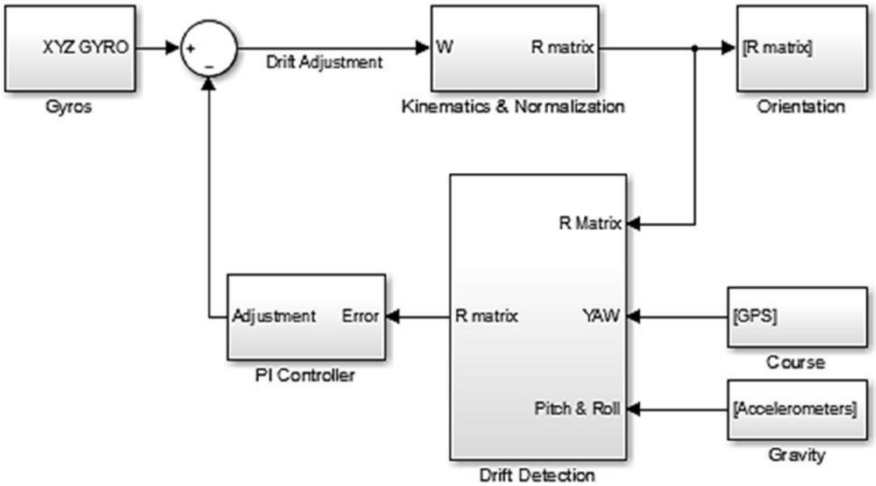

Figure 4: Process flow of DCM filtering

6. CONTROL SYSTEM

The second most important aspect of this research work is to model a control system for the UAV that ensures the stability of the system as well robust enough to counter the changes in almost real time. The stability factor of the UAV are achieved somewhat by the structural design and somewhat by designing an efficient control system so that to ensure safe and stable flight at higher altitudes under different conditions and circumstances.

PID (Proportional Integral Derivative) control is one solution to stabilize a system and achieve desired results. The PID control is widely used due to its feedback system, better results, and most importantly the ease of implementation gives it an edge over other solutions (Li and Li, 2011).

6.1 PID Control

PID (proportional-integral-derivative) is closed-loop control system that tries to get the actual result closer to the desired result by adjusting the gain of the controller. Tri-copters or multi-copters use PID controller to achieve stability.

There are 3 parts of a PID controller they are P, I, and D respectively. P depends on the present error, I on the accumulation of past errors, and D is a prediction of future errors, based on current rate of change (Azfar and Hazry, 2011). To have any kind of control over the tri-copter or multi-copter, we need to be able to measure the tri-copter sensor output (for the pitch, roll and yaw angle), so we can estimate the error (how far we are from the desired reference angle usually 0). We can then apply the PID gains to the error in order to make it the output as close to the reference input as possible.

The structure of the controller implemented in the project maybe seen in Figure 5, where y(k) represents the current state of the system sampled by the sensors, u(k) the control signal sent to actuators, that are motors, k is the current discrete time and KP, KI and KD are the gains respectively proportional, integral and derivative.

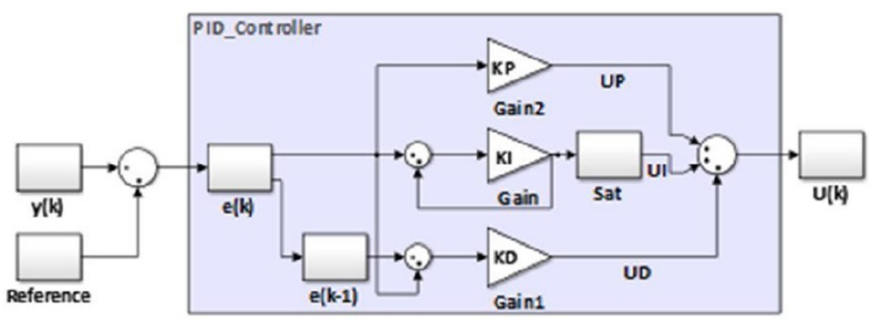

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Figure 5: Per Axis PID structure

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The variation of each of these parameters alters the effectiveness of the stabilization. Generally, there are 3 PID loops with their own P I D coefficients, one per axis, so you will have to set P, I and D values for each axis (pitch, roll and yaw). To a tri-copter, these parameters can cause different behaviors.

6.2 Proportional Gain coefficient (Kp*)*

This coefficient controls the rise time of the response. This is the most important coefficient and usually the tuning process is started with this coefficient to implement the PID.

6.3 Integral Gain coefficient (Ki)

This coefficient is used to control the steady state error in the response this coefficient is rarely used in modern multicopter autopilots. This coefficient if implemented is usually the last one in tuning process of PID.

6.4 Differential Gain coefficient (Kd*)*

This coefficient controls the percentage overshoot and thus acts as a sluggish factor to the Proportional Gain Coefficient above. It also predicts the future and determines how fast or how slow a change is occurring and acts accordingly. The important point is for the appropriate parameters to be calculated and all parameters are in relation each other shown in (3) and (4).

$$K_i = \frac{K_p}{Ti} \tag{3}$$

$$K_{d=} K_p . T_i \tag{4}$$

T_i parameter shown in Eq. 3 refers to reset time and Td parameter shown in (4) refers to how many times K_p multiplied in the minutes that is response speed of the system. Figure 6 shows a much-generalized concept of PID controller operating in a feedback loop. In this sense, mathematical definition of the PID controller is given as follows:

$$PID = K_p . \frac{K_i}{s} . K_d S \tag{5}$$

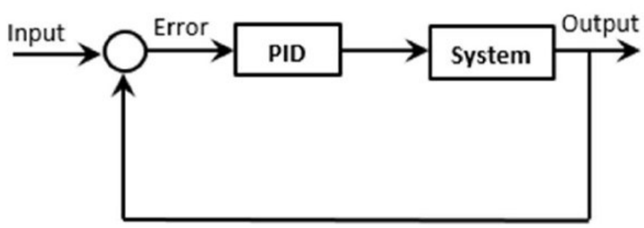

Figure 6: Applying the PID controller to the system

The PID controller is usually a combination of PD and PI controllers. It can be used to improve the steady state error and the system transient response. It is popular for industrial application. In this study, PID controller will be used. The parameters of PID controller are initially found using Ziegler Nichols closed loop method and the subsequently fine-tuned for appropriate response.

6.5 Implementation of the PID

The PID was implemented first on each single motor then on by combining the front two motors to control the roll and then by combining the results from the roll with the results from the pitch in order to achieve a complete PID controlled Tri-copter. Once we know the values of the coefficients for one motor we can use the same method and find the values for others as well. In the case of roll, once we have different value of the roll for each motor we combine the values using the following method.

1. We take the lowest values of the coefficients and then divide it equally between the two motors.

$$0.5\ (CorrectionFactor1) + 0.5\ (CorrectionFactor2) \tag{A}$$

Where CorrectionFactor1 is the PID value for motor 1 and CorrectionFactor2 are the PID values for motor 2.

2. Then we change the values of the coefficients until we reach an optimum point between the two motors.

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The motors usually have a different step sizes from each other. This means that if one motor increases by a factor of one then the other will increase by a factor greater or smaller that one. The real reason for this is the fact that each motor starts at different speeds and since the ultimate speed of each motor is 180 (using the servo command in Arduino) each motor uses a different step size to reach the ultimate point. Due to this reason, equation (A) can become marginally valid. Hence, we are then required to modify the equation by finding the weightage of each motor speed

I. The speed difference of motor 1 is noted from the final speed (in this case 180-65).
II. Then the speed difference of motor 2 is noted from the final speed (in this case 180-82).
III. The values obtained in step 1 are divided by the values obtained in step 2 as following.
180-65=115, 180-82=98, 115/98=1.17
IV. We then multiply 1.17 by 0.5 to get 0.58. This is the real weightage of motor 1 so equation (A) can be rewritten as

$$0.58\ (CorrectionFactor1) + 0.42\ (CorrectionFactor) \quad \text{(B)}$$

Now that we have the values of roll and we have to combine the values obtained from the roll with the PID values of the back motor so that we can get the correction factor of the pitch. We use the same method as in case of roll so the final PID of the system would look like.

$$\frac{0.58\ (CorrectionFactor1) + 0.48\ (CorrectionFactor2)}{2} + \frac{CorrectionFactor3}{2} \quad \text{(C)}$$

Where CorrectionFactor3 is the correction factor of the back motor. Now since we have the same problem of different step sizes, so we use the same method of finding the weightages.

$$0.58\ (CorrectionFactor1) + 0.48\ (CorrectionFactor) \times 0.4 + 0.6\ (CorrectionFactor) \quad \text{(D)}$$

$$0.24\ (CorrectionFactor1) + 0.19\ (CorrectionFactor2) + 0.58\ (CorrectionFactor3 \quad \text{(E)}$$

Table 2: INDIVIDUAL MOTOR VALUES (PID)

Individual Motor Values		
Motor 1	**Motor 2**	**Motor 3**
$K_P = 0.02$, $K_D = 2$	$K_P = 0.02$, $K_D = 3$	$K_P = 0.03$, $K_D = 3$

Table 3: ROLL COMBINED VALUES (PID)

Roll Combined Values		
Motor 1	**Motor 2**	**Motor 3**
$K_P = 0.02$, $K_D = 3$	$K_P = 0.02$, $K_D = 3$	$K_P = 0.03$, $K_D = 3$

Table 4: Final Combined Values (PID)

Final Combined Values		
Motor 1	**Motor 2**	**Motor 3**
$K_P = 0.02$, $K_D = 3$	$K_P = 0.02$, $K_D = 3$	$K_P = 0.04$, $K_D = 3$

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7. CONCLUSION

In conclusion, this research article discusses first the structural design and different factor associated with the UAVs and specifically tri-rotors. Next it describes the control system designed with the PID controller and different tuning strategies used specific to the problem discussed. The Stabilization test for each parameter of the PID was conducted individually. While controlling one parameter the other two were fixed and impulse disturbances were applied, the UAV would stabilize itself using the PID technique. Then further fine tuning was performed by changing the gains of PID and complete stabilization was achieved. The solution can further be enhanced by using a more sophisticated and fine rather complex filtering technique such as Kalman's filter instead of the DCM filter for accelerometer and gyroscope data.

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MULTI ECHELON LOCATION ANALYSIS FOR EMERGENCY RESPONSE SERVICE WITH INPESHAWAR

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ABSTRACT:

This research paper is about the multi echelon location analysis for emergency response service (EDHI) with in Peshawar. The focus is on providing the emergency service as soon as possible i.e reducing the time required to provide the service. Greedy method is used to find the optimal route [22] for ambulances. On the basis of the analysis of the last 1000 trips data it is concluded that which location (facility) is the best to provide service to a particular case in a specific location. The purpose is to reduce time/distance by selecting optimal route for the ambulance. The Greedy method is implemented and as a result of this the time taken by ambulance is reduced by 34.22% i-e the ambulance is only taking 65.78% of the time it was taking earlier. This reduction in time is due to the decrease in the distance. The distance is reduced from 26.6km to 17.5km in the example discussed.

INTRODUCTION:

Emergency response services have a great importance anywhere in the world. Especially in the city like Peshawar emergency services has great importance due to large number of accidents and terrorist attacks. The emergency response services are doing well but due to lack of planning, managing and proper routing many people are losing their precious lives. As there is not enough work done in routing of EDHI ambulance service by previous researchers. Therefore there is a great area for improvement in this area.

The main purpose of this paper is to solve the routing problems which EDHI ambulance series is facing, which in turn will help to see which facility should serve any particular demand and which routes does it uses so that the service could be provided as soon as possible. Therefore, the main focus is to reduce the time of service through improved routing.

The routing problem in Emergency response service has a great room of improvement in the routing of their ambulances as there is no proper way to assign a particular case to a specific facility which use a predefined route not considering whether it is optimized route or not. Therefore, by observing the past data and applying different routing techniques, noticeable improvements can be made.

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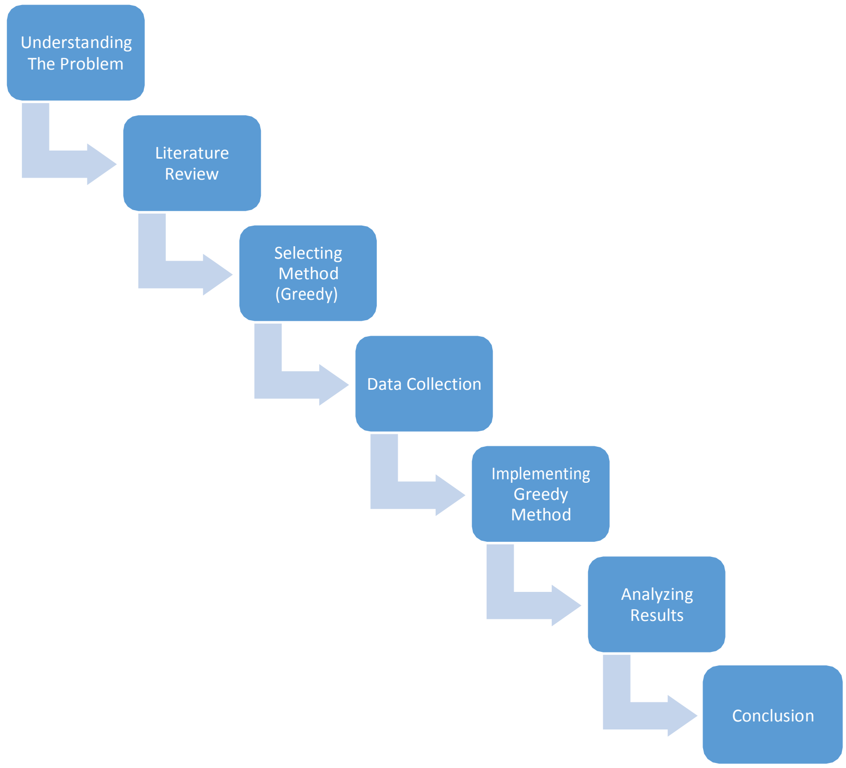
LITERATURE REVIEW:

As this problem is multi Echelon location problem. All over the world different researchers are using different approaches to solve these kind of problem [15]. Most of the researchers are working on Greedy Method and Dynamic Vogel Approximation Method. Both methods has their pros and cons. But for the sake of this problem Greedy Method is a better choice as it is used to make locally optimum choice in the hope of achieving globally optimum solution. In this case the ambulance have different possible routes. So Greedy Method can be used to find the optimum route.

METHODOLOGY:

The following figure explains the steps which are used to solve this problem.

Figure 1- Methodology.



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Greedy Algorithm:

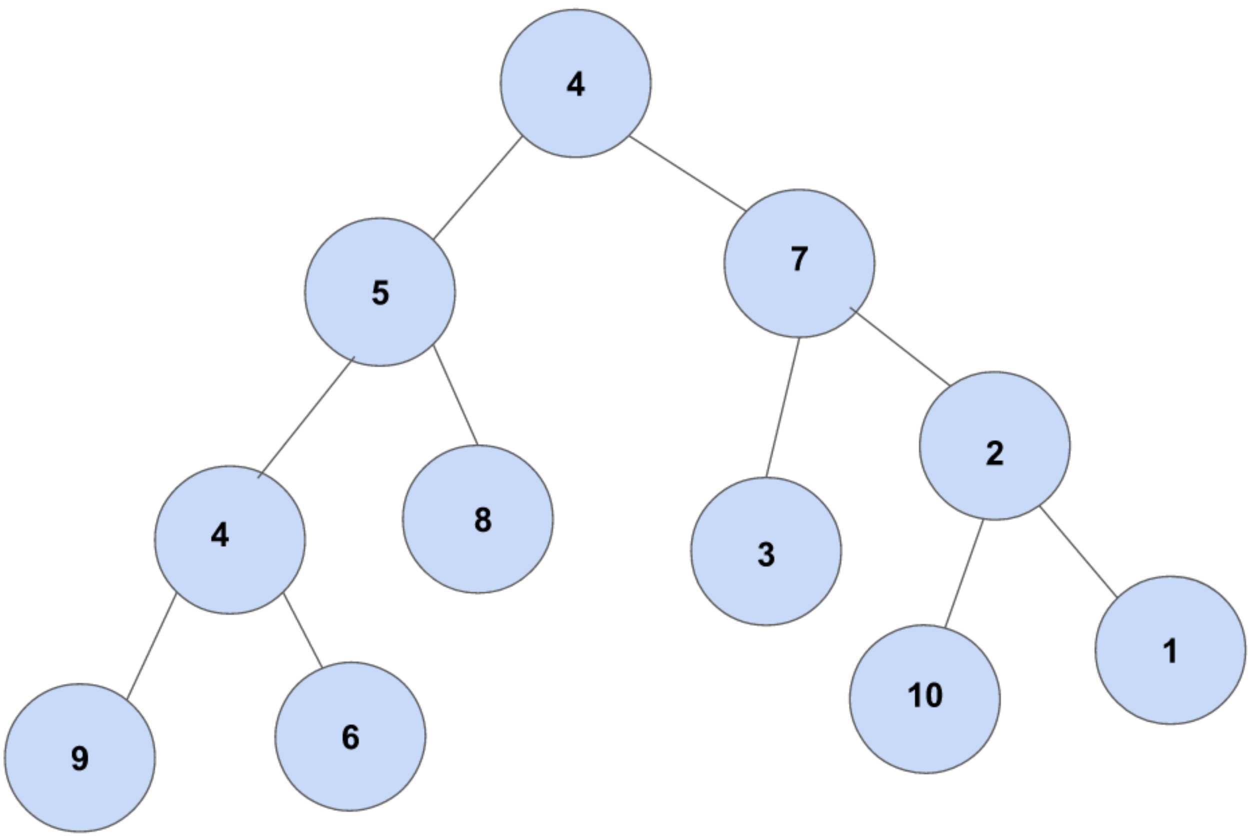
The method used will be Greedy method. Greedy method/algorithm is an algorithm paradigm that fallows the problem solving heuristic of making the locally optimal choice at each stage, with the hope of finding the global optimal. Greedy method gives the locally optimal solution but it may or may not give globally optimal solution.

Greedy method have following five components.

- Candidate set.
- Selection Function.
- Feasibility Function.
- Objective Function.
- Solution Function.

Greedy method obtain optimum solution by making sequence of choices. Decisions are made one by one in some order. Each decision is made by Greedy choice property or Greedy criterion. A decision once made is usually not changed.

Figure 2- Greedy-Routes.



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Data Collected:

For analysis the latest data of 1000 trips were collected. The data was about which facility was used to serve any particular case and from which center ambulance moves and to which location.

For Example, from EDHI main center an ambulance goes to site of accident and after picking the patient it moves to the hospital. As it forms two levels. Therefore, it is a multi-Echelon Location problem.

Table 1- EDHI Center Data (5 Cases From Each Center).

CENTER	FROM	AREA	TO	AREA
EDHI MAIN MARKAZ	CMH	AREA3	FAUJI FOUNDATION	AREA3
EDHI MAIN MARKAZ	LRH	AREA1	TARNAB FARM	AREA1
EDHI MAIN MARKAZ	LRH	AREA1	HAYATABAD	AREA3
EDHI MAIN MARKAZ	EDHI MARKAZ	AREA1	WORKSHOP	AREA3
EDHI MAIN MARKAZ	LRH	AERA1	UMAR PAYAN	AREA4
P-4 TOWN	PESHAWAR UNI	AREA4	DABGARI	AREA4
P-4 TOWN	WARSAK RD	AREA2	LRH	AREA2
P-4 TOWN	HAYATBAD F3	AREA2	KTH	AREA2
P-4 TOWN	TOWN	AREA2	RMI	AREA2
P-4 TOWN	TOWN	AREA2	KTH	AREA2
SWATI PHATAK	LRH	AREA1	TARUJABBA	AREA1
SWATI PHATAK	DABGARI	AREA1	KHURSHAN	AREA1
SWATI PHATAK	LRH	AREA1	WARSAK GARI	AREA1
SWATI PHATAK	LRH	AREA1	ARBAB RD	AREA3
SWATI PHATAK	LRH	AREA1	HMC	AREA1
P-2	UMEED ABAD	AREA3	KMC	AREA3
P-2	P-2	AREA2	MAANI BAI PASS	AREA4
P-2	P-2	AREA2	MARKAZ	AREA1
P-2	KAKSHAL	AREA1	QABRISTAN	AREA2
P-2	CMH	AREA1	QISSA KHWANI	AREA1
GULBHAR	LRH	AREA3	CHAMKANI	AREA4
GULBHAR	EDHI MARKAZ	AREA3	UNIVERSITY	AREA3

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GULBHAR	PKHA GULAM	AREA1	LRH	AREA1
GULBHAR	DOURA RD	AREA3	LRH	AREA1
GULBHAR	EDHI MARKAZ	AREA3	KTH	AREA3
P-1 HAJI CAMP	P-1	AREA2	JAMEL CHOWK	AREA4
P-1 HAJI CAMP	P-1	AREA2	SARBAND	AREA3
P-1 HAJI CAMP	NEW CITY HOME	AREA1	KMC	AREA3
P-1 HAJI CAMP	P-1	AREA2	LRH	AREA1
P-1 HAJI CAMP	P-1	AREA2	KMC	AREA3

Method:

This Multi Echelon Location problem has two levels. The first level is when any ambulance moves from center to patient's position. And the second level is when it moves from patient's location to Hospital.

Level 1:

As there are total of 6 EDHI centers in Peshawar. So, for the sake of analysis each EDHI center's covering area is divided into 4 areas and these areas are called as Area1, Area2, Area3 and Area4. Each center has 4 areas. In the data, it is noted that the ambulance goes in which area and for how many times. It gives us the frequency of each area. And it becomes clear from which area the demand is maximum.

Level 2:

For Level 2, the center cannot be same like used in Level 1. As, it will mean that every demand location will become a center point which will result in 1000 centers (total 1000 observations). Therefore, for the sake of analysis the center is taken at overall center of Peshawar city. This overall center at EDHI main center.

Similar like Level 1 this center is also divided into 4 Areas i.e. Area1, Area2, Area3 and Area4. For each observation it is noted that in Level 2 the ambulance goes to which Area and how many times. It gives the frequency of Level 2.

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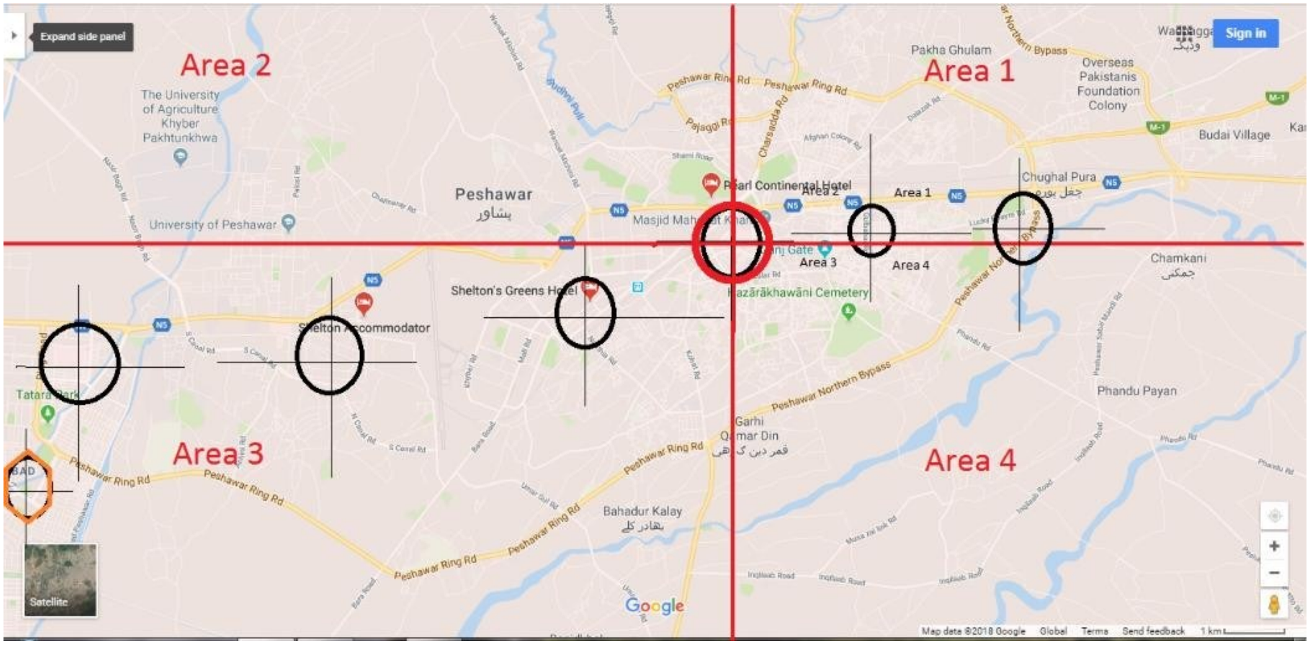
Figure 3- 6 EDHI Centers (Peshawar) Classification In Different Areas.



1. ANALYSIS:

5.1. Implementing Greedy Method:

As Greedy method make locally optimum solution and it may or may not give globally optimum solution. So the route selected should be locally optimum route. In this case the Greedy method is implemented on two levels i.e. Level 1 and Level 2.

In Level 1 the ambulance moves from center to the patient's location. As there are more than 1 possible routes to move from center to the patient's location. Therefore, the distance between each route may vary. And if the distance vary the time also vary[1]. As Greedy method make locally optimum solution so the Greedy method will choose the route which has least distance which as a result will have minimum time.

Similarly in Level 2 the ambulance will pick up the patient and will move from that location to the nearest hospital where that patient can be treated. Again there are many possible routes from patient's location to hospital. Each of these paths have different distance therefore, have different traveling time. Greedy method will again make locally optimum solution my selecting the shortest route possible. Which in turn will have the minimum time of all possible routes.

As on both Level 1 and Level 2 the locally optimum solution is made. So, there is a great chance that globally optimum solution is also achieved. The resulting path will have the minimum distance and will require minimum time to pick up the patient and take the patient to the hospital.

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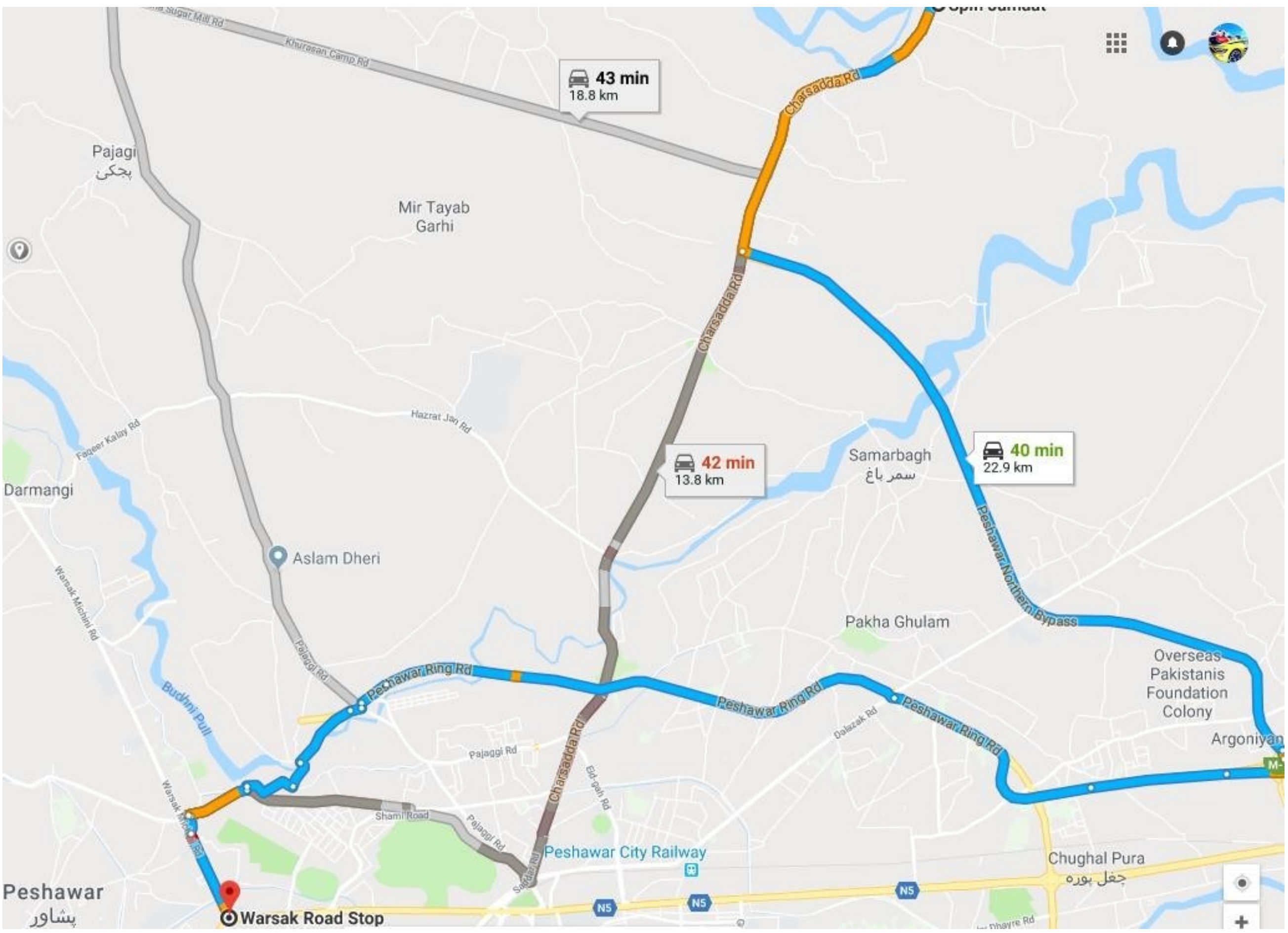
[1] Rush is considered to be same on all routes means there is no rush affect.

For Example:

Let us take the example of P-4 EDHI center Peshawar. As shown in the data table an ambulance go from P-4 center to Warsak road to pick up a patient. After picking the patient, the ambulance take the patient to Lady Reading Hospital (LRH). When the ambulance moves from P-4 center to Warsak road, it becomes Level 1.

As shown in the Fig that there are three possible routes at Level 1. One route is through Charsada road, second route is through khurasan_Camp road and the third route is through Peshawar Ring Road. Using Greedy method to see which path the ambulance should fallow, the Greedy method gives us the Locally optimum solution i.e. Charsada road as it has a minimum distance of 13.8 km as compared to others which are 22.9 (Peshawar Ring road) and 18.8 (Khurasan_Camp road).

Figure 4- Different Routes Of Level-1.



In Level 2, the ambulance took the patient to Lady Reading Hospital (LRH). Again there are more than 1 possible routes through which ambulance could move from Warsak road to Lady Reading Hospital (LRH). There are total of three possible routes that the ambulance could fallow. The first one is through Grand Trunk Road, second is road going next to Peshawar museum and the last one is road next to Edward college Peshawar.

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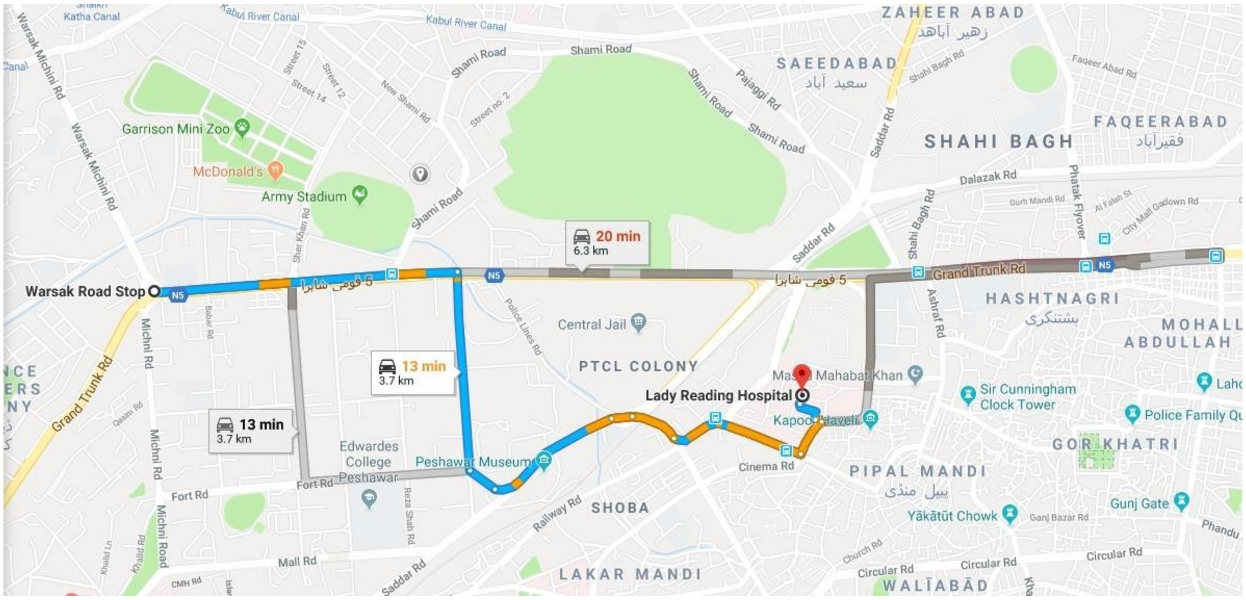
Using Greedy method the locally optimum solution are road next to Peshawar Museum or road next to Edward College Peshawar as both of these routes have equal distance i.e. 3.7km. On the other hand the Grand Trunk road is not an optimal choice due to large distance i.e. 6.3km.

Figure 5- Different Routes Of Level-2.



As Greedy method made the locally optimal choice on both the Level 1 and Level 2. Therefore, there is a great chance that the overall solution is also globally optimal solution. Which results in minimum distance and minimum time.

RESULTS AND DISCUSSION:

Implementing Greedy method results in much better routing which in turns reduces the distance and as a result the ambulance takes minimum possible time to provide the service. Greedy method optimizes both the Level 1 and Level 2 by making locally optimum decisions. Locally optimum decision on both levels have great impact on distance and time.

Greedy method optimized two things. First is the distance, which is done by making the locally optimum choice between different possible routes available. And the second is Time, which obviously decreases as the distance traveled is decreased.

The distance traveled through normal routine was 26.6 km in the example discussed earlier. After applying Greedy method the distance reduced to just 17.5 km. Time analysis shows that the time taken by ambulance after applying Greedy method is only 65.78% of the time taken by same ambulance, traveling through same route and same distance. This 34.22% of time saved could be the difference between life and death of the patients.

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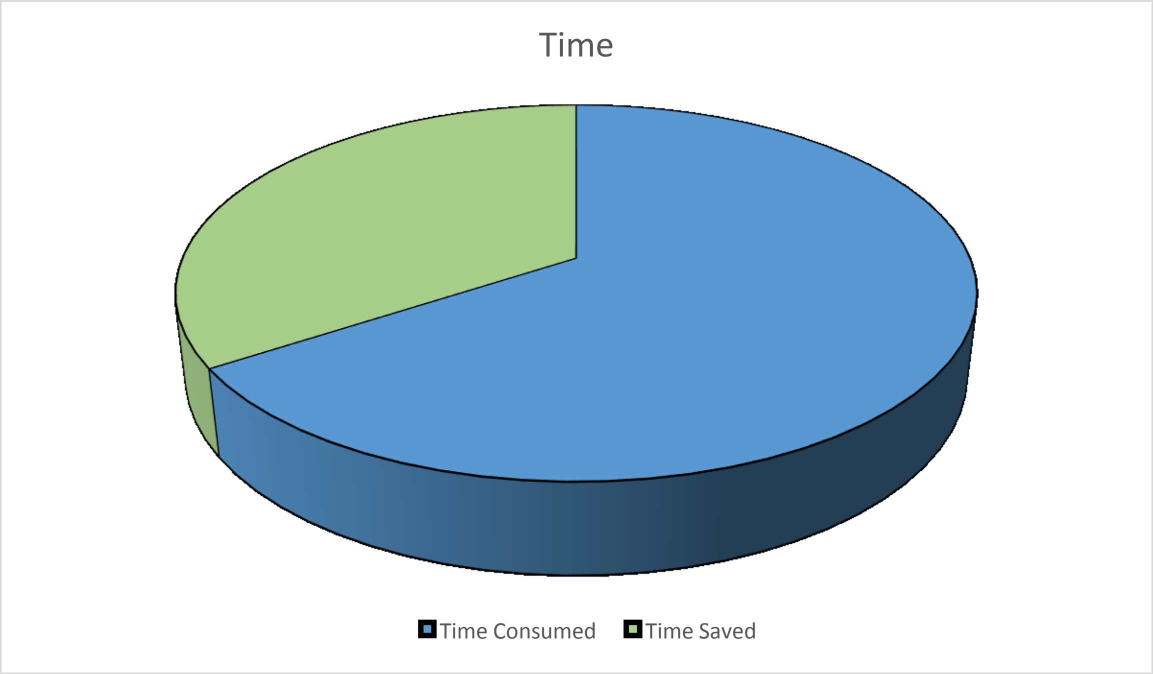
Figure 6- Pie Chart Showing The Amount Of Time Saved.



CONCLUSION:

Implementation of Greedy method results in major reduction in time which the ambulance takes on both the level 1 and level 2. Total amount of time taken after the implementation of Greedy method is reduced by 34.22%. This time saved is more than one third of the total time, which in this case can be a difference between patient's life and death. Now, the ambulance can serve the patients in only 65.78% of the time as compared to time taken by ambulance before applying the Greedy method.

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DESIGN AND TESTING OF VIBRATION BASED MACHINE MONITORING SYSTEM

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ABSTRACT

In industries machines run continuously till failure and then need maintenance which may results in poor production, damage to the machine and be hazardous to the maintenance staff. Therefore, failure oriented and time based preventive maintenance needs to be replaced by predictive maintenance. In this work, a low cost and portable vibration analyzer for detecting different type of faults was designed and tested on different rotary machines. The analyzer detects various flaws in the machine from the patterns of spectrum. The results are providing identification of flaws before failure occurs and prove beneficial in saving of the costs associated failure. Spectrum produced by each fault was also compared with normal machine's spectrum.

Keywords- preventive maintenance, predictive maintenance, vibration analyzer, rotary machines, spectrum

1. INTRODUCTION

In predictive maintenance, Machine Condition Monitoring (MCM) is the main part where machine condition is periodically examined and then matched with earlier condition. Different approaches available for MCM are Laser Technology, Ultrasound Inspection, Infrared Thermography, Lubrication Analysis and Vibration Analysis. Amongst all these, vibration method is the best choice because of quick response and low cost. Vibration analysis is an effective and reliable technique in the field of online fault detection in rotating machines as each fault produce in machine has its own distinct vibration. Online machine monitoring systems like FFT analyzer based on DSP were developed which have the ability of detecting faults like misalignment, high load on the machinery and broken part etc. from the vibration produced by rotating machines (Betta et al, 2001).

In machines especially rotating machines for diagnosing abnormal and infrequent vibrations a system known as VIBEX (Vibration Expert) was developed which was based on decision tree and decision table (Yang, Lim, and Tan, 2005). When the experts are not accessible in industries then VIBEX is an expert systemwhich enables the operators to solve vibration related problems in rotating machines i.e. it provided information that would likely to replace the expert's advice.

Field programmable gate array (FPGA) is a fast processing device having reconfigurable logic blocks and paths between them which has the ability of prototyping and it can meet the demand by time as its manufacturing time is less. FPGA has also the ability of parallel processing i.e. it can do more than one task in a single time. All these features make this device a fast processing and easily designable device. Using the concept of FPGA vibration analyzers have also developed for the online diagnosis of rotating machines (Medina et al, 2010). These multiple channelvibration analyzers were suitable for the industrial environment where they detected multiple faults in rotatory parts of machines like unbalancing, looseness and broken bars and most specially they were designed for rolling bearings (Costa, Mathias, and Pinheiro, 2012).

Accidents occurred due to the mechanical faults is mostly due to improper lubrication. Overheating occurs in mostly machines is due to insufficient lubricant and so can be the cause of many major faults and accidents. Many researchers worked on such cases and their work was totally based on the vibration analysis technique and from their study they diagnosedperfectly the deficiency of lubrication in many rotary equipments (Souza et al, 2014). They successfully predicted the condition of rolling bearing before entering the first stage of wear by using the technique of vibration analysis.

Induction motors are mostly used in different machines in every production industry. During machines' operation many faults occur in induction motor which affects the efficiency and production of the machine. Each and every fault produce in induction motor has its own frequency and amplitude which is different from its normal frequency (Agoston, 2014).

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Researchers practically showed that every fault in the motor whether electrical or mechanical has a specific type of vibration and so has a specific frequency. Matlab Simulink was used and simulation results showed that each fault produced has its own

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distinct spectrum i.e. different vibration spectrum were produced for faults like unbalancing, bearing looseness, base structure, resonance, looseness and electrical imbalance.

The goal of every industry is to manufacture quality products and to minimize the use of raw materials. In other words the call of the day is to shift over to the concept of environmental sustainability. Many researchers worked on this concept i.e. how to increase the quality of products by using minimum resources. They significantly showed the effect of predictive maintenance on environmental sustainability of an industry (Almorza et al, 2014). When vehicle's bearings are manufactured in industry then finally external grinding is done to those bearings and during the process some vibration is observed which is produced due to the process, not due to flaw of the machine. These bearings can cause damage as its quality is affected by this unwanted vibration. Work was done on such industry products and vibration spectrum techniques were used to choose quality final products which were free from unwanted and hazardous vibrations. The methodology simple favors the environment as quality problems are prevented in the final products produced and so more efficient use of resources will be needed in the next batch of production to overcome all the shortcomings.

2. FAST FOURIER TRANSFORM

Fast Fourier Transformer (FFT) is a fast computation algorithm for Discrete Fourier Transform (DFT) in which an array of time domain waveform samples is taken and FFT processes those to produce a new array of frequency domain spectrum samples as shown in fig. 1. The span in the time domain is Td while that of frequency domain is Bb which stands for bidirectional bandwidth. Input has real-valued samples while output side has complex-valued samples. Due to complex values we normally work with magnitude and phase representations of the complexvalues.

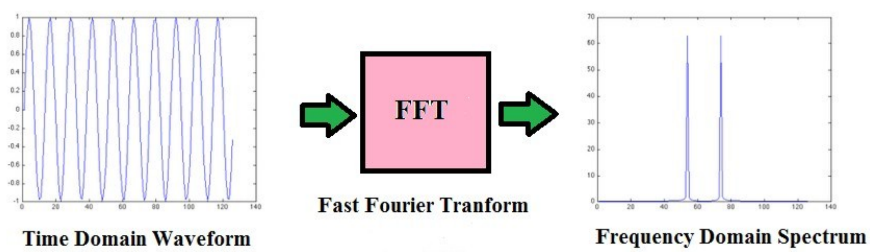

Figure 1. Basic Concept of FFT

3. METHODOLOGY

Microcontroller is used as central processing component because of its fast processing feature. Vibration signal obtained through mic (sensor) was send to Microcontroller after high pass filter. After getting time domain signal its spectrum was calculated using Fast Fourier Transform (FFT) and then the results of the spectrum was displayed. An Alphanumeric LCD was also used to show type of fault occurring in machine. For interfacing of Microcontroller and LCD an Arduino board was used. The methodology flow diagram is shown in fig. 2. As Arduino is a programming environment in which programming can be done in different languages. In the project programming was done in C language.

A liquid crystalwas included for LCD and EEPROM for ROM. FFT is taken as linear output of 8 bits. Number of samples have taken as 256 i.e. 128 real and 128 imaginary. A scale of 16 bits have taken in the project but a scale of 8 bits or 32 bits can also be used.

Basically frequencies of the normal running machine were saved and then these frequencies were compared with the frequencies of faulty parts. The value of the amplitude of each frequency of normal part was compared with the same value of the amplitude of the frequency of the faulty part. In this way faults in a running machine were detected. Similarly for detecting other type of faults the frequency spectrum of that part was compared with the pattern of normal and first saved faulty part. In this manner patterns of almost all types of fault occurring in rotating and back and forth type of machines were saved. Now to check any fault the frequency pattern of the test part was compared with the pattern of all saved patterns and in this manner faults were detected.

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Margin of error was taken as ±15db which means if comparison of the test part's frequency pattern is in the range of ±15db with the saved patterns then frequencies will match and if it exceeds than ±15 then frequencies will not match and it will be then detected as new fault and we will save and give name to that fault. Furthermore, if maximu m 3 frequencies out of 128 do not match while the remaining125 matches then it is acceptable and the test pattern will match with one of the saved pattern but if it exceeds 3 then it will not match with the saved patterns and will be considered as a new fault.

As frequency pattern of the normal running part and a part which has some type of fault e.g. fault 1 has been saved. For next fault detection same process will be done and the value of the amplitude of the frequency of fault 2 will be compared with the value of the amplitude of the frequency of normal part and fault 1. If comparison is not in the range of ±15 with both normal and fault 1 pattern and also frequency errors are more than 3 then it will be detected as second fault named as fault 2. For third fault the pattern will be compared with all the saved samples. Same process will be done for saving and detecting fault 4, 5 and so on.

Amplitude of the frequencies quickly goes up and down, so to normalize the pattern and for a constant graph average of each sample has been taken and then the pattern were saved. For saving pattern of the average valued sample an array named as table has been made which is placed in RAM and it can store 128 values. Now for detecting a fault its pattern is compared with the pattern saved in the table i.e. samples of the faults are compared with samples saved in the table.

When microcontroller starts then the subroutine setup starts only one time while loop runs continuously. Same baud rate i.e. 115200 bits per second were set at both serial ports i.e. at Visual Basic (VB) and Arduino (Microcontroller) for communication because if baud rate is different at both terminals then error will occur and signals receiving will not be pos sible.

Codes (programming) for the conversion of the signals into their respective frequency were taken from the concerned FFT library. In the FFT library all codes are present through which all types of signals can be converted into their frequency pattern. For our case we have taken code for the conversion of 128 bytes data. When it converts signals into frequency pattern then buzzer goes ON for 100 millisecond. Now loops runs and it calls fft get average. fft lin_out is a table of 128 bytes so data comes into in this table. Then all values of this tables go to table "world table_sum" and add. Similarly other samples come and add in this table. In our case 10 samples of the same part were taken and then got its average simply divide by 10.

When all the data of the table send to serial port then we will be able to start and run our program Visual Basic. Visua l Basic will just show the frequency pattern of the required part vibration. It was noted that the pattern was in a very strange and irregular form. To get the pattern in a regular pattern we went to library of fft Arduin o and pick fft programming. We did changes in the programming for our 128 bytes data. The program is now suitable for 128 bytes data. 128 bytes of data goes into serial port so we run the Visual Basic and it showed its graphical form in a very regular form.

When this data was sent to computer then it calls compare 1 i.e. Normal, compare 2 i.e. NormalLoad, compare 3 i.e. LoosePart and compare 4 LooseLoad. As four samples were taken in the project so it goes up to 4 only. If the samples were nine then it will go up to compare "9". What actually happens in compare subroutine is that it takes value from 0 to 50 from EEPROM and compare with the table "fft_lin_out8". Every value of the sample pattern is compared with same value of the table. If margin of error is more than or less than 15 then frequency do not match and 1 is added to wrong.

For compare (1) it makes a local variable "f" and put zero for wrong. It takes values from 0 to 50 from EEPROM which has already saved and compare with table of "fft_lin_out8". x value is in the EEPROM, so it put the first value from EEPROM and put in x. values from the "fft_lin_out8" table are also taken and then comparison of the values of x and "fft_lin_out8" table take place. If x is greater than or less than 15 then it is out i.e. not in the range, so it adds 1 in the wrong variable which means we got 1 mistake. Similarly all the 50 values are compared and wrong is added in the similar way. If wrong is not greater tha n 3 which are simply errors then it will write "found 1 i.e. Normal" on the LCD i.e. it detected first saved sample. For any error it will write Found NormalLoad, LoosePart or LooseLoad on LCD. Beep is also connected so it alerts the concerned person that some fault has detected. For 3 seconds he will be able to see the name of the detected pattern. After a second the name will be repeated for every 3 seconds on the LCD.

In EEPROM there is addresses and data. We can store up to 512 bytes of data for addresses. We have taken the first sample as from address 0 to 50 as pattern 1. Similarly 100 to 150 as pattern 2, 200 to 250 as pattern 3 and 300 to 350 as pattern 4. In compare (1) it compares from 0 to 50. In compare (2) it compares from 0 to 50 but will plus 100 means from 100 to 150. Similarly in compare (3) comparison takes place from 200 to 250 and in compare (4) from 300 to 350. As we have made our own table so it will get samples and will compare with all the saved patterns in the table. If the sample match w ith one of the saved sample then it will beep and will show you as found 1, 2, 3 or 4.

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Basically sample is provided to serial port first then it compares with the store samples and if any sample match then it will be shown. Now if data is available on the serial port then it will go to get command. Now what get command do is that if you click on Normal on Visual Basic then it will call save 1 i.e. save your first pattern. Similarly for Normal_Load it will call save 2 i.e. save 2nd pattern. In this way 3rd and 4th pattern can be saved and we can go up to 9 using the same microcontroller.

In save 1 it makes a loop from 0 to 50 and save samples from 0 to 50 in "fft_lin_out8" table and then write on LCD as save 1 and call a beep for 300 milliseconds. Similarly for save 2 save samples from 100 to 150, 200 to 250 for save 3 and 300 to 350 for sample 4.

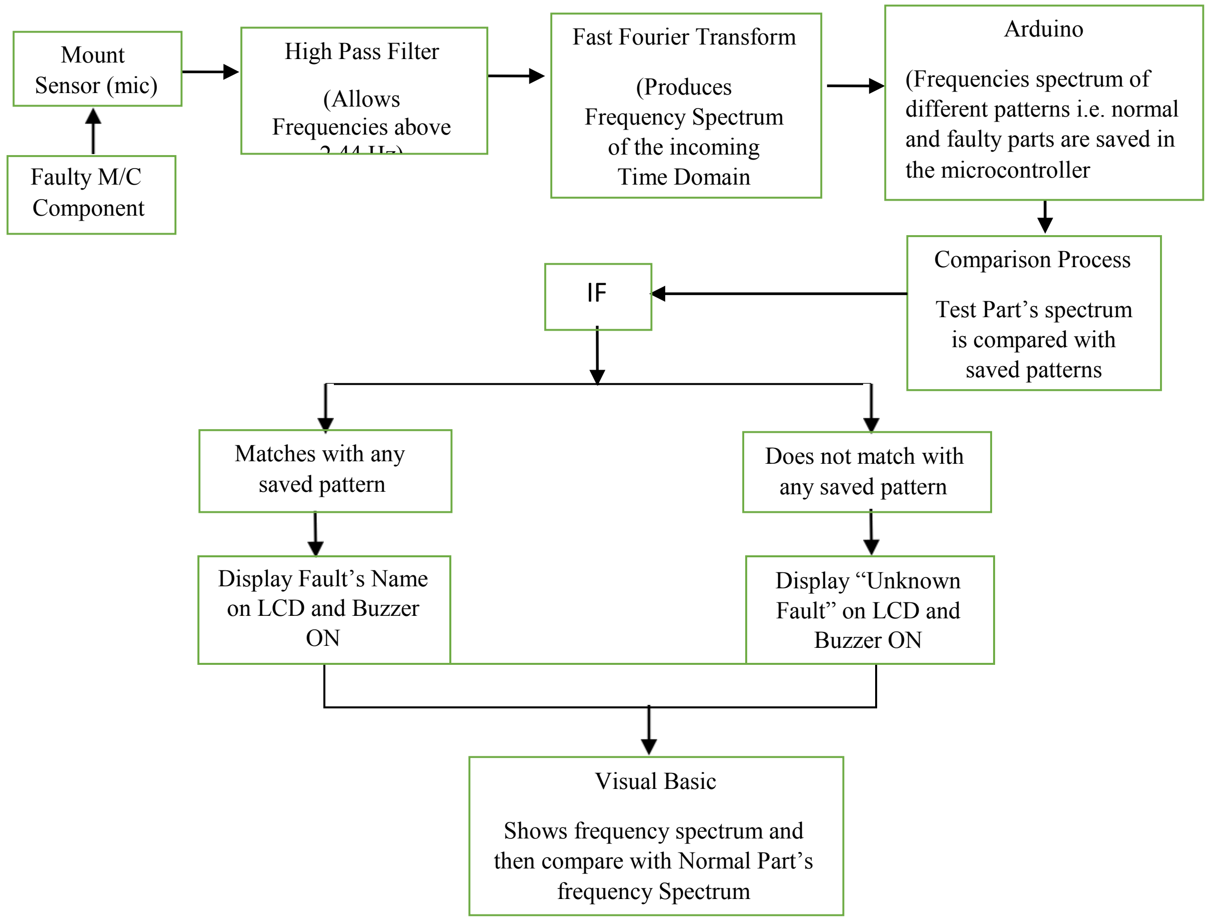

Figure 2. Methodology Flow Diagram

4. CALIBRATION

To check the accuracy of sensor, a new sewing machine motor of National Company was taken. It requires 150W power, 100/125V voltage, produces 7500 rpm and its frequency is 50-60 Hz. The frequency spectrum of this motor was recorded and compared with its standard frequency spectrum, which matched. Later, for all experiments, before the mic was mounted to any faulty part, its function was checked by detecting the spectrum of that new machine. Before performing all experiments it matched which showed that the sensor hasn't any error. If the mic has some error then the frequency of the new motor will not match with its standard frequency pattern and then you need to calibrate it before each measurement. For calibration you can use any external calibrator by putting it on mic and turn it on, which will calibrate your mic. You can also use Insert voltage technique to calculate the open circuit sensitivity of a condenser mic for calibration of mic.

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5. EXPERIMENTAL SETUP AND RESULT

Mic was mounted on a new sewing machine motor as shown in fig. 3 and saved its pattern in Visual Basic (VB) by the name “Normal” as shown in fig. 4. The sensor was then removed. Again the sensor was put on it. LCD showed “Found Normal” as shown in fig. 4, means it has detected the first saved pattern. Then Visual Basic (VB) was opened for frequency pattern’s detection. VB clearly showed its pattern as shown in fig.5 and it was saved in it.

Figure 3. Overall Setup

Figure 4. LCD Display (Saving and Detecting Normal Part)

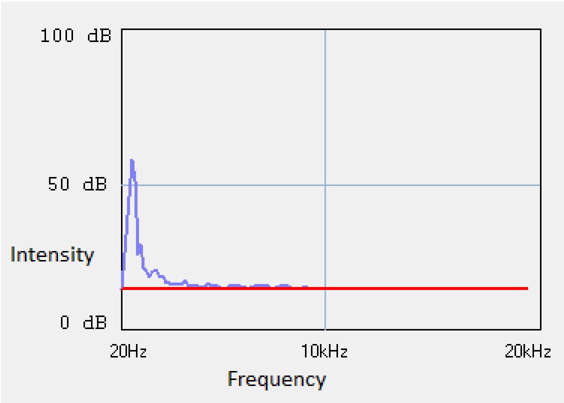

Figure 5. Frequency Pattern of Normal Part

In the second phase a load is added to that new sewing machine motor and again mic was mounted to it and saved its pattern. This time the pattern was saved by the name “Normal_Load”, as shown in fig. 6. The sensor and load were then removed. Again the sensor was put on it which showed “Found Normal” on LCD, as shown in fig.4, means the first saved

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sample. Then a small load was added to it and this time detected as “Found Normal_Load” as shown in fig. 6. Again VB was opened for pattern detection. VB clearly showed its frequency pattern, as shown in fig.7, which was saved successfully.

Figure 6. LCD Display (Saving and Detecting Loaded Part)

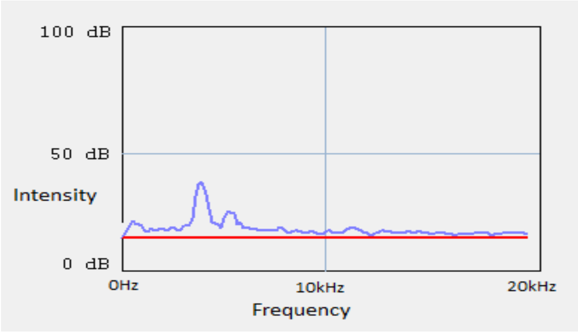

Figure 7. Frequency Pattern of Overloaded Part

In the third phase a loose sewing machine motor was taken. For saving its pattern mic was mounted to it. This time the pattern was saved by the name “Loose_Part”. The sensor was then removed. Now on putting the sensor on normal part it detected “Found Normal”, on overloaded normal part detected “Found Normal_Load”. When the sensor was mounted to the loose part, it showed “Found Loose_Part” on LCD as shown in fig.8. Its frequency pattern was shown (fig. 9) and saved in the VB by the same method.

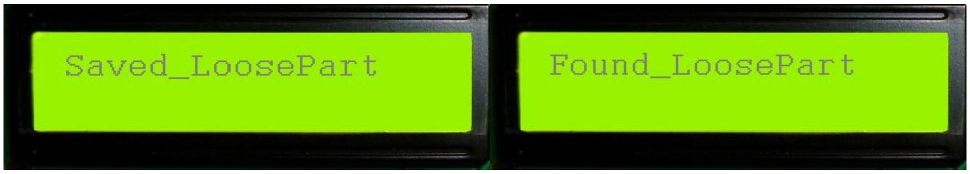

Figure 8. LCD Display (Saving and Detecting Loose Part)

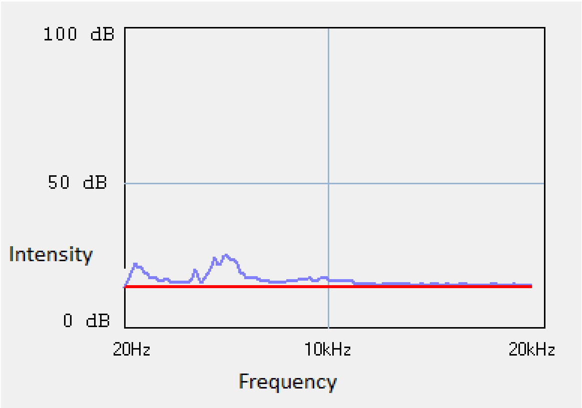

Figure 9. Frequency Pattern of Loose Part

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In the 4th phase a load was added to that loose sewing machine motor. Same process was repeated for saving its pattern. This time the pattern was saved by the name “Loose_Load” as shown in fig. 10. The sensor was then detached. Now when sensor was mounted to normal part it detected “Found Normal”, for overloaded normal part detected “Found Normal_Load ”. When mounted to the loosed machine showed “Found Loose_Part” and then when the same load was added to loose part it showed “Found Loose_Load” as shown in fig.10. Then VB was opened for its frequency pattern (fig. 11) and the required pattern was saved in the same way as done for other patterns.

Figure 10. LCD Display (Saving and Detecting Overloaded Loose Part)

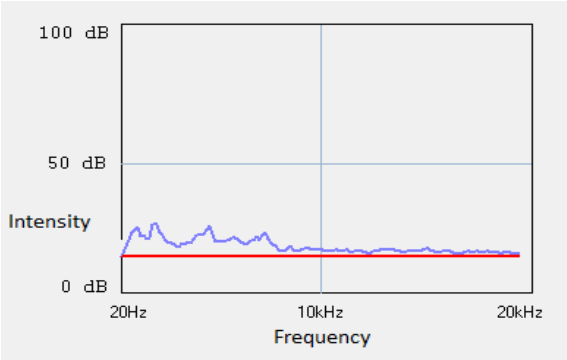

Figure 11. Frequency Pattern of Overloaded Loose Part

6. Unknown Fault

Only four patterns have saved in the microcontroller. When mic is mounted on any running machine then its frequency spectrum starts matching with the saved frequency patterns. Now when any fault in the machine which is not saved in the microcontrolle r will be displayed as “Unknown Fault” in the LCD as shown in fig 12. The next step will be to find that which type of fault was this. When the nature of fault is detected by the experts, then its frequency will be saved by its name. In this way patterns of almost all types of faults can be saved.

Figure 12. LCD Display (Detecting Unknown Fault)

7. EXPERIMENTAL RESULTS DISCUSSION

The spectrum of the Normal part shows that intensity is maximum i.e. 60 db at the range of 20 Hz to 1 kHz. Then after 1 kHz it showed almost constant intensity i.e. 20 db up to 20 kHz.

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Spectrum comparison of Normal and Overloaded part shown in fig. 13, shows that the major difference in the intensity of their frequencies were observed at 6-7 kHz. Overall pattern's frequency was similar to that normal part's frequency. The difference observed is due to load factor. If load is varied then changes can be observed at other points too.

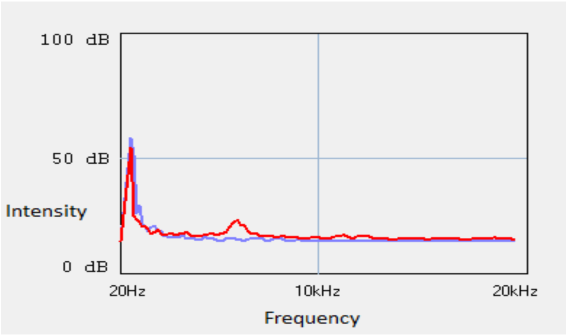

Figure 13. Frequency Comparison of Normal and Overloaded Part

The spectrum of the loose part was almost irregular. When it was compared with Normal part then it was observed that their spectrum was completely different from each other (fig.14). The prominent difference in intensities which were observed was at 20 Hz to 1 kHz and 4 kHz to 6 kHz

When normal and overloaded part were compared as shown in fig. 15, then it was observed that their overall frequency pattern was different from each other. The prominent difference in intensities were observed at 20 Hz to 6 kHz. If you change the load then you will also observe more differences at different points.

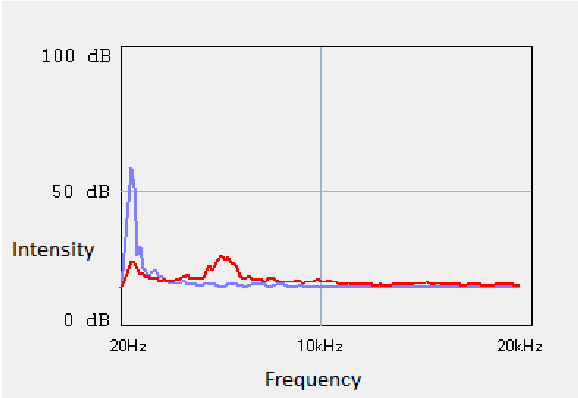

Figure 14. Frequency Comparison of Normal and Loose Part

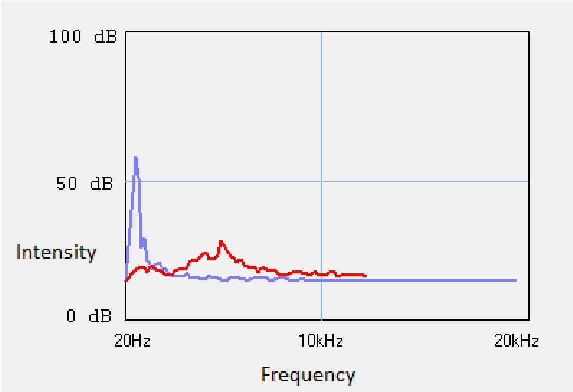

Figure 15. Frequency Comparison of Normal and Overloaded Loose Part

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8. CONCLUS ION

In this paper design and working of a portable vibration analyzer is described which will be used for detecting different typ e of faults in rotary and back and forth type of machines in industry. This low cast vibration analyzer was tested on different ro tary type of machines which verified the expected result. Main component of the systemwas fast processing microcontroller in which we sent the vibration signals obtained through vibration sensor and it produced its corresponding spectrumwhich was calculate d by using FFT. Moreover, fault's name was also displayed on the Alphanumeric LCD which will give users the facility of detecting fault's name occurring in the machine. Experimental results shows that the vibration analyzer works properly and it can be replicated and used in industries with a low cast.

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OPTIMIZATION OF EMERGENCY PROCEDURE IN HOSPITALS: PESHAWAR CITY A CASE IN POINT

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ABSTRACT

Terrorism is the record devastating phenomenon of the today's world. Terrorism has proved to be a major curse for Pakistan peace and prosperity after 9/11 attack. According to a report of Global Terrorism Index 2017, Pakistan ranks fifth out of 163 countries in an account of terrorist attacks. The worst affected region in Pakistan is Khyber Pakhtunkhwa (KPK) province due to its geo-strategic location. Terrorists frequently use tactics of bomb blasts and suicide attacks to disturb KPK region especially its capital city Peshawar. In any tragic event of terrorist attack, the first people to deal with the situation are the medical staff. The quick and organize response of medical staff is vital to reduce the casualties. The case of Lady Reading Hospital in Peshawar is considered in this study for analyzing the overcrowding situation due to terrorist attack. This can be achieved by two goals; firstly to analyze the average waiting time of patient in a queue during normal as well as in emergency situations by using queuing theory. Secondly to utilize linear programming (LP) for optimizing the doctor's schedule. Overall, this paper will help to optimize the emergency procedure in medical units.

Keywords: Terrorism, Lady reading hospital, emergency procedure, queuing theory and linear programming.

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1. Introduction

Medical treatment in Emergency situations has made significant developments in recent decades, especially after the 9/11 accident. In the emergency event, it is needed that all medical staff should work efficiently. Hospital staff made their effort to deliver effective medical treatment even in emergency situations. Efficient emergency treatment led to the development of training staff to address the needs of emergency response. However, lack of training for dealing with the emergency situation made the efforts of hospital staff suboptimal. Optimal emergency treatment is one of the most active factors for effective treatment. Otherwise, unsympathetic treatment for patients arises in case of extreme events such as bomb blast, natural disaster etc. (Merriel, et al., 2016). The sort of injuries due to these extreme events might vary from wounds and bruises to loss of limbs. Variation in the injuries makes difficult to optimally treat all patients.

Optimal treatment in an emergency situation is still challenging task in under developing countries such as Pakistan. Reports show that private hospital is showing much quality treatment to tackle the situation of emergency. Due to this reason, about 70% of healthcare demand of Pakistani citizen is fulfilled by private sectors (Mir, et al., 2015). However, the number of visits to government hospital as compared to private is much higher. The reason behind this situation is a large difference in medical treatment fees. Due to the low capacity of the primary health care facility, patients mostly prefer to admit in Emergency Department (ED) even without any emergency need (Mehmood, et al., 2012). The greater than before use of the ED as first-choice should be discouraged as they are an extra load on these departments (Bilal, et al., 2016). There is a serious requirement to attention on policy making to optimize the load on ED as well as training of medical staff to ensure better treatment for all patients. The delays in treatment of patients in the emergency room are critical because it will result in loss of precious lives.

Optimization of ED is more important in Pakistan scenario as according to a report of global terrorism index, Pakistan ranks fifth in terrorist attacks (START, 2017). In Pakistan, Khyber Pakhtunkhwa (KPK) province is most affected region due to terrorism as it is closest to Federally Administrated Tribal Area (FATA) region which is considered as the hideouts for terrorist groups.

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According to statistics, seven attacks occurred close to Peshawar region in 2017, altogether it causes the death of 25 people. The civilian medical staff as compared to armed medical staff face more difficulty in curing injuries that caused by such bomb blasts accidents. This is a motivation for initiating this project to optimize ED activities in extreme events. This can be achieved by application of queuing theory for reducing patient's time in a queue and linear programming for determining an optimal number of doctors needed in ED.

This project utilizes queuing theory models to evaluate the queue during an emergency situation in Lady Reading Hospital (LRH) Peshawar. LRH is one of the largest Government hospitals in Peshawar with a capacity of 1800 patients. The hospital has a capacity of 200 beds and a paramedical staff of 25 per shift. Total no of doctors assigned to ED are 20 and total no of nurses present are 26. Both doctors and nurses are capable of doing a shift of 12 hours each. It was established in 1924 and it is just 200 meters away in the south of the Grand Trunk Road. The tale of the hospital of its coming into being is the visit of Viceroy of India from 1921 to 1926 to Peshawar. In this study, we assume medical professionals working within a time-stressed emergency in which treatments require hasty physical mediations. One more assumption is that medical professionals can be at any phase of their professional job.

The remainder of the paper is organized as follows. Section 2 describes the literature review about optimization of an emergency situation in hospitals, queuing theory, and linear programming application. Section 3 discusses a method for QT and LP. Section 4 discusses a QT and LP based results. It illustrates the number of servers needed and optimized no of doctors per shift needed. Finally, Section 6 summarizes the paper and recommend future policy to reduce the delay in treatment of patients in an emergency situation.

2.0 Literature Review

Overcrowding in the emergency department is a common phenomenon (Sprivulis, 2006). The increasing number of patients in the emergency department are facing severe operational problems, which results in contradictory situations (Boudreaux, 2004).

Furthermore queuing theory was used by (van Rossum, 2007) for modeling the emergency cardiac in patient flow. According to (Arifin, 2015) queuing theory was used for obtaining a proper

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queuing system and minimal cost in the supply of tobacco. Moreover, (Green, 2002) used queuing theory for estimation of bed unavailability in intensive care units and obstetric units in case of New York City. Work done by (Fomundam, 2007) shows that mean service time and variability in demand for healthcare services are improved by improved by queuing theory. The effectiveness of emergency department and providing staff was optimized by (Green, 2006) by using queuing theory.

Linear programming is used by (Shi, 2002) for data mining to classify the behavior of credit card holders. Fuzzy linear programming was used by (Wang, 2004) for aggregate production planning. Moreover, linear programming is used to calculate hotel efficiency in terms of competition, location and management by (Anderson, 2000). In this research paper, a combination of queuing model and linear programming is used for optimization of emergency procedure in hospitals of Peshawar city (Pakistan). This research will help authorities to deal with accidents under normal and emergency situations by minimizing the queuing time and providing proper doctor's schedule.

3.0Methodology

In this study, we are using queuing theory and linear programming for optimization of emergency procedure in hospitals of Peshawar city Pakistan. The purpose of using queuing theory is to minimize the queuing time for patients, and linear programming will help in providing a proper schedule for doctor's availability during normal and emergency procedures.

3.1 Queuing Theory

Queuing theory is the examination of waiting for lines (queues). The main purpose of the queue model is to predict the queue lengths and waiting times. This models usually deal with customer arrivals at a service facility such as hospital case in this project. We are using this model because it will aid us to assess the number of servers needed to fulfill customer demand. For Arrivals of customers to a service, the facility is taken as a Poisson distribution and the service duration taken as an exponential distribution. Poisson distribution is one of the discrete distribution that shows the probability of arrivals in a given time period. By using M/M/2 Queue model we adopt that:

$$\frac{\lambda}{nu} < 1 \tag{1}$$

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Where λ= arrival rate, u= service rate, n = Number of sethe rver (provider)

$$p_k = p_o \left(\frac{\lambda}{u}\right)^k \frac{1}{k!} \tag{2}$$

$$p_k = p_o \left(\frac{\lambda}{u}\right)^k \frac{1}{n!n^{k-n}} \tag{3}$$

Moreover, the overall sum of probabilities must be:

$$\sum_{k=0}^{\infty} P_k = 1 \tag{4}$$

Where p = utilization, p_k= probability of k units in sythe stem, p_o= probability of 0 units in the system and $1/u$= service time.

Probability $p_o$basically shows that no patient is in the system which is an ideal thing because in case of emergency, the value of waiting time for the patient is not equal to zero.

Arrival Rate

Arrival rate (λ) = average number of arrivals per unit time period.

$$n = \frac{(e^{-\lambda}\lambda^n)}{n!} \tag{5}$$

Inter-Arrival time

$$t = \lambda \mathrm{e}^{-\lambda \mathrm{t}} \tag{6}$$

$$p(x, \lambda) = p(x) = \frac{e^{-\lambda}\lambda^x}{x!} \tag{7}$$

Where P(x) = probability of x arrivals, X = number of arrivals per unit of time, e = 2.7183 and λ = average arrival rate,

Service Time

$$Prob(t) = ue^{-ut} \tag{8}$$

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Exponential Distribution

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$$F(x) = \lambda e^{-\lambda x} \quad \text{Where } x \geq 0 \tag{9}$$

$$F(x) = \left(\frac{1}{u}\right) e^{\frac{-x}{u}} \tag{10}$$

Multi Server Queuing Model

$$\rho = \frac{\lambda}{su} \tag{11}$$

$$P_o == \left[\sum_{n=0}^{s-1} (\lambda/\mu)^n/n! + (\lambda/\mu)^s/s!\,(1/1-\rho)\right]^{-1} \tag{13}$$

$$\text{For } 0 < n < s \qquad \frac{P_o\left(\frac{\lambda}{u}\right)^n}{n!} \tag{14}$$

$$\text{For } n \geq s \qquad P_o\frac{\left(\frac{\lambda}{u}\right)^n}{s!s^{n-s}} \tag{15}$$

$$L_b = P_0\,(\lambda/\mu)^s \rho\,/s!(1-\rho)^2 \tag{16}$$

Where L_b = average number of customers in the waiting line

$$W_q = \frac{L_q}{\lambda} \tag{17}$$

Where W_q is the average time spent in the system, including service

$$W = \frac{W_q + 1}{u} \tag{18}$$

Where W is an average time spent in the system, including service

$$L = \lambda W \tag{19}$$

Where L is the average number of customers in the service system

We have calculated all the parameters involved in queuing model by using excel and estimate the

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waiting time for a patient.

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3.2 Linear Programming (with integer constraints)

Linear programming is a mathematical tool for optimizing resource (raw material human resource, equipment) to maximize profit. It consists of three main parts:

1. An objective function which shows the relationship between desired variables in order to maximize or minimize the desired function
2. Decision variables that are unknown whose appropriate values has to be found.
3. Profit or cost coefficient are the values of decision variables in an objective function.
4. Constraints are the set of equations to show limitations in linear programming model to get the required objective function. There can be three form of constraints
   a. Less than and equal to (<=)
   b. Greater than and equal to (>=)
   c. Equal to (=)

We have used linear programming to find the number of doctors needed at a particular time. Although this is purely an integer programming problem. It is beyond the scope of our study hence we have included integer constraints in our linear programming. There are two shifts of doctors at LRH each of which is 12 hours. Morning shift timing is from 9:00 am to 21:00 pm and night shift timing are from 21:00 pm to 9:00 am. To develop linear programming model, we divided 24 hours of a day into 8 shifts each of three hours as shown in table 1.

	First	Second	Third	Fourth	Fifth	Sixth	Seventh	Eighth
Time period	9.00-12.00	12.00-15.00	15.00-18.00	18.00-21.00	21.00-00.00	00.00-3.00	3.00-6.00	6.00-9.00

Table 1 showing division of shift timing

Decision variables:

Y1: Number of doctors whose shift start at 9.

Y2: Number of doctors whose shift start at 12 (zero).

Y3: Number of doctors whose shift start at 15 (zero).

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Y4: Number of doctors whose shift start at 18 (zero).

As the morning shift starts at 9:00 hence **y2, y3, y4** are zero.

Y5: Number of doctors whose shift start at 21

Y6: Number of doctors whose shift start at 24 (zero).

Y7: Number of doctors whose shift start at 3 (zero).

Y8: Number of doctors whose shift start at 6 (zero).

Since the night shifts start at 21:00 and ends at 9:00, **y6, y7, and y8** are zero.

Objective function:

$$Min\ Z = \sum_{n=1}^{8} y_i \tag{20}$$

Constraints:

According to the LRH Management, the average number of patients treated by a single doctor is 20. From this, we calculated the average number of doctors required at each interval of three hours for e.g. from 9-12pm. This was calculated by dividing the total sum of patients arrived in one shift over the average number of patients a doctor can treat. From this calculation, we further calculated the optimal value of doctors required. Those values are then added to the constraint equations and integer values are calculated. This procedure was repeated for all the 8 intervals for determining the number of doctors needed.

	First	Second	Third	Fourth	Fifth	Sixth	Seventh	Eighth
TIME PERIOD	9.00-12.00	12.00-15.00	15.00-18.00	18.00-21.00	21.00-00.00	00.00-3.00	3.00-6.00	6.00-9.00
Number of doctors per hour	7.35	7.85	7.1	6.2	3.5	0.6	1.25	4.15

Table 2 Number of doctors needed in the emergency department

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$$y1 \geq 7.35 \qquad \text{(a)}$$

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$$y1 + y2 \geq 7.85 \quad \text{(b)}$$

$$y1 + y2 + y3 \geq 7.1 \quad \text{(c)}$$

$$y1 + y2 + y3 + y4 \geq 6.2 \quad \text{(d)}$$

$$y5 \geq 3.5 \quad \text{(e)}$$

$$y5 + y6 \geq 0.6 \quad \text{(f)}$$

$$y5 + y6 + y7 \geq 1.25 \quad \text{(g)}$$

$$y5 + y6 + y7 + y8 \geq 4.15 \quad \text{(h)}$$

Constraints of non-negativity

$$y1, y2, y3, y4, y5, y6, y7, y8 \geq 0$$

Integer constraints

$$y1, y2, y3, y4, y5, y6, y7, y8 \ are \ all \ integers$$

4.0 Discussion

This section includes evaluation steps for queuing theory and linear programming. Finally, this section is then wrapped up with the discussion on comparison of both technique results. Furthermore, data and results are given in the appendix tables.

4.1-Queuing Model

The behavior of the model is determined by using M/M/2 queuing model as there are two servers in an LRH. These two servers are the reception counters of the hospital. There are two shifts that are morning and evening. The patients are referred to the doctor once they have got there slip from the counter. They are directly sent to the doctor if their condition is severe and if the condition is non-fatal than they are directly been sent home without being admitted to the hospital. According

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to the survey, 80% of the patients are sent home without being admitted and the rest 20% are given full-time medical care.

It is assumed that inter-arrival time between two consecutive patients and serving time is independent and service time is assumed to be 75 patients per hour. The system is continuous and there are two possible servers. The average arrival rate is calculated by taking the average number of patients each day at the two servers. Appendix A4 represents the patient's arrival time and the number of patients being served in one shift. One more assumption is that according to queue theory the patients should be treated in the same order as they reach the hospital that is first come first serve basis.

If utilization ratio

$\rho > 1$= Patients have to wait

$\rho < 1$= arrival rate is less than service time so the queue will be small

$\rho = 1$ Patients will smoothly travel as the service time and arrival rate will be the same.

If arrival rate is less than the service rate the system is smoothly working and there is no queue. We have calculated all the required parameters as shown in appendix A1 by using the equations as already mentioned in the methodology. Table 3 represents the waiting line model results for the time between 12 to 15 pm. Remaining results of other time periods are shown in the appendix A2.

Average arrival rate = λ It has been calculated by summing $\lambda 1+ \lambda 2+ \lambda 3$	157.0000
Average service rate = μ	104
Utilization = ρ	0.2516

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Average waiting time in line W_q	0.0002
Average time in system= W_s	0.0034
Average Number in line= L_q	0.0340
Average number of customers in the service system=L_s	0.5372
Probability system is empty=p_0	0.5980

Table 3 Queuing model Results for 12-15 Pm.

4.2-Linear programming solution

There is various software available to manipulate linear programming. However, we have used EXCEL SOLVER for linear programming model by using the simplex method technique. This technique helps to calculate the number of Doctors needed by keeping the time factor constant. The Excel Solver Solution is attached in Appendix A3.

Z	Y1 (9.00-12.00)	Y2 (12.00-15.00)	Y3 (15.00-18.00)	Y4 (18.00-21.00)	Y5 (21.00-00.00)	Y6 (00.00-3.00)	Y7 (3.00-6.00)	Y8 (6.00-9.00)
13	8	0	0	0	4	1	0	0

Table 4 additional doctors needed in the emergency department

The minimum number of overall doctors needed is thirteen. From the above table, “y1=8” represent that at least 8 doctors are required in the emergency department for the time interval between 9:00 to 12:00 AM. Since y2, y3, y4 is zero which means no additional doctor is needed

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other than the doctors who are available on the morning shift. In other words, Number of Doctors in the morning shift are satisfactory to deal with emergency cases.

For the evening shift, the additional minimum number of doctors needed is four i.e. y5=4. Also at the 6^{th} time interval i.e. from 00:00 to 3:00 only one additional doctor is needed. From 3:00 to 6:00 am no additional doctor is required which means that the number of doctors working in that shift is enough.

4.3-Comparison of linear programming and Queuing theory

Linear programming with integer constraints helped us in finding the optimal number of doctors for three hour time interval. Furthermore, queuing theory helped us in scheduling the number of doctors, both the models were done separately and their results were than collaborated and were sorted in order to meet the patient's requirement. Queuing model helped us in determining the number of doctors needed in each shift keeping the time constant. But the exact value could not be calculated from this model as we cannot convert the decimal value to a whole number. For this purpose, we used LP with Integer Constraints.

5. Conclusion

In this paper, we analyzed the emergency situation in hospitals by using linear programming and queuing model i.e. M/M/2. Moreover in emergency situations i.e. in case of suicidal attacks the patients flow rapidly increases and this can only be managed by increasing number of servers and doctors. Obviously, space is limited and the hospital management has to manage the increasing number of patients through temporary servers. The average waiting time for a patient in the queue will decrease with the increase in servers.

The number of doctors needed in emergency situations determined by using linear programming simplex method. Results show that an overall minimum number of doctors needed is 13.The arrival rate is also calculated by using the priority base selection. We considered three cases of patients arriving in the hospital i.e. seriously affected, Moderately Affected, Least Affected. Furthermore, we also estimate the arrival rate of patients at the hospital for all eight-time intervals. The priority-based selection helped us in determining the exact number of doctors that are needed.

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This model is highly recommended because the benefit of this model is twofold for a hospital management team. One this will help to divide the doctors on the priority basis and second to estimate the number of doctors needed to fulfill the requirement in the emergency case. Moreover, the Queuing Model will assist in estimating the number of patients that will arrive at the hospital in the emergency case. Both models are very beneficial as they will assist in scheduling the doctors without making them exhausted and will also help in finding the minimum number of doctors needed. So, the treatment of the patients will be performed optimally.

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Appendix A1

Total No of Patients in a day	total no of doctors per day	Total no of nurses per day	arrival rate λ per hour	service rate μ per hour	λ/μ	utilization 2 servers	P_0	Average no of patients in hrs Lq	Average waiting time of patients in line Wq	average time a patient spend in a system W	Averag e no of patients in the system L	utilization for 3 servers
1105.00	40.00	48.00	23.96	75.00	0.32	0.16	0.73	0.01	0.00	0.01	0.33	0.11
1111.00	40.00	48.00	24.42	75.00	0.33	0.16	0.73	0.01	0.00	0.01	0.33	0.11
1255.00	40.00	48.00	25.29	75.00	0.34	0.17	0.72	0.01	0.00	0.01	0.35	0.11
1253.00	40.00	48.00	30.04	75.00	0.40	0.20	0.68	0.02	0.00	0.01	0.42	0.13
1450.00	40.00	48.00	30.71	75.00	0.41	0.20	0.68	0.02	0.00	0.01	0.43	0.14
949.00	40.00	48.00	21.42	75.00	0.29	0.14	0.76	0.01	0.00	0.01	0.29	0.10
1401.00	40.00	48.00	33.00	75.00	0.44	0.22	0.66	0.02	0.00	0.01	0.46	0.15
915.00	40.00	48.00	18.92	75.00	0.25	0.13	0.78	0.00	0.00	0.01	0.26	0.08
900.00	40.00	48.00	19.50	75.00	0.26	0.13	0.78	0.00	0.00	0.01	0.26	0.09
1216.00	40.00	48.00	28.83	75.00	0.38	0.19	0.69	0.02	0.00	0.01	0.40	0.13
1227.00	40.00	48.00	26.42	75.00	0.35	0.18	0.71	0.01	0.00	0.01	0.36	0.12
1007.00	40.00	48.00	23.00	75.00	0.31	0.15	0.74	0.01	0.00	0.01	0.31	0.10
1007.00	40.00	48.00	22.17	75.00	0.30	0.15	0.75	0.01	0.00	0.01	0.30	0.10
1261.00	40.00	48.00	27.46	75.00	0.37	0.18	0.70	0.01	0.00	0.01	0.38	0.12
1154.00	40.00	48.00	26.25	75.00	0.35	0.18	0.71	0.01	0.00	0.01	0.36	0.12
1125.00	40.00	48.00	22.46	75.00	0.30	0.15	0.75	0.01	0.00	0.01	0.31	0.10
1080.00	40.00	48.00	22.58	75.00	0.30	0.15	0.75	0.01	0.00	0.01	0.31	0.10
1527.00	40.00	48.00	34.29	75.00	0.46	0.23	0.65	0.03	0.00	0.01	0.48	0.15
1348.00	40.00	48.00	30.08	75.00	0.40	0.20	0.68	0.02	0.00	0.01	0.42	0.13
1142.00	40.00	48.00	24.92	75.00	0.33	0.17	0.73	0.01	0.00	0.01	0.34	0.11
722.00	40.00	48.00	16.50	75.00	0.22	0.11	0.81	0.00	0.00	0.01	0.22	0.07
807.00	40.00	48.00	16.92	75.00	0.23	0.11	0.80	0.00	0.00	0.01	0.23	0.08
1052.00	40.00	48.00	19.33	75.00	0.26	0.13	0.78	0.00	0.00	0.01	0.26	0.09
1109.00	40.00	48.00	23.08	75.00	0.31	0.15	0.74	0.01	0.00	0.01	0.32	0.10
1112.00	40.00	48.00	25.42	75.00	0.34	0.17	0.72	0.01	0.00	0.01	0.35	0.11
993.00	40.00	48.00	19.92	75.00	0.27	0.13	0.77	0.00	0.00	0.01	0.27	0.09
1519.00	40.00	48.00	34.04	75.00	0.45	0.23	0.65	0.03	0.00	0.01	0.48	0.15
1171.00	40.00	48.00	25.17	75.00	0.34	0.17	0.72	0.01	0.00	0.01	0.35	0.11
653.00	40.00	48.00	10.17	75.00	0.14	0.07	0.87	0.00	0.00	0.01	0.14	0.05
1156.00	40.00	48.00	27.58	75.00	0.37	0.18	0.70	0.01	0.00	0.01	0.38	0.12
1013.00	40.00	48.00	23.08	75.00	0.31	0.15	0.74	0.01	0.00	0.01	0.32	0.10
823.00			24.42		0.33	0.16	0.73	0.01	0.00	0.01	0.34	0.11
778.65												
586.00			24.42									

Table 5 shows the parameter for queuing model

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A2 (a)

Multiple Priorities Waiting Line Model

		System	Class 1	Class 2	Class 3
Service rate	μ =	312			
Service time	$1/\mu$ =	0.0032			
Number of servers (max 12)	M =	2			
Arrival rate	λ =	147.0000	50	31	66
System Utilization	ρ =	0.2356			
Probability system is empty	P_0 =	0.6187			
Average number in line	L_q =	0.0277	0.0078	0.0056	0.0143
Average number in system	L_s =	0.4988	0.1681	0.1049	0.2258
Average time in line	W_q =	0.0002	0.0002	0.0002	0.0002
Average time in system	W_s =	0.0034	0.0034	0.0034	0.0034

Calculations:

M			P0
1	1.000	0.891	0.529
2	1.471	0.145	0.619
3	1.582	0.021	0.624

Table 6 Shows the no of patients in a 9-12 shift

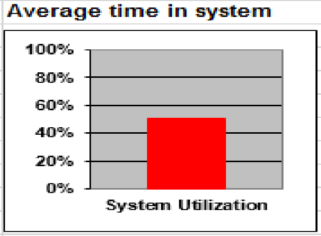
(b)

Multiple Priorities Waiting Line Model Basic

<Back

Number of servers M = 1

		System	Class 1	Class 2	Class 3	Class 4
Service rate	μ =	312				
Increment	$\Delta\mu$ =	1				
Service time	$1/\mu$ =	0.0032				
Arrival rate	λ =	157.0000	45	64	48	
System Utilization	ρ =	0.5032				
Probability system is empty	P_0 =	0.4968				
Average number in line	L_q =	0.5097	0.0848	0.1854	0.2395	
Average number in system	L_s =	1.0129	0.2290	0.3905	0.3934	
Average time in line	W_q =	0.0032	0.0019	0.0029	0.0050	
Average time in system	W_s =	0.0065	0.0051	0.0061	0.0082	



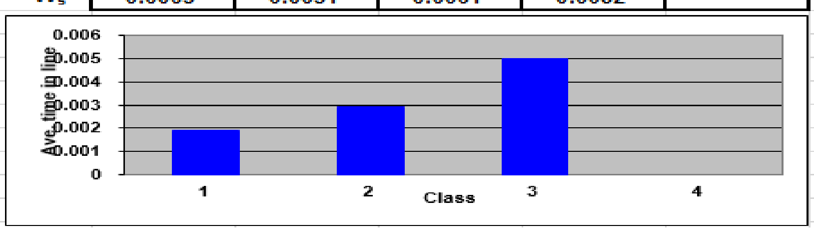


Table 7 Shows the no of patients in 12-15 shift

(c)

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Multiple Priorities Waiting Line Model

Service rate	μ =	312			
Service time	$1/\mu$ =	0.0032			
Number of s	M =	2			
			Class		
		System	1	2	3
Arrival rate	λ =	142.0000	68	32	42
System Utili:	ρ =	0.2276			
Probability s	P_0 =	0.5980			
Average nur	L_q =	0.0236	0.0098	0.0055	0.0083
Average nur	L_s =	0.4787	0.2278	0.1081	0.1429
Average tim	W_q =	0.0002	0.0001	0.0002	0.0002
Average tim	W_s =	0.0034	0.0033	0.0034	0.0034

Calculations:

M			P0
1	1.000	1.013	0.497
2	1.503	0.169	0.598
3	1.630	0.026	0.604

Table 8 Shows the no of patients in 15-18 shift

(d)

Multiple Priorities Waiting Line Model

Service rate	μ =	312			
Service time	$1/\mu$ =	0.0032			
Number of s	M =	2			
			Class		
		System	1	2	3
Arrival rate	λ =	124.0000	57	20	47
System Utili:	ρ =	0.1987			
Probability s	P_0 =	0.5980			
Average nur	L_q =	0.0146	0.0059	0.0024	0.0063
Average nur	L_s =	0.4121	0.1886	0.0665	0.1570
Average tim	W_q =	0.0001	0.0001	0.0001	0.0001
Average tim	W_s =	0.0033	0.0033	0.0033	0.0033

Calculations:

M			P0
1	1.000	1.013	0.497
2	1.503	0.169	0.598
3	1.630	0.026	0.604

Table 9 Shows the no of patients in 18-21 shift

A3

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1												
2		y1	y2	y3	y4	y5	y6	y7	y8			
3	REQUIRED	8	0	0	0	4	1	0	0			
4												
5	objective function											
6												
7	required	8	0	0	0	4	1	0	0			
8	number	1	1	1	1	1	1	1	1			
9												
10	total	13										
11												
12	CONSTRAINTS											
13		y1	y2	y3	y4	y5	y6	y7	y8	TOTAL		
14	9.00-12.00	1	0	0	0	0	0	0	0	8	>=	7.35
15	12.00-15.00	1	1	0	0	0	0	0	0	8	>=	7.85
16	15.00-18.00	1	1	1	0	0	0	0	0	8	>=	7.1
17	18.00-21.00	1	1	1	1	0	0	0	0	8	>=	6.2
18	21.00-24.00	0	0	0	0	1	0	0	0	4	>=	3.5
19	24.00-3.00	0	0	0	0	1	1	0	0	5	>=	0.6
20	3.00-6.00	0	0	0	0	1	1	1	0	5	>=	1.25
21	6.00-9.00	0	0	0	0	1	1	1	1	5	>=	4.15

Table 10 represents a solution for Linear Programming using EXCEL SOLVER

A4

	Number of patients							
Time	**Day 1**	**Day 2**	**Day 3**	**Day 4**	**Day 5**	**Day 6**	**Day 7**	**Average No of Patients per shift**
9.00-12.00	138	142	162	152	145	140	153	147.4285714
12.00-15.00	152	160	142	151	152	156	189	157.4285714
15.00-18.00	160	142	134	138	149	151	125	142.7142857
18.00-21.00	129	112	122	117	123	129	134	123.7142857
21.00-24.00	65	71	63	67	66	79	76	69.57142857
24.00-3.00	16	9	11	10	13	14	13	12.28571429
3.00-6.00	27	34	20	27	27	31	12	25.42857143
6.00-9.00	95	87	63	75	85	91	87	83.28571429

Table 11 represents the patient's arrival time and the no of patients being served in one shift

A4 (b)

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	9.00-12.00	12.00-15.00	15.00-18.00	18.00-21.00	21.00-24.00	24.00-3.00	3.00-6.00	6.00-9.00
Highly Affected	50	45	68	57	30	3	12	45
Moderately Affected	31	64	32	20	15	6	8	23
least Affected	66	48	42	47	25	3	5	15
Total patients	147	157	142	124	70	12	25	83
No. of doctors needed	7.35	7.85	7.1	6.2	3.5	0.6	1.25	4.15

Table 12 shows the category of patients as well as no. of doctors needed for every three-hour division.

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MULTIPLE SPOONS MOLD DESIGN FOR INJECTION MOLDING OF POLYPROPYLENE

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ABSTRACT

Mold design and process parameters that are routinely performed in injection molding industries have a direct and dramatic influence on product quality, cost and life time. This project presents designing of a mold for multiple spoons, installing at injection molding machine, analysis of injection molding process parameters and also material selection for spoons that is non-hazardous to health (nontoxic) and mold. The initial concept of the mold is to model in Pro-E. If the model satisfies the requirements of the injection mold process, the mold is then processed for stress and thermal analysis. Once the mold passes through thermal and stress analysis, the next stages are manufacturing of the mold through 5-axis CNC machine and then the installation of the mold is carried out at the injection molding machine for casting of the product. The process parameters of the product of the given material including injection temperature, injection pressure, total time and mold temperature is optimized by design of experiments (DOE) techniques to obtain the desire specimen with good qualities of characteristics.

Index terms---- Designing, Manufacturing, Process Optimization

1. INTRODUCTION

Now- a-days, injection molding put up the responsibility of a mass producing plastic parts to meet the apace rising market demand because of large number of consumer products are made of injection molding parts. The product quality depends upon selection of material for mold, mold design, and process parameters of the injection molding process. Here in this project the factors that affect the quality of the molded part can be classified into the following three factors.

1.1. Injection molding

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Injection molding is a manufacturing process for producing plastic parts by injecting molten material into a mold. It uses plastics in the form of pellets or granulates as a raw material. After heating the raw material, the melt material is injected into the mold cavity where it is allow to solidification to obtain the intended shape of the part after opened the mold and the part is ejected. The process parameters of the product of the given material including fill time, cooling time, injection speed, injection time, injection pressure, and mold temperature need to optimized by design of experiments (DOE) techniques to obtain the desire specimen with good qualities of characteristics. The trail-and-error method is costly and time consuming, thus not suitable for complex injection molding processes. The common quality problems that mostly occur due to injection molding process include, short shot, flash, weld lines, burns, and incompetency of operator. These problems usually arise from the setting of injection molding process parameters. The main objective of this project is the optimal setting of injection process parameters that affect the quality (surface roughness) of the specimen. In order to optimize the injection molding process parameters, here full factorial method is applied.

1.2. Design of experiment

Design of experiment is a method to determine the relationship between factors effecting a process and output of that process. In other words, it is used to determine cause-and-effect relationship. Obviously this information is used to manage the process input in order to optimize the output. Factorial design methods are a major set of building blocks for many experimental designs. In factorial design experiment all possible combination of factor levels are analyzed in each replicate.

2. LITERATURE REVIEW

From literature and local market survey it is concluded that polypropylene is used for various products. A polypropylene spoon which is extensively used in food products but there molds are not normally designed locally because of lack of facility and expertise for which the local industries have to visit the other cities where the process input requirements for making of molds are not considered according to the specifications of the machines available in local industries which cause various quality problems and also wastage of material.

2.1. Selection of plastic materials for spoons

Spoon can be made from Polystyrene (PS), Oxy-Biodegrade, and Polypropylene (pp). But from literature review polypropylene is concluded to be best as compared to others due to some reasons which includes,

I. Its melt flow rate (MRF) or melt flow index (MFI), here for the spoons polypropylene is selected. Melt flow rate is a measure of molecular weight of pp. This measure helps to determine how easily the molten material will flow during the process. So because of its higher MRF polypropylene will fill the mold more easily during the injection or blow-molding production process.

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II. Polypropylene is resistant to most chemical solvents and acids on different environmental conditions i.e high temperature, humidity etc still makes up a significant part of the market (less reactive and nontoxic).

III. Polypropylene has low density as compared to other plastic materials and having more flexibility and hardness.

IV. The production of plastic for utensils is also an intensive energy and materialistic process, having a large environmental impact for the amount of product generated. In figure 3, the numerical demand of resources needed to produce one pound of either polypropylene or polystyrene, the two main plastics used in plastic spoon production.

Table 2.1 (Worldcentric.org, 2012)

Manufacturing 1 lb of material	Energy Used (kWh)	Water Used (gal.)	Solid Waste (lbs.)	CO2 Emissions (lbs.)
Polypropylene	9.34	5.12	0.029	1.67
Polystyrene	11.28	20.54	0.113	2.51

2.2. Selection of material for mold

Mild steel also known as low carbon steel its composition contains 0.05%-0.25% carbon and up to 0.4% manganese while phosphorus and sulphur is also present in little amount as impurities. It is low cost material and is easy to shape. It is not hard as high carbon steels but possess enough strength, carburizing can add its hardness. Mild steel is basically an alloy made by mixing metals and nonmetals. Sometimes a pure metal cannot fulfill all the properties needed for manufacturing product. So additives are included in the pure metal to obtain some specific properties necessary for the production. Mild steel is made by adding carbon and other elements in the iron. These elements improve the hardness, ductility and tensile strength of the metal. The reasons for the selection of mild steel as mold material are,

I. It is low cost material and is easy to shape.

II. Mild steel is not hard as high carbon steel but have high tensile (400Mpa) and yield strength (250Mpa). So as a result it can maintain its shape under enough high forces and also machined easily in lathe, milling etc.

III. Its melting point is 1400 Celsius which makes it stable under heavy temperature when we do casting in mild steel mold.

IV. The mild steel is less brittle and much ductile than other high carbon steel and these properties make it good for easy and proper machining and surface finish.

V. The reduced content of carbon in mild steel makes it malleable and less brittle than other grades of carbon steel. So for this reputation of versatility it makes popularity for number of manufacturing industries of mold making and household items.

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3. OBJECTIVES OF RESEARCH

Main objectives of this research are,

I. To design, analyze and manufactured the mold using PTC Creo, solid works and 5-axes CNC milling machine.

II. To create the best possible combination of input parameters for polypropylene spoon using injection molding machine.

4. RESEARCH METHODOLOGY

To achieve the expected goals and objectives of the study, the selection of proper methodology and its proper execution is always important. Therefore this research work is planned and executed in a way to achieve the desired objectives.

In methodology first mold is design and analyze in PTC Creo and solid works respectively. After this manufacturing of mold is done on 5-axes CNC milling machine and then same mold is installed in injection molding machine where experiments are carried out to optimize process parameters for spoon of polypropylene to decrease quality problems such as surface roughness.

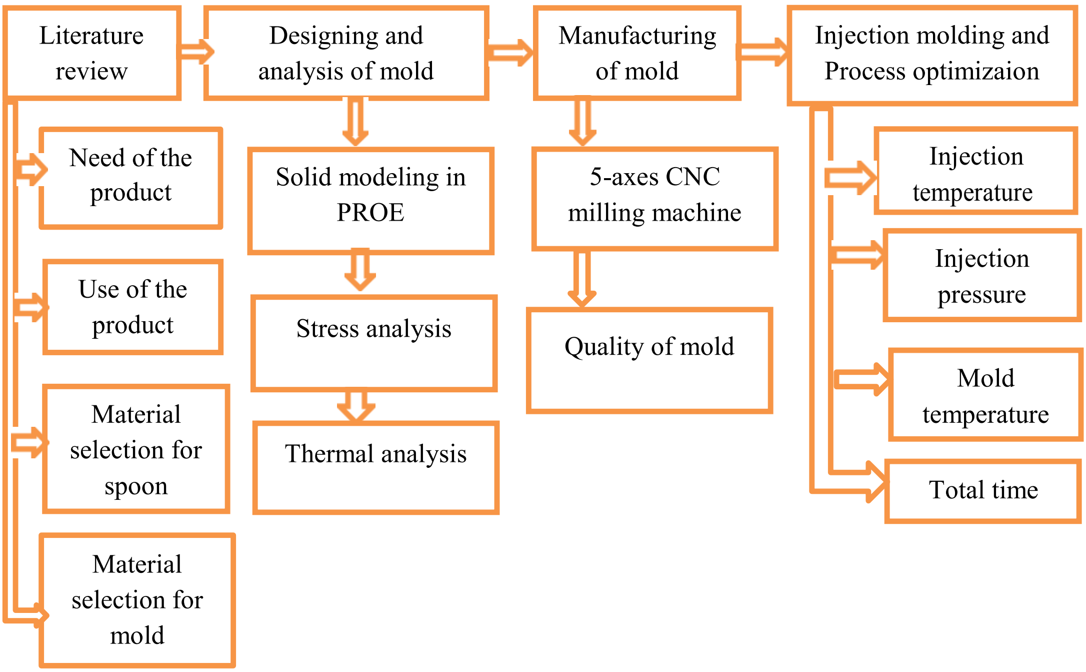

Figure 4.1 (Methodology procedure)

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5. MOLD MODELING IN PTC CREO

Mold can be model in PTC Creo along with final design of spoon. Cavity (drag) and core (cope) of the mold are made and assembled. Core of the mold is designed according to the bed of injection molding machine keeping in view the area of the bed of injection molding machine. This part of the mold is clamped with the bed of machine. While cavity is attached to the upper portion of the machine.

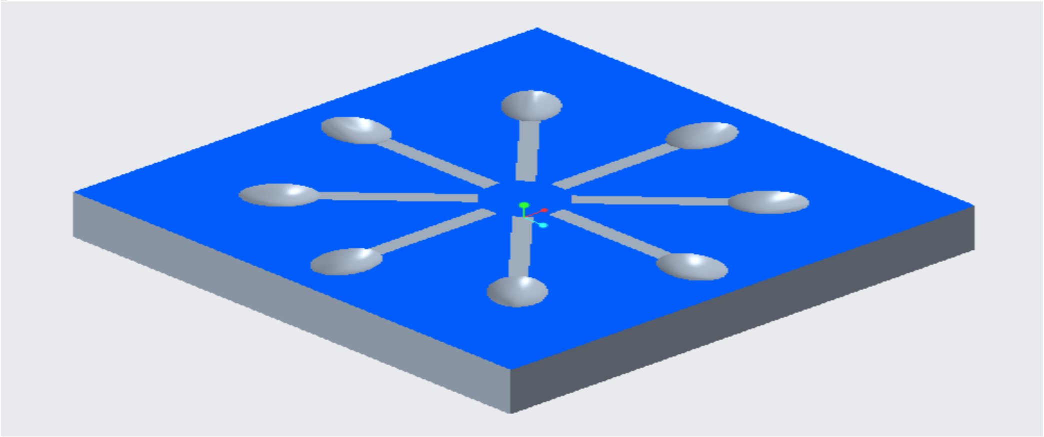

Figure 5.1 (Cavity of multiple spoons mold)

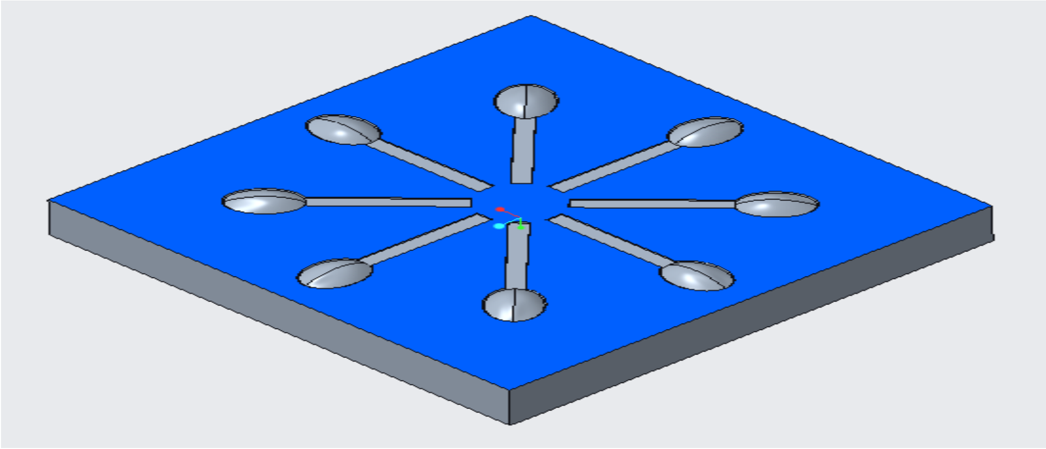

Figure 5.2 (Core of multiple spoons mold)

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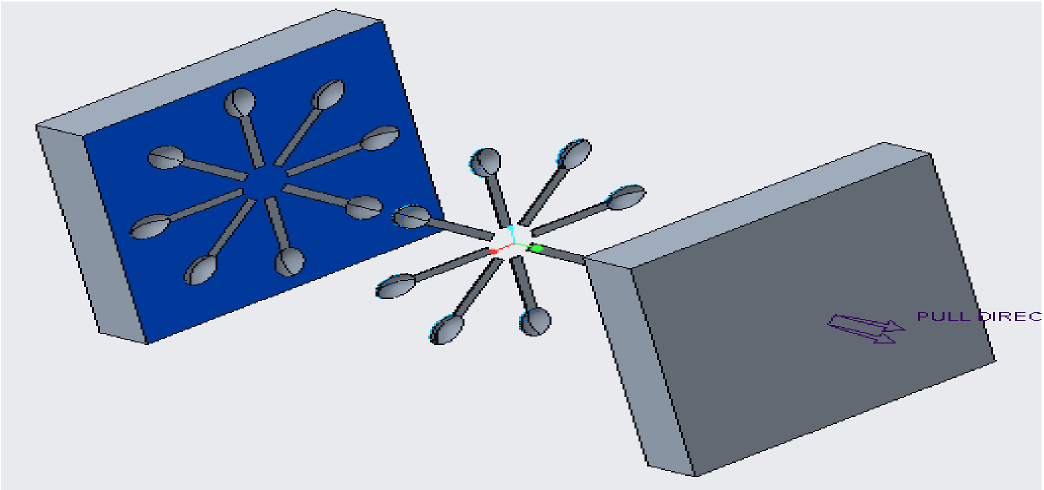

Figure 5.3 (Exploded view of the multiple spoons mold)

The dimension of the mold can be made by keeping in view the area of the bed of the injection molding machine. So due to this constraint the area of the core and cavity are set accordingly. The final model of the mold is then installed in injection molding machine after fabrication through CNC 5 axes milling machine. The final model of the mold contains core, cavity, cavity back plate, cavity plate, stepper plate, ejector plate, ejector back plate, punch, punch holding plate, spacers and bottom plate with their proper calculated dimensions.

6. ANALYSIS OF MOLD

Solid works Simulation enables every engineer and designer to carry out structural simulation on parts and assemblies with finite element analysis (FEA) while they work to improve and validate performance and reduce the need for costly prototypes or design changes later on.

The flow chart of analysis of mold:

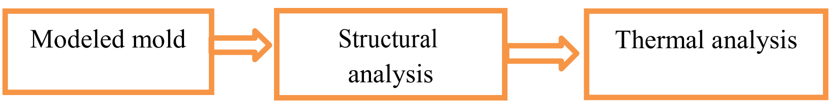

Figure 6.1 (Flow chart of mold analysis)

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In analysis more interest is in stress and thermal analysis that what changes will occur as a reaction after applying pressure and temperature on the mold. The result of thermal and stress analysis are shown later in results.

7. EXPERIMENTAL SETUP

Manufacturing of mold on 5-axes CNC milling machine is discussed and features of injection molding machine and all other experimental work which is done on this machine.

7.1. Manufacturing of Mold

For the manufacturing of mold CNC 5-axes milling machine is used which is available in advance lab industrial department UET Peshawar. Mold fabrication itself is a very tough task. For manufacturing of mold only 3 axis are going to used we detached fourth and fifth axis as our job cutting was possible through 3 axis. In manufacturing of mold extra material is removed and facing can be done on each part to smooth the surface of mold. For machining of different parts of mold program can be developed from creo parametric drawings which are then communicated with the machine. After programming different parameters concerned with the manufacturing of mold are selected mostly depth of cut, speed and feed and their values are set in such a way to give a quality mold.

7.2. Installation of mold on injection molding machine

The machine on which optimization of a process parameters are carried out is vertical molding machine known as vertical type plastic injection molding machine available in Industrial department UET Peshawar.
Special attention should be given to the center of gravity of the machine and place the machine straight and steady. Before injecting material into the mold both parts of the mold are closed. They are clamped together by a clamping unit. And then complete mold is attached to the machine and both halves are held tight while poring material.

7.3. Working principle

The molding material polypropylene is poured into hopper from where it is transmitted to the heating section of the machine where increase in temperature and pressure takes place. As due this the material is melted and is forced at high pressure via nozzle into a closed mold which forms the final specimen. Then the mold split and eject the finished part. The mold must be cooled by circulating water and control system is there to control the process.

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8. ANALYSIS OF PROCESS PARAMETERS ON INJECTION MOLDING MACHINE

The analysis of process parameters on injection molding machine can be carried out by selecting different input parameters and are optimized to get good quality product.

8.1. Design of experiment

Design of experiment is a systematic tool which is used to find the relationship among input factors upsetting process and the response of that process.

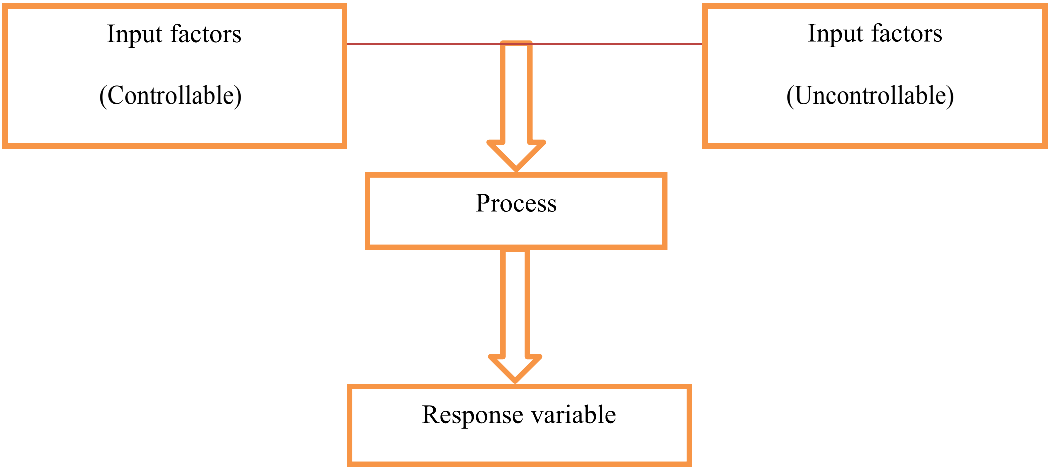

Figure 8.1 (Design of experiments)

8.2. Full factorial design

Factorial design method are a major set of building blocks for many experimental designs. In factorial design experiment all possible combination of factor levels are analyzed in each replicate.
Four parameters are taken as process parameters which includes injection temperature, injection pressure, total time and mold temperature while surface roughness as response variable. After this by taking 3 levels of each factor the total number of experiments obtained are 81 by taking replication of 1.

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Sr. No.	Full factorial design experiment				
1	Factors:04			Replicates:01	
2	Total runs:81			Base runs:81	
3	No of levels	03	03	03	03

Table 8.1.a (Experiment obtained from four factors having three levels of each)

9. RESULTS AND DISCUSSIONS

Results of structural and thermal analysis in solid works are discussed and results of analysis of variance is also discussed that what is the best possible combination of temperature, pressure, time and mold temperature for better output response.

9.1. Stress analysis

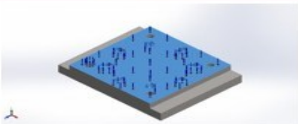
Load name	Load Image	Load Details
Pressure-1		Entities: 17 face(s) Type: Normal to selected face Value: 1.4e+7 Analysis type: static Units: N/m^2 Phase Angle: 0 Units: deg

Figure 9.1 (Load details)

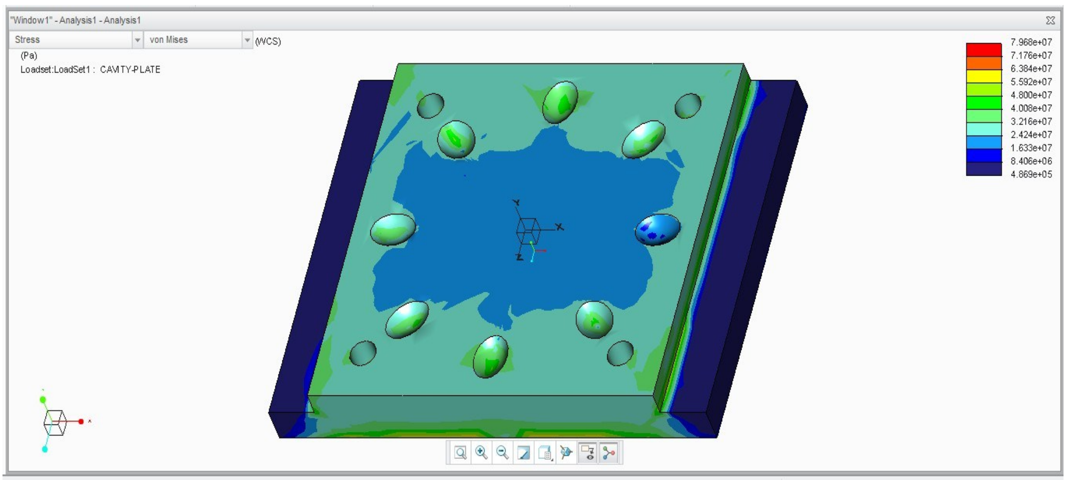


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Figure 9.2 (structural static stress analysis of multiple spoons mold)

The maximum level of pressure of injection molding machine is 140bar when we apply this 140 bar pressure on mold during analysis it will noted that the maximum static stress is 7.968e+07pa (796.8bar) and minimum static stress is 4.869e+05pa (4.869bar) respectively. So it is in the range as the yield strength of mild steel is 250MPa.

9.2. Thermal analysis

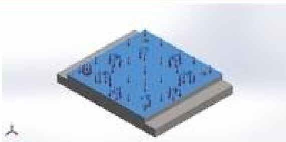
Temperature-1		Entities: 17 face(s) Temperature: 240 Celsius

Figure 9.3 (Load details)

Name	Type	Min	Max
Stress1	VON: von Mises Stress	7.983e+006 N/m^2 Node: 1410	3.400e+008 N/m^2 Node: 19250

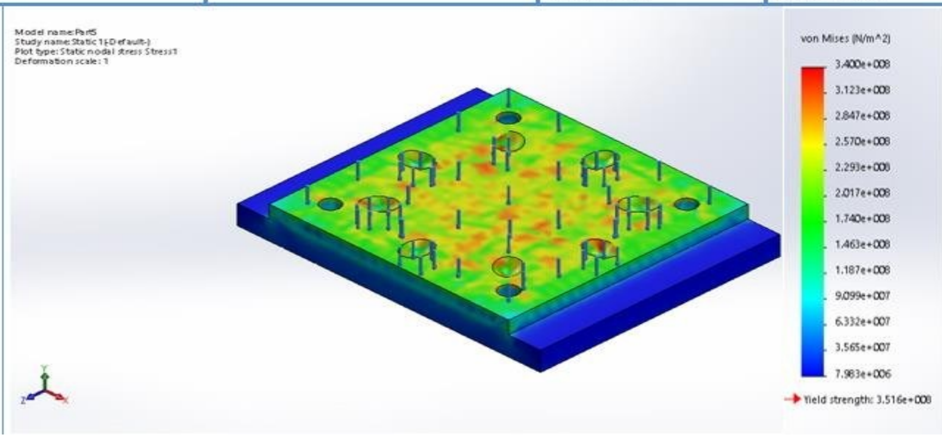


Figure 9.4 (Thermal stress analysis of multiple spoons mold)

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Name	Type	Min	Max
Strain1	ESTRN: Equivalent Strain	1.6264e-006 Element: 10878	0.00248131 Element: 4853

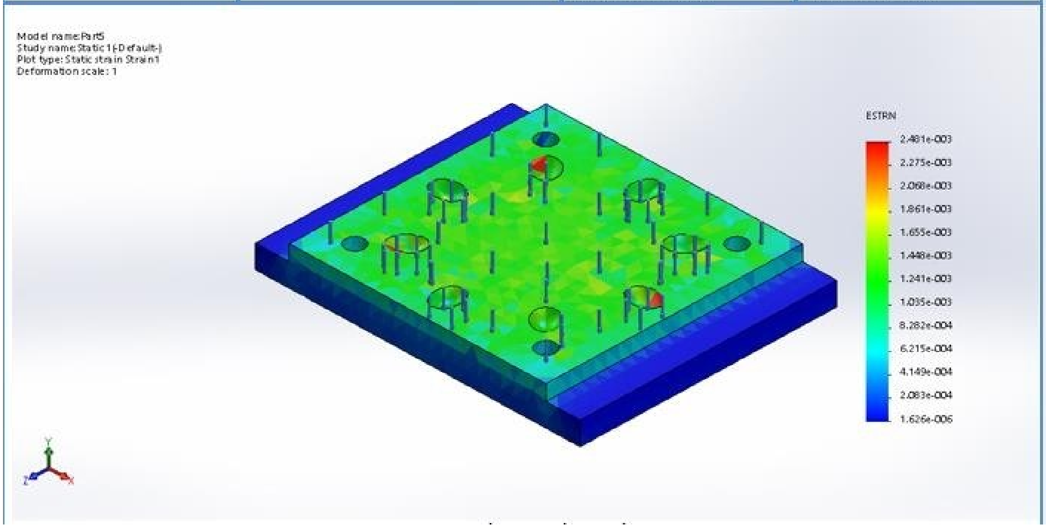

Figure 9.5 (Thermal strain analysis of multiple spoons mold)

The change in temperature of the mold can produce substantial deformation, stresses and strains. Thermal stress analysis can refer to a static stress analysis that's include the effect of the temperature. The result of thermal strain is also given. The above thermal analysis is carried out at 240 C and we know that mild steel often melts at 1370 degree C which is very high than 240 degree C hence the mold is not going to deform.

9.3. Response variable

The response variable is surface roughness for which four parameters are taken as process parameters which includes injection temperature, injection pressure, total time and mold temperature while surface roughness as response variable. After this by taking 3 levels of each factor the total number of experiments obtained are 81 by taking replication of 1. The final result that are obtained from analysis of variance (ANOVA) which eliminate all insignificant input variables (treatments) and their interrelations. From analysis of variance it is concluded that total time and mold temperature are the significant factors contributes to response variable and then run the experiments and calculate the minimum surface roughness from these four factors.

10. CONCLUSION

Following are the conclusion of this research paper,

I. Designing and analysis of a mold is one of the objective of this research paper which is done using PTC Creo and Solid works software. After this fabrication of mold is done on CNC 5-axes milling machine with complete control system to get better quality mold.

II. On injection molding process the best combination of selected parameters (injection temperature, injection pressure, total time, injection time are made to optimize the process and get the better surface finish of the final product.

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SUPPLIER SELECTION FOR OIL REFINERY BY USING MCDM APPROACH: CASE OF PAKISTAN REFINERY LIMITED (PRL) IN A POINT

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GIK Institute, Topi, Pakistan

Abstract

The competitive environment of sales and technological market increased the importance of Supplier Selection Process (SSP). Through SSP firms identify, evaluate and contract with suppliers. Since the major portion of the firm budget is spend on purchasing raw material and component parts. Therefore, the firm have to properly identify the most economical suppliers. In this study, SSP of third largest oil refinery in Pakistan named Pakistan oil Refinery Limited (PRL) is investigated. The process plant of PRL is operating since 1962 to refine crude oil into gasoline, kerosene, asphalt base, etc. To attain maximum profit and enhance industrial growth of these products, a proper Supply Chain Management (SCM) for PRL is necessary. The aim of this research is, to choose the best crude oil supplier for PRL from five available sources namely Local Crude (Badin), Upper-Zakum, DAS, Murban and Light Arabian. These suppliers of crude oil are studied using cost, technology, viscosity, toxicity, API gravity, sulfur content, and alkane content as criterions for selection. For this purpose, Multi Criteria Decision Making (MCDM) tool "Technique of Order Preferences by Similarity to the Ideal Solution" (TOPSIS) and "Analytic Network Process" (ANP) is used respectively. Furthermore, sensitivity analysis is performed to check the behavior of crude source when certain selection criteria's of crude oil are varied. After analysis, it revealed that alternative DAS is the most economical and cost effective supplier. Additionally, the model presented in this paper can also be used in other organizations as well.

Keywords: SSP, SCM, MCDM, ANP, TOPSIS, PRL, Sensitivity Analysis

1 Introduction

The optimization of operations to maximize both speed and efficiency are important part of SCM (Dekker, 2012). Speed is necessary because customer needs fast service. Usually, the fast service increase the cost of the organizational product (Card, 1993). Therefore, the efficiency is equally important along with fast service. Basically, the SCM involves the delivery of raw material from supplier to manufacturer, and ends with the supply of final product or service to the customers (Harland, 1996). According to (Goffin, 1997) supplier management is the important factor of SCM because the

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cost of raw material and component part constitutes the main cost of the product. Mainly, in high technology industries the cost of raw material and services signifies about 80% of total product cost (Weber, 1993). Therefore, the procurement department of organization focus on selecting the best supplier that reduces the purchasing cost and increase the organization profitability (Ghodsypour, 2001). Supplier selection is a multi-criteria problem which considers the qualitative and quantitative factors (Amid, 2011) . Furthermore, different criteria's are identified, on the basis of these proposed criteria's all alternatives are analyzed. In this research, the SSP for PRL is under consideration and different criteria's are specified for this purpose. These criteria's are analyzed by using MCDM tools called ANP and TOPSIS followed by sensitivity analysis.

1.1 TOPSIS

TOPSIS or 'Technique of Order Preference by Similarity to the Ideal Solution' was firstly proposed by Hwang & Yoon (Ching-Lai Hwang, 1981). Basically, TOPSIS is an MCDM tool used to choose the best alternative having shortest distance from ideal solution and longest distance from anti-ideal solution (Karsak, 2002). For TOPSIS, all the criteria's are divided into benefit criteria and cost criteria's. For benefit criteria, the higher value criteria is chosen as best alternative while in cost criteria, the lower value criteria is considered as best alternative. Therefore, the ideal solution increases the benefit criteria to a maximum while decreasing the cost criteria to a minimum. On the other side, the anti-ideal solution increases the cost criteria to a maximum while decreasing the benefit criteria to a minimum. (Alessio Ishizaka, 2013).

1.2 Analytic Network Process

ANP or 'Analytic Network Process' is first proposed by Thomas Saaty in 1996 (Saaty T. , 2006). ANP is also MCDM tool that provides the decision-maker a solution which takes interdependence and feedback into consideration. In ANP, a network contains clusters which in turn consist of elements (Aragonés-Beltrán, 2010). These clusters are categorize into three types those are source cluster, sink cluster and transient cluster. Source clusters only have arrows entering to them whereas the sink cluster only have arrows leaving them. Additionally, the transient cluster behave in both way i.e. arrows entering and leaving at single time (Saaty T. , 1996). Moreover, dependency in a network can be divided into two types: inner dependency and outer dependency (Saaty T. , 2004). In outer dependency, the cluster's element affect the other elements of the cluster, whereas, in inner dependency, the element of one cluster affect each other (Sadeghi, 2012).

1.3 Sensitivity Analysis

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Sensitivity analysis is the study of how the uncertainty in the output of a mathematical model or system (numerical or otherwise) can be apportioned to different sources of uncertainty in its inputs. (Saltelli, 2002) In operations management is a technique used to determine how different values of an independent variable impact a particular dependent variable under a given set of assumptions. (Sudret, 2008)

1.4 Pakistan oil Refinery Limited (PRL)

PRL produces major portion of Pakistan energy requirements by refining and processing crude oil. PRL is the leading crude oil refinery in Pakistan. In PRL, different petroleum products such as Kerosene oil, Furnace Oil, Jet fuel, High Speed Diesel, Motor gasoline are isolated from crude oil. Currently, PRL carries out its operations in Karachi and the products are distributed locally and exported to meet the demands of the suppliers, both local and abroad (Limited,2015).

PRL receive crude oil from five different sources, one of which is a local source situated in Badin, Sindh. The four other sources are situated in the Middle East, namely, Light Arabian, Upper-Zakum, DAS and Murban. The existing model for the selection criterion at PRL is not Cost effective. Currently, the technical department review the crude oil quality and inform operation department to process crude blend. Therefore, supply Chain Department checks the Margin on a daily basis, thus deducing which crude is the best choice in terms of Refinery Profitability. Hence, it is required to develop a model for PRL to select the best source on the basis of specified criteria's for crude oil.

The specified criteria's of PRL for selection of best crude oil is cost, quality, technology, sulfur content, alkane content, viscosity and API gravity. The attributes associated with crude oil from available five sources are different from each other. Therefore, the company has to constantly update its decision regarding selection of optimal source. Hence, the selection of best source is of critical importance for producing high quality products and to maximize profit for the business.

The paper proposes, to devise a model for PRL by which the company can select the best crude oil source by ranking the criteria in terms of their importance in the selection process. Analytic Network process (ANP) has been used to synthesize the preferred solution and the solution has been verified by Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS). Furthermore, sensitivity analysis is carried out on both the MCDM techniques. This sensitivity analysis will provide the critical region within which the preferred solution is expected to change.

2 Literature review

Selection of supplier is basically the process to find out the most economical supplier who can fulfill the demanded quality and quantity of required material. During recent years organizations started focusing on study of SCM and SSP for their business growth. Nowadays, the customer need to have best quality product with lower price and good after sale services (Matzler, 1998). Therefore, companies always work on their SSP to decrease their material cost while maintaining their customers satisfied with their product. SSP is a multi-criteria problem and can be solved with three

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major types of models, those models are: mathematical programming models, cost based models, and categorical models (Kilincci, 2011). The MCDM technique used for this research is, ANP and TOPSIS followed by sensitivity analysis of all alternatives.

These different mathematical programming models used in SSP aim to optimize cost, quality and profit of the organization. These mathematical models are multi-objective approach aim to minimize cost, enhance the quality and on time delivery of product to customers (Amin, 2012). Furthermore, the cost based model also aim to study cost and benefit analysis of different projects (Lappe, 2014).

The Analytic Hierarchy Process (AHP) is widely used by decision makers and researchers. This tool provides solution to decision maker which takes feedback and interdependence under consideration. Furthermore, ANP approach can be used to find out the risk associated with SSP (Hsu, 2009). Beside this, AHP approach can also be used for the risk assessment of sustainable ground improvement (Cerić, 2013). Additionally, ANP approach can further be used in making different complex decisions about benefits, opportunities and cost-estimation (Dağdeviren, 2008). Furthermore, ANP method collaborated with Fuzzy is used for the selection of best supplier in SCM (Wei, 2010). Furthermore, ANP approach is also used to study the impact of different factors on SCM and making different strategic decisions in competitive business environment (Jayant, 2011).

The TOPSIS approach is MCDM tool and is widely used for ranking problems in real time conditions with finite number of alternatives (Chamodrakas, 2009). In this method, all alternatives are analyzed according to their distances from ideal solution. The alternative having the shortest geometric distance from ideal solution is considered best alternative (Aliakbarzadeh, 2014). Furthermore, TOPSIS approach collaborated with Fuzzy is used for the selection of plant location on the basis of various criteria (Chu, 2002), these criteria's are assessed in linguistic terms by using fuzzy numbers. Furthermore, TOPSIS approach is also used for group multi-criteria supplier selection problems (Zouggari, 2012).

AHP and TOPSIS both used for this research because of easy to compute and easily understood. Furthermore, these methods directly provides a definite value to calculate their final results. AHP along with TOPSIS approach under Fuzzy environment is used for transshipment site selection (Önüt, 2008). Furthermore, the same approach is used for the selection of appropriate operating system for firms by evaluating different criteria's of the system (Ballı, 2009). Beside this, this approach is also applicable for the selection of best supplier to any firm. Therefore, this technique is used for the selection of best supplier for automotive industry under different proposed criteria of suppliers (Junior, 2014).

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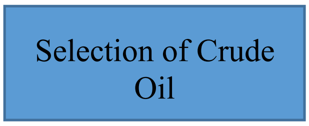
After successfully implementation of the aforementioned MCDM tools, sensitivity analysis is performed to check the behavior different sources while varying the criteria's. The methods used for performing sensitivity analysis are classified as: Mathematical, Statistical and Graphical (Christopher Frey, 2002). The mathematical method mainly involve the calculation of output using few values of input that signify the possible range of the input (Van Griensven, 2006). Whereas, the statistical methods include the simulation where probability distribution is assigned for inputs provided (Christopher Frey, 2002). Furthermore, the graphical methods are used to provide visual representation of the results when the inputs are varied.

3 Methodology

This paper employs two different multi criteria decision making (MCDM) techniques namely, ANP and TOPSIS along with their sensitivity analysis. Both techniques are used to rank alternatives in the presence of multiple criterion.

3.1 Selection Criteria

Selection of the best crude oil source is one of the most essential decisions in an oil refinery. Like every refinery, PRL aims to maximize the profit and minimize the costs. For this purpose, PRL evaluate seven criteria on the basis of which they analyze five different crude oil sources. Figure 1 shows the relationship between the different criteria and alternatives while keeping the objective of selecting the crude oil source in mind. Furthermore, Table 1 displays the definitions of the different selection criteria being taken under consideration.



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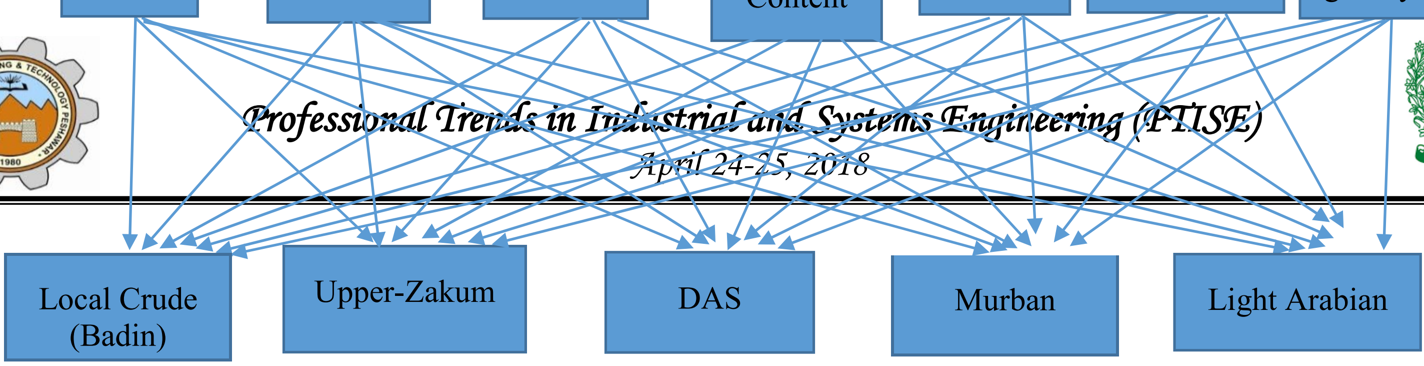

Figure 1. selection Criteria of crude oil

Criteria	Definition
Cost	The price of purchasing one barrel of crude oil.
Technology	The amount and quality of refining equipment the crude oil requires to create the desired products.
Toxicity	It refers to how dangerously poisonous the oil and its refining processes are to local life.
Viscosity	It relates to the oil's resistance to flow. It affects the transport and refining processes.
Sulfur content	The amount of sulfur present in the crude oil.
API Gravity	A specific gravity scale developed by API to measure the relative density of crude oil.
Alkane content	The amount of different types alkanes (a class of hydrocarbons) present in the crude oil.

Table 1. Selection Criteria Definitions

The Table 2 given below contains the absolute values of each criteria relative to each alternative and is obtained by a PRL's personnel.

Attributes	Alternatives				
	Local Crude (Badin)	**Upper-Zakum**	**DAS**	**Murban**	**Light Arabian**
Cost ($/barrel) for September, 2016	30.45	42.80	44.85	45.50	42.92
Technology	Much higher	Lower	Lower	Higher	Much lower
Toxicity (mg/L)	13	8	5	7	11
Viscosity (mPa.s at 15°C)	11.59	9.06	4.73	7	14
Sulfur content (wt %)	1.54	1.84	1.14	0.78	1.8

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API Gravity	37.6	39.9	38.8	40.5	33.4
Alkane content (wt %)	65	67	72	81	51

Table 2. Attribute Parametric Values

3.2 TOPSIS

TOPSIS assumes that there are *m* alternatives and *n* attributes/criteria and the criterion are either divided into positive and negative attributes. The score of each option is given with respect to each criterion. The weights of the criteria are calculated in the following manner:

- Rate the criteria on a scale of 1-9
- Sum the weights
- Divide each rating by the sum.

The TOPSIS procedure consists of the following steps:

STEP 1: Establish a performance matrix.

The z_{ij} represents the performance values of the alternatives with respect to some attribute/criterion.

STEP 2: Normalize the performance matrix.

The normalized performance matrix can be obtained using the following transformation formula:

$$n_{ij} = \frac{z_{ij}}{\sqrt{\sum^{m} (z\ )^2}}, \qquad j = 1, \dots, n, i = 1, \dots, m. \tag{1}$$

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$j=1 \quad ij$

STEP 3: Construct the weighted normalized performance matrix. The weighted normalized value is calculated as:

$$v_{ij} = w_j \times n_{ij}, \quad j = 1, \dots . n, i = 1, \dots, \qquad (2)$$

STEP 4: Determine the ideal and anti-ideal solutions.

The ideal value set A^+ and the anti-ideal value set A^- are determined as follows:

$$A^+ = \{v_1^+, \dots, v_n^+\} = \{(\max_i v_{ij}, j \in J)(\min_i v_{ij}, j \in J')\} \quad i = 1,2, \dots, m \qquad (3)$$

$$A^- = \{v_1^-, \dots, v_n^-\} = \{(\min_i v_{ij}, j \in J)(\max_i v_{ij}, j \in J')\} \quad i = 1,2, \dots, m \qquad (4)$$

Where J is associated with benefit attribute, and J' is associated with negative attribute.

STEP 5: Calculate the separation measures.

The separation of each alternative from the ideal solution A^+ is given as follows:

$$d_i^+ = \{\textstyle\sum_{j=1}^n (v_{ij} - v_j^+)^2\}^{\frac{1}{2}}, \quad i = 1, \dots, m \qquad (5)$$

The separation of each alternative from the anti-ideal solution A^- is given as follows:

$$d_i^- = \{\textstyle\sum_{j=1}^n (v_{ij} - v_j^-)^2\}^{\frac{1}{2}}, \quad i = 1, \dots, m \qquad (6)$$

STEP 6: Calculate the relative closeness to the ideal solution.

The relative closeness R_i to the ideal solution can be expressed as follows:

$$R_i = \frac{d_i^-}{d_i^+ + d_i^-}, \quad i = 1, \dots, m \qquad (7)$$

$$If\ R_i = 1 \rightarrow A_i = A^+$$

$$If\ R_i = 0 \rightarrow A_i = A^-$$

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Where the $\bar{R}_i$ value lies between 0 and 1. The i^{th} alternative will get more priority when $\bar{R}_i$ value get closer to 1.

STEP 7: Rank the preference order

Rank the best alternatives according to R_i in descending order.

Sensitivity analysis on TOPSIS

It was realized that the criteria ratings of all alternatives are subject to random and frequent changes depending on the overall oil quality and world market prices. The objective was to see how reliable the decision is and what are the parameters that are critical in the decision. Furthermore, any minor variations in these critical parameters can lead to the decision being nullified. Thus, carrying out a sensitivity analysis was necessary to determine the extent of stability in the decision made.

The sensitivity analysis performed in this research is quite different. Even after sufficient literature review about reasonable method, within our scope, was not found. As a result, a new and innovative method was devised by the team which is outlined below.

An iterative technique was carried out on excel. By changing one variable and keeping others constant, it was found how far a particular variable can affect the decision.

A directional sensitivity analysis was carried out. Through this, direction in which the selection of the present decision would be favored was neglected. Additionally, the direction in which its selection would be at risk was analyzed. Furthermore, for each criterion the change in decision rating was noted at the point where the decision changed.

Following from aforementioned explanation, the negative attribute characteristics were reduced and the positive attribute characteristics were increased for all alternatives except DAS (selected alternative), where it was done the opposite.

Then a difference was found between the values of attributes before and after the decision was changed. This indicated the deviation or change that a particular criterion undergoes to cause a change in decision.

3.3 ANP

Following are the steps for selection of the best crude oil supply as a raw material for Pakistan Refinery by the application of Analytic Network Process.

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Step 1: Problem definition and model construction

The application of ANP is initiated by a definition of the problem through clearly stating the objective, criteria, and the possible alternatives. Once all the concerned elements identified, then a network structure can be formed. Furthermore, this will help in constructing a model to apply ANP. The analytic network structure formed is a pictorial representation of the relations involving the cluster groups of elements. Furthermore, this also help in identifying the single way or double way dependence of elements to each other. In this case, there exist five different alternatives for PRL to choose their crude oil supply source. Furthermore, there are several criteria that affect this selection of crude oil supply source. It is worth noting that the objective that is source selection is dependent on the influence of each criterion. However, the alternatives and criteria have a correlation of interdependence.

Step 2: Data Acquisition and Industrial Survey

According to ANP structure a pairwise comparison of elements is supposed to be made using a fundamental scale of absolute numbers. For this purpose, data from PRL was acquired that provided cost, quality, contamination, and other parameters of each crude oil source so that a comparison could be made. A questionnaire was also sent to several experts at the Refinery for additional insights on the preferences maintained.

Step 3: Pairwise comparison

ANP involves pairwise comparison of all elements that depend on each other so that all dependencies are catered to when finding the ideal alternative. For this comparison a scale of 1-9 is used shown in Table 3, which is fundamental scale of absolute numbers. The comparison within a criterion for various alternatives is simple with 9 for best and 1 for worst alternative according to that criterion. However, the comparison of one criterion to another for a certain alternative is intricate and complex. It is done by comparing the relative position of the said alternative in criterion to the relative position of that alternative in the next criterion. Furthermore, the better rank of alternative in one criterion is to rank in the next criterion for the same alternative. If this get higher scale number then it is consider to be best criterion. The following scale was used.

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Degree of Importance	Meaning	Description
1	Equal Importance	Equal contribution by two activities to the objective.
2	Weak	
3	Moderate Importance	One activity is favored slightly over the other due to judgment and experience.
4	Moderate plus	
5	Strong importance	One activity is favored strongly over the other due to judgment and experience.
6	Strong plus	
7	Very strong or demonstrated importance	One activity is favored very strongly over the other due to judgment and experience.
8	Very, very strong	
9	Extreme importance	Favoring of the highest possible order of one activity over the other.

Table 3. The Fundamental Scale of Absolute Numbers

For pairwise comparison a matrix is constructed in which element a_{ij} is the relative importance of i^{th} criterion or alternative to the j^{th} criterion or alternative. The matrix below is called pairwise matrix.

$$A = \begin{bmatrix} 1 & a_{12} & \cdots & a_{1n} \\ 1/a_{12} & 1 & a_{23} & a_{2n} \\ \vdots & 1/a_{23} & \ddots & \vdots \\ 1/a_{1n} & 1/a_{2n} & \cdots & 1 \end{bmatrix} \tag{8}$$

Step 4: Eigenvalues and eigenvector calculation

The procedure ahead includes calculation of eigenvector "w" and eigenvalues $\lambda_{\max}$ by the following formula.

$$A.w = \lambda_{max} \cdot w \tag{9}$$

Where A is the pairwise matrix. In order to find the eigenvalues, you first need the eigenvector by the formula below that is known as the average of normalized columns method.

$$w = {}^{1}\sum^{n} \quad a_{ij} \tag{10}$$

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$i \quad \bar{n} \quad j=1 \overline{\sum_i^n a_{ij}}$

Then perform the matrix calculations as shown below:

$$\begin{bmatrix} 1 & a_{12} & \cdots & a_{1n} \\ 1/a_{12} & 1 & a_{23} & a_{2n} \\ \vdots & 1/a_{23} & \ddots & \vdots \\ 1/a_{1n} & 1/a_{2n} & \cdots & 1 \end{bmatrix} \times \begin{bmatrix} w_1 \\ w_2 \\ \vdots \\ w_n \end{bmatrix} = \begin{bmatrix} W_1 \\ W_2 \\ \vdots \\ W_n \end{bmatrix} \tag{11}$$

$$\lambda_{max} = \frac{1}{n}\left(\frac{W_1}{w_1} + \frac{W_2}{w_2} + \cdots + \frac{W_n}{w_n}\right) \tag{12}$$

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Step 5: Check for inconsistencies

Before moving further one needs to ensure that the judgment was reasonable enough. For this purpose, a method of checking the consistency in the values after manipulation is derived that uses consistency ratios (C.R.).

$$C.R. = \frac{C.I.}{R.I.}$$

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(13)

Where R.I. is the random index from the table below:

	1	2	3	4	5	6	7	8
R.I.	0	0	0.58	0.90	1.12	1.24	1.32	1.41
N	9	10	11	12	13	14	15	
R.I.	1.45	1.49	1.51	1.48	1.56	1.57	1.58	

$$C.\,I. = \frac{\lambda_{max} - n}{n-1} \quad (14)$$

Now, if C.R. is less than 0.1, the process is regarded as satisfactory in consistency.

Step 6: Super matrix Formation

Now to get global priorities, the super matrix lists down all the sub-matrixes consisting of all the clusters and necessary elements where each matrix segment represents a relationship between two nodes (components or clusters).

$$W = [\begin{matrix} [W_{11}] & [W_{21}] & \cdots & [W_{1n}] \\ [W_{12}] & [W_{22}] & \cdots & [W_{2n}] \end{matrix} \quad (15)$$

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$$\begin{matrix} \vdots & \vdots & \ddots & \vdots \\ & [W_{n1}] & \cdots & [W_{nn}] \end{matrix} \Big] \; [W_{n1}]$$

Step 7: Weighted Super matrix Formation

To get the weighted super matrix, the influence of the clusters on each cluster with respect to the control criterion is determined. This yields an eigenvector and influence of the clusters on each cluster. Then the un-weight super matrix is multiplied by the priority weights from the clusters, which yields the weighted super matrix.

Step 8: Limit Super matrix Formation

To achieve a convergence, the weighted super matrix is raised to the power of $2k + 1$, where k is an arbitrarily large number, and the new matrix is called the limit super matrix. Step 9:

Optimal Source Selection.

The optimal alternative is selected by normalizing the rows of all the alternatives and then depicting them on a 0 to 1 scale with 1 being the highest magnitude in the normalized column. This is done by dividing the normalized entries with highest entry in the normalized column. (A. Yildiz1, 2015)

Sensitivity Analysis on ANP

The sensitivity analysis performed on ANP focuses on the critical region within which the preferred solution changes. Furthermore, during this changes the weights of each criteria are also varied, one by one, with respect to the best solution chosen by performing ANP. As the result obtained from performing ANP was DAS. Therefore, effect of changing the weights of criteria with respect to DAS is analyzed. For this purpose, weight of each criteria is changed using a software called Super Decisions. Through this software, critical points were obtained where the decision changes from DAS to some other crude oil source. This software uses the same methodology as described above under ANP to evaluate results.

4 Results and Discussion

The results obtained from TOPSIS, ANP and from their sensitivity analyses are presented below:

4.1 TOPSIS

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Table 4 shows the list of selection criteria and their importance ratings that have been obtained from PRL. These weights are calculated by summing the ratings and dividing each rating by the sum.

Criteria	Importance	Weights
Cost	8	0.228571
Technology	4	0.114286
Toxicity	2	0.057143
Viscosity	3	0.085714
Sulphur content	7	0.200000
API Gravity	6	0.171429
Alkane Content	5	0.142857

Table 4. Weightage for each Selection Criteria

The performance matrix, shown in Table 5, has been constructed from the attribute parametric values (see Table 2). For this, scale of 1-9 is used to rate each parametric value with respect to each alternative. A low parametric value is given a low rating, and a high parametric value shows higher rating.

	Negative Attributes						**Benefit Attribute**
	Cost	**Technology**	**Toxicity**	**Viscosity**	**Sulfur content**	**API Gravity**	**Alkane content**
Local Crude (Badin)	5	9	9	7	7	7	6
Upper-Zakum	7	5	6	6	9	9	6
DAS	8	5	4	3	5	8	7
Murban	9	7	6	5	3	9	9
Light Arabian	7	3	8	9	9	4	5

Table 5. Performance Matrix

The ratings from the performance matrix of Table 5 were normalized by summing each column and dividing each rating by its column sum. Then the columns were multiplied respectively by the weights of each criteria given in Table 4. The results of these steps have produced the Weighted Normalized Performance Matrix, shown in Table 6.

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	Negative Attributes						Benefit Attribute
	Cost	Technology	Toxicity	Viscosity	Sulfur content	API Gravity	Alkane content
Local Crude (Badin)	0.06981098	0.07482	0.033692	0.042426265	0.089443	0.070345422	0.056890513
Upper-Zakum	0.097735372	0.041565416	0.022461	0.03636537	0.114997782	0.090444114	0.056890513
DAS	0.111697568	0.041565416	0.014974	0.018182685	0.063887656	0.080394768	0.066372265
Murban	0.125659764	0.058191583	0.022461	0.030304475	0.038332594	0.090444114	0.085335769
Light Arabian	0.097735372	0.02493925	0.029948	0.054548056	0.114997782	0.040197384	0.047408761

Table 6. Weighted Normalized Performance Matrix

The highest entry from each column of Table 6, corresponding to a benefit attribute, and the lowest entry from each column of Table 6, corresponding to a negative attribute. These benefit and negative attributes are extracted to form the ideal solution presented in Table 7. On the other side, the lowest entry from each column of Table 6, corresponding to a benefit attribute, and the highest entry from each column of Table 6, corresponding to a negative attribute. Now, this benefit and negative attributes are extracted to form the anti-ideal solution, presented in Table 7.

	Negative Attributes						Benefit Attribute
	Cost	Technology	Toxicity	Viscosity	Sulfur content	API Gravity	Alkane content
Ideal Solution	0.06981	0.02494	0.01497	0.01818	0.03833	0.04020	0.08534
Anti-Ideal Solution	0.12566	0.07482	0.03369	0.05455	0.11500	0.09044	0.04741

Table 7. Ideal and Anti-ideal Solutions

Separation from the ideal solution for each alternative is shown in Table 8. This has been calculated from the Weighted Normalized Performance Matrix and Table 7, using the formula given in equation 1. Whereas, separation from the anti-ideal solution for each alternative, shown in Table 9, has been calculated from the Weighted Normalized Performance Matrix and Table 7 using the formula given in

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equation 2.

Relative Closeness to Ideal Solution is shown in Table 9. This closeness value is calculated by dividing the Separation from Anti-Ideal Solution by the sum of Separation from Ideal Solution and Separation from Anti-Ideal Solution. The preference order is the ranking of the Relative Closeness to Ideal Solution from its smallest to the largest value.

	Separation from Ideal Solution	Separation from Anti-Ideal Solution	Relative Closeness to Ideal Solution	Preference Order
Local Crude (Badin)	0.088069598	0.066430014	0.429968808	4
Upper-Zakum	0.103219599	0.049316643	0.323310989	5
DAS	0.068259952	0.077757996	0.53252355	1
Murban	0.083381851	0.091139003	0.522224142	2
Light Arabian	0.098195972	0.076199636	0.436935521	3

Table 8. Separation, Relative Closeness, and Preference Order

Sensitivity Analysis on TOPSIS

An iterative technique was carried out on excel. By changing one variable and keeping others constant. This help to find out how far a particular variable can affect the decision. The negative attribute characteristics were reduced and the positive attribute characteristics were increased for all alternatives except DAS (selected alternative), where it was done the opposite. The resulting values at which decision changed is shown in the table. 'N.A' denotes total insensitivity to the decision under current situation.

	Negative Attributes						Benefit Attribute
	Cost	**Technology**	**Toxicity**	**Viscosity**	**Sulfur content**	**API Gravity**	**Alkane content**
Local Crude (Badin)	3	7	N.A	N.A	4	3	N.A
Upper-Zakum	3	N.A	N.A	N.A	6	2	N.A
DAS	9	6	9	4	6	9	6

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Murban	8	6	2	2	2	8	N.A
Light Arabian	4	N.A	N.A	N.A	6	1	N.A

Table 9. Values at which DAS is no longer preferred

Then a difference was found between the corresponding values of Table 9 and Table 5. This provide difference table shown as Table 10. This difference table indicate the deviation that a particular criterion undergoes to cause a change in decision.

	Negative Attributes						**Benefit Attribute**
	Cost	**Technology**	**Toxicity**	**Viscosity**	**Sulfur content**	**API Gravity**	**Alkane content**
Local Crude (Badin)	2	2	-	-	3	4	-
Upper-Zakum	4	-	-	-	3	7	-
DAS	1	1	5	1	1	1	1
Murban	1	1	4	3	1	1	-
Light Arabian	3	-	-	-	3	3	-

Table 10. Difference Table

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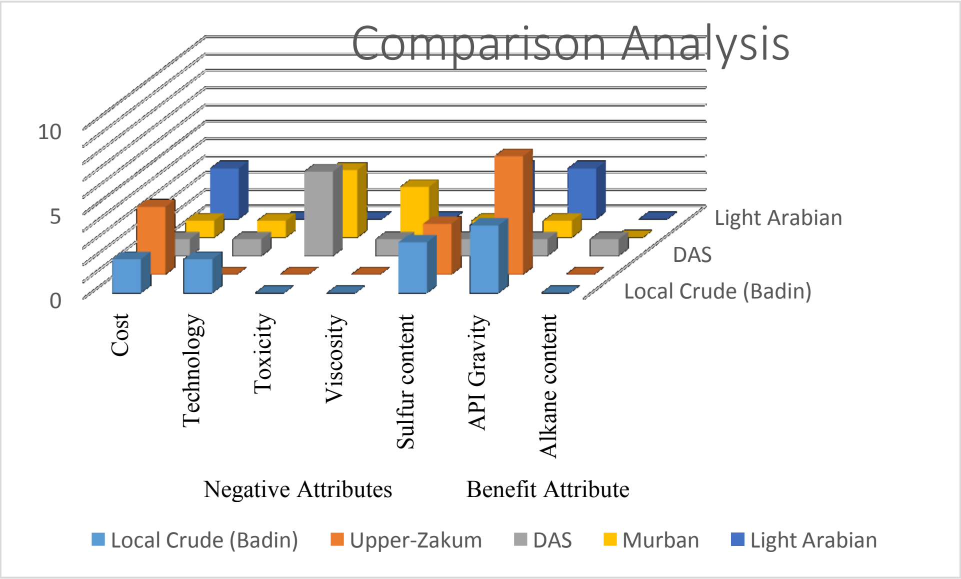

Figure 2. Comparison Analysis of alternatives

A criterion is defined to be sensitive if the 'rating difference' is less than or equal to 1. This is a reasonable choice. If the 'rating difference' becomes 2 or more, than the extent of sensitivity will fall. Thus, the rectangle shown in Figure 3 represents the criteria that are critical to the decision. That is, if they change even slightly then the whole decision may change.

The critical criteria are mentioned as follows (shown in Figure 2):

1) Alkane content of DAS
2) API gravity of Murban
3) API gravity of DAS
4) Sulfur content of Murban
5) Sulfur content of DAS
6) Viscosity of DAS
7) Technology of Murban
8) Technology of DAS
9) Cost of Murban
10) Cost of DAS

4.2 ANP

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The network for the ANP consists of the objective, alternatives, and criteria node clusters. The relationships between these clusters are shown in Figure 3.

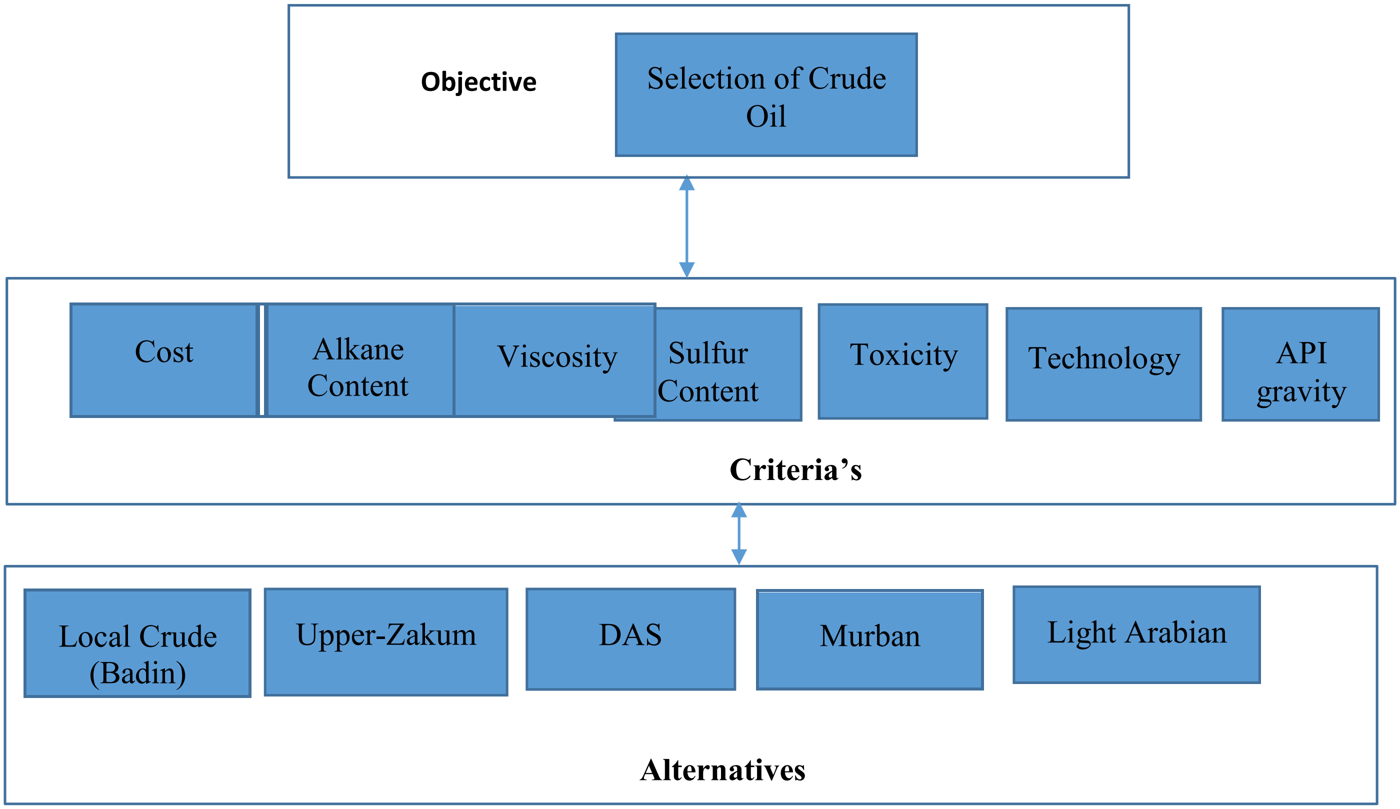

Figure 3. ANP Network Model

Furthermore, Table 11 (see Appendix A) shows the Un-weighted Super matrix which is formed from the priority vectors relating alternatives to the criteria, criteria to the alternatives, criteria to objective, and objective to criteria.

The Weighted Super matrix, Table 12 (see Appendix B) is obtained by weighing the node clusters against each other and multiplying the Un-weighted Super matrix by these weight

Finally, the Limit Super matrix, given in Table 13 (see Appendix C), is the result obtained by multiplying the Weighted Super matrix by itself until the entries in the matrix stop changing by further multiplication.

Alternative	**Ideal**	**Normals**	**Raw**	**Preference Order**
Local Crude (Badin)	0.862057	0.210208	0.070069	3
Upper-Zakum	0.522096	0.12731	0.042437	5

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DAS	1	0.243844	0.081281	1
Murban	0.972315	0.237093	0.079031	2
Light Arabian	0.744513	0.181545	0.060515	4

Table 14. Preference order of ANP

The raw order in Table 14 are the entries from Table 13 corresponding to the alternatives. The normal column is the result of normalization by summing the raw order column and dividing each entry by the sum. Finally, the ideal column is obtained by dividing each entry in the normal column by the highest entry in the same column. The preference order ranks the entries in the ideals column from largest to smallest.

Sensitivity Analysis on ANP

The sensitivity analysis performed on ANP focuses on the critical region within which the preferred solution changes when the weights of each criterion are changed alternatively. This variation is done with respect to the best solution chosen by performing ANP. As the result obtained from performing ANP was DAS, thus the effect of changing the weights of criteria with respect to DAS is analyzed. Furthermore, the effect of change in weights of criteria for each alternative is observed and recorded.

A graph of the sensitivity analysis in which the weights of each criterion with respect to DAS is plotted against the priority vector. The colored lines represent the different alternatives being considered. The criterion being considered in each of the following cases will be increasing or decreasing while keeping the weights of other criteria constant.

The different alternatives are represented by their corresponding colors and they are defined below:

Alternative	Colour
Local Crude (Badin)	Red
Upper-Zakum	Blue
DAS	Black
Murban	Green
Light Arabian	Yellow

Table 11. Color scheme for Sensitivity Analysis Graphs

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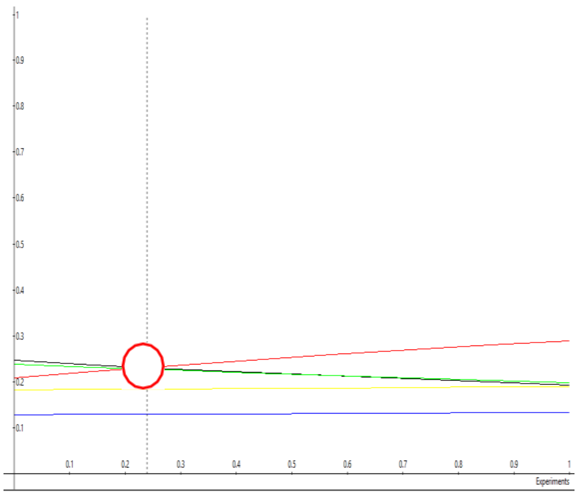

Figure 4. DAS Cost

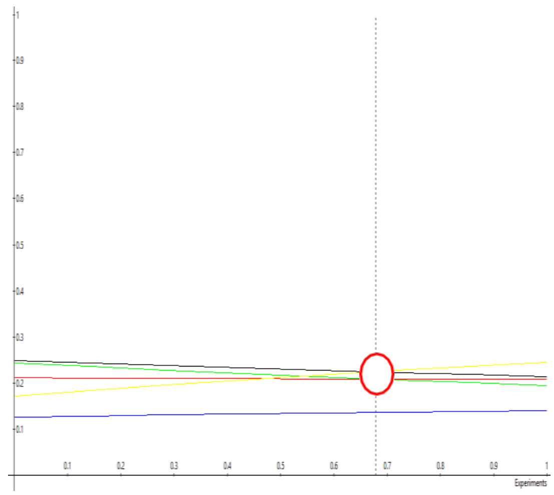

Figure 5. DAS Technology

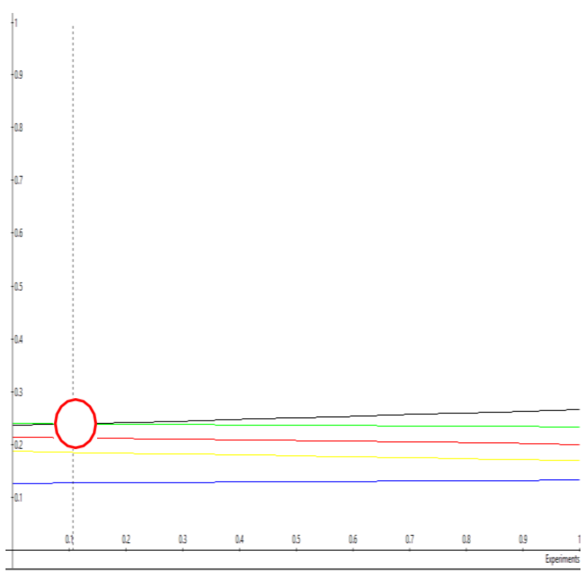

Figure 6. DAS Toxicity

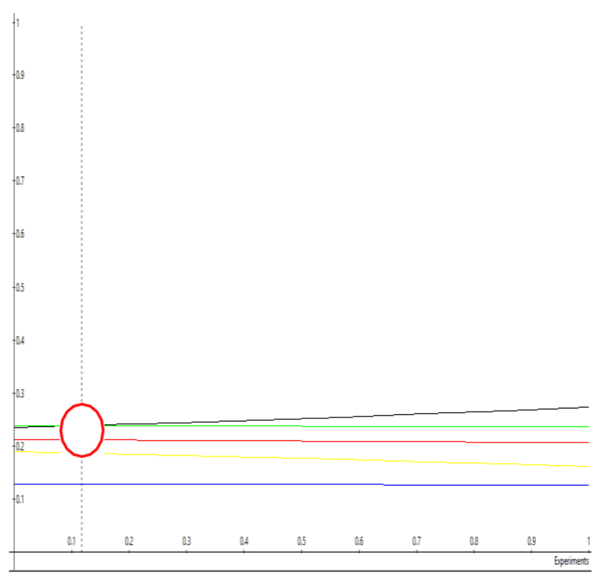

Figure 7. DAS Viscosity

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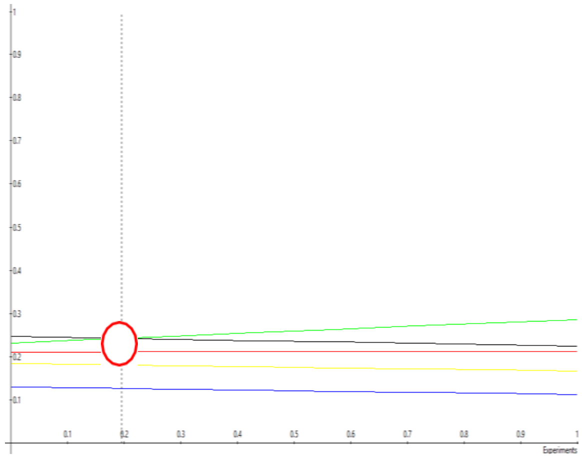

Figure 8. DAS Sulfur Content

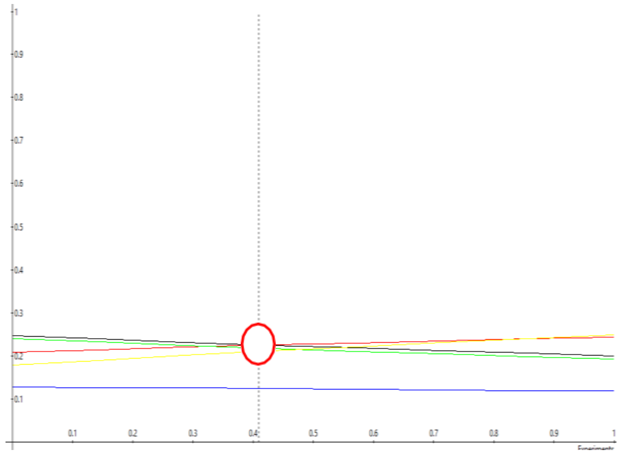

Figure 9. DAS API Gravity

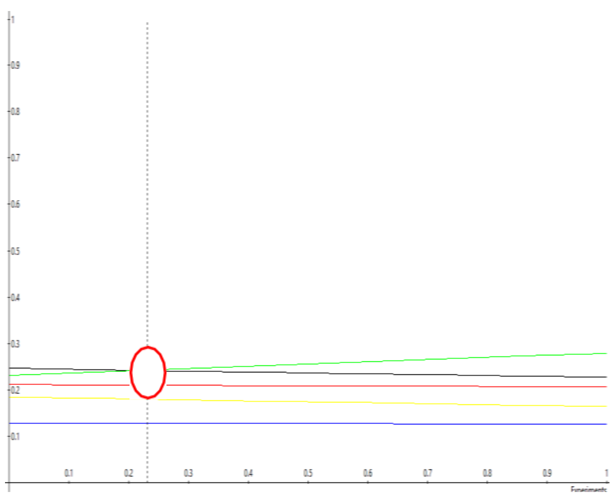

Figure 10. DAS Alkane Content

Figure 4 shows the sensitivity analysis of the cost criterion, it is revealed that cost of local crude oil is the minimum. Furthermore, weight of local crude oil criterion increases with respect to DAS when priority vectors increased. On the other side, Upper-Zakum and Light Arabian have the second and the third lowest costs respectively. Whereas, the weight of these criterions are very little effected with increase in priority vector. At the end, Murban and DAS have the highest and second highest costs respectively. The weight of criterion of Murban and DAS decreases with respect to DAS, this indicates that both of these alternatives are least preferable with respect to cost. The intersection point of DAS with Local Crude at 0.226 as marked in the graph is the critical point; this is the point where the preferred solution changes. For the range

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(0, 0.226), the preferred solution is DAS and for the range (0.226, 1), the preferred solution is changed.

Figure 5 shows that Local Crude and Murban have the highest and second highest technology requirement respectively. Therefore, by increasing priority vector the weight of criterion of these alternatives decreases with respect to DAS. Moreover, the Light Arabian has the lowest technology requirement. Furthermore, by increasing priority vector, the weight of criterion of this alternative increases with respect to DAS. The intersection point of DAS with Local Crude and DAS at 0.663 as marked in the graph is the critical point; this is the point where the preferred solution changes. For the range (0, 0.663), the preferred solution is DAS and for the range (0.663, 1), the preferred solution changed.

Figure 6 shows the toxicity level of each alternative, it is revealed that Local Crude has the highest toxicity level. Furthermore, the increase in priority vector decreases the weight of criterion with respect to DAS, therefore, this alternative is least preferable with respect to toxicity. On the other side, alternative DAS has the lowest toxicity level and it became more preferable as the weight of the criterion is increased. All the alternatives with respect to DAS have toxicity levels more than that of DAS. Hence, changing the weight of toxicity with respect to DAS does not have any effect on the preferred solution and therefore, no intersection point is obtained in this analysis.

Figure 7 the viscosity level for each alternative, from figure it is discovered that Light Arabian has the highest viscosity level. Furthermore, the increase in priority vector decreases the weight of the criterion with respect to DAS. Therefore, this alternative is least preferable with respect to viscosity. On the other side, alternative DAS has the lowest viscosity level and it becomes more preferable as the weight of the criterion is increased. All the alternatives with respect to DAS have viscosity levels more than that of DAS and hence, changing the weight of viscosity with respect to DAS does not have any effect on the preferred solution and therefore, no intersection point is obtained in this analysis.

Figure 8 shows the sensitivity analysis of the sulfur content criterion. From figure it is clear that Murban has the lowest sulfur content. Furthermore, the weight of the criterion for this alternative with respect to DAS increases drastically. Hence, Murban is more preferable supplier with respect to sulfur content. The intersection point ofDAS with Murban at 0.203 as marked in the graph is the critical point; this is the point where the preferred solution changes.

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For the range (0, 0.203), the preferred solution is DAS and for the range (0.203, 1), the preferred solution is changed.

Figure 9 shows the sensitivity analysis of the API gravity criterion. As from figure the API gravity of the Light Arabian is lowest and weight of the criterion also increases drastically with respect to DAS. Therefore, this alternative becomes more preferable with respect to API gravity. The intersection points of Local Crude and DAS at 0.392 and Light Arabian and DAS at 0.545 are marked on the graph, but the intersection point at 0.392 is the critical point; this is the point where the preferred solution changes. For the range (0, 0.392), the preferred solution is DAS and for the range (0.392, 1), the preferred solution is not DAS.

Figure 10 shows the sensitivity analysis of the alkane content, from figure it is clear that Muban has highest alkane content. Furthermore, the weight of the criterion with respect to DAS increases with increase in priority vector. Therefore, this alternative is most preferable with respect to alkane content. The intersection point of Murban and DAS at 0.203 as marked in the graph is the critical point; this is the point where the preferred solution changes. For the range (0, 0.203), the preferred solution is DAS and for the range (0.203, 1), the preferred solution is changed.

4.3 Comparison of TOPSIS and ANP results

Alternatives	Order of Preference	
	TOPSIS	ANP
Local Crude (Badin)	4	3
Upper-Zakum	5	5
DAS	1	1
Murban	2	2
Light Arabian	3	4

Table 12. Preference Order Comparison

The purpose of solving the problem with two different MCDM approaches is to find the consistency in the results. The advantage that TOPSIS has over ANP is that it is relatively simpler and it allows for easy decision making since it divides the criteria into positive (benefit) and negative criteria. However, there are some limitations offered by the TOPSIS method and therefore, the assumptions made during the decision-making process

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are that the criteria are independent of each other and the value of each criterion should either be decreasing or increasing and that too linearly.

Whereas, the advantage offered by ANP over TOPSIS is that it takes the interdependence of the different criteria into consideration and therefore, the assumption of the criteria being independent does not need to be considered. The ANP provides a more realistic result since the real-life cases involve interdependence among the criteria and the alternatives. There is only one difference in the order of preference of the two techniques; the Light Arabian and Local Crude have interchanging orders of preference. All the other alternatives have the same orders of preference.

The technique for sensitivity analysis on TOPSIS is seen to be very effective in predicting the changes in the alternative selection. This technique is simple and robust and can be expanded readily to any number of criteria or alternatives. The method gives us the parameters that are crucial in the decision making and these are the parameters whose ratings need to be assigned very carefully.

5 Conclusions

The oil is industry is a highly profitable industry as well as very crucial for a country's economy. Our focus of attention was Pakistan Refinery Limited and how can it select the best crude oil for further processing by fractional distillation and other processes. The PRL personnel were contacted and the data was extracted. Parametric values of the attributes in [table 2] were given by PRL in raw form and the criteria weightage [table4] were evaluated on a subjective basis in an interview.

Although the proposed framework in this paper is illustrated with respect to PRL, it can easily be replicated to include any refinery and to judge what factors are critical in the selection of a particular source. Any selected alternative may change depending on the external fluctuations in cost, technology, toxicity, viscosity, sulfur content, API gravity, alkane content or any additional criterion. Also if internal variations in the refinery occur, that is, the weights of any of the aforementioned criteria change then the resulting alternative may be different. These changing effects are taken into account by the sensitivity analysis and this procedure can be extended to any refinery.

Further research can be carried out in TOPSIS by determining the effect of changing multiple criteria, as what would happen when cost increases but sulfur content decreases. Not only may the sensitivity of the current solution be observed but the resulting new alternative can also be determined without repeating similar calculations and analysis.

Further research in ANP may be carried out by assigning practical units to the priority vector in sensitivity analysis.

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The priority vector can be quantified with its respective unit, that is, saying when cost exceeds this much dollars is when the decision will change and not simply mentioning the priority vector which conveys little meaning.

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Appendix A

Un-weighted Super-matrix														
		Alternatives					**Criteria**							**Objective**
		Local Crude (Badin)	**Upper-Zakum**	**DAS**	**Murban**	**Light Arabian**	**Cost**	**Technology**	**Toxicity**	**Viscosity**	**Sulphur Content**	**API Gravity**	**Alkane Content**	**Selection of Best Crude Oil Source**
Alternatives	**Local Crude (Badin)**	0	0	0	0	0	0.58105	0.03216	0.0341	0.06592	0.10229	0.2615	0.06338	0
	Upper-Zakum	0	0	0	0	0	0.17604	0.21498	0.16443	0.12621	0.04183	0.06338	0.12898	0
	DAS	0	0	0	0	0	0.07154	0.21498	0.49428	0.52067	0.25022	0.12898	0.2615	0
	Murban	0	0	0	0	0	0.04042	0.05995	0.24527	0.25776	0.55249	0.03333	0.51281	0
	Light Arabian	0	0	0	0	0	0.13095	0.47793	0.06193	0.02943	0.05317	0.51281	0.03333	0
Criteria	**Cost**	0.43988	0.25459	0.02734	0.02375	0.09331	0	0	0	0	0	0	0	0.37681
	Technology	0.02879	0.29024	0.11552	0.046	0.3678	0	0	0	0	0	0	0	0.05852
	Toxicity	0.02902	0.15648	0.28768	0.14555	0.06713	0	0	0	0	0	0	0	0.02733
	Viscosity	0.06102	0.12668	0.28768	0.14555	0.02885	0	0	0	0	0	0	0	0.04153
	Sulfur Content	0.19729	0.07756	0.11552	0.30769	0.04625	0	0	0	0	0	0	0	0.26017
	API Gravity	0.18299	0.03608	0.05074	0.02375	0.3678	0	0	0	0	0	0	0	0.16174
	Alkane Content	0.06102	0.05838	0.11552	0.30769	0.02885	0	0	0	0	0	0	0	0.0739
Objective	**Selection of Best Crude Oil Source**	0	0	0	0	0	1	1	1	1	1	1	1	0

Table 11. Un-weighted Super-matrix

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Appendix B

Weighted Super-matrix-														
		Alternatives					**Criteria**							**Objective**
		Local Crude (Badin)	**Upper-Zakum**	**DAS**	**Murban**	**Light Arabian**	**Cost**	**Technology**	**Toxicity**	**Viscosity**	**Sulphur Content**	**API Gravity**	**Alkane Content**	**Selection of Best Crude Oil Source**
Alternatives	**Local Crude (Badin)**	0	0	0	0	0	0.38736	0.02144	0.02273	0.04395	0.06819	0.17433	0.04225	0
	Upper-Zakum	0	0	0	0	0	0.11736	0.14332	0.10962	0.08414	0.02789	0.04225	0.08598	0
	DAS	0	0	0	0	0	0.0477	0.14332	0.32952	0.34712	0.16681	0.08598	0.17433	0
	Murban	0	0	0	0	0	0.02695	0.03997	0.16351	0.17184	0.36833	0.02222	0.34187	0
	Light Arabian	0	0	0	0	0	0.0873	0.31862	0.04128	0.01962	0.03545	0.34187	0.02222	0
Criteria	**Cost**	0.43988	0.25459	0.02734	0.02375	0.09331	0	0	0	0	0	0	0	0.37681
	Technology	0.02879	0.29024	0.11552	0.046	0.3678	0	0	0	0	0	0	0	0.05852
	Toxicity	0.02902	0.15648	0.28768	0.14555	0.06713	0	0	0	0	0	0	0	0.02733
	Viscosity	0.06102	0.12668	0.28768	0.14555	0.02885	0	0	0	0	0	0	0	0.04153
	Sulfur Content	0.19729	0.07756	0.11552	0.30769	0.04625	0	0	0	0	0	0	0	0.26017
	API Gravity	0.18299	0.03608	0.05074	0.02375	0.3678	0	0	0	0	0	0	0	0.16174
	Alkane Content	0.06102	0.05838	0.11552	0.30769	0.02885	0	0	0	0	0	0	0	0.0739
Objective	**Selection of Best Crude Oil Source**	0	0	0	0	0	1	1	1	1	1	1	1	0

Table 12. Weighted Super-matrix

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Appendix C

Limit Supermatrix														
		Alternatives					**Criteria**							**Objective**
		Local Crude (Badin)	**Upper-Zakum**	**DAS**	**Murban**	**Light Arabian**	**Cost**	**Technology**	**Toxicity**	**Viscosity**	**Sulphur Content**	**API Gravity**	**Alkane Content**	**Selection of Best Crude Oil Source**
Alternatives	**Local Crude (Badin)**	0.07007	0.07007	0.07007	0.07007	0.07007	0.07007	0.07007	0.07007	0.07007	0.07007	0.07007	0.07007	0.07007
	Upper-Zakum	0.04244	0.04244	0.04244	0.04244	0.04244	0.04244	0.04244	0.04244	0.04244	0.04244	0.04244	0.04244	0.04244
	DAS	0.08128	0.08128	0.08128	0.08128	0.08128	0.08128	0.08128	0.08128	0.08128	0.08128	0.08128	0.08128	0.08128
	Murban	0.07903	0.07903	0.07903	0.07903	0.07903	0.07903	0.07903	0.07903	0.07903	0.07903	0.07903	0.07903	0.07903
	Light Arabian	0.06051	0.06051	0.06051	0.06051	0.06051	0.06051	0.06051	0.06051	0.06051	0.06051	0.06051	0.06051	0.06051
Criteria	**Cost**	0.11417	0.11417	0.11417	0.11417	0.11417	0.11417	0.11417	0.11417	0.11417	0.11417	0.11417	0.11417	0.11417
	Technology	0.05937	0.05937	0.05937	0.05937	0.05937	0.05937	0.05937	0.05937	0.05937	0.05937	0.05937	0.05937	0.05937
	Toxicity	0.05218	0.05218	0.05218	0.05218	0.05218	0.05218	0.05218	0.05218	0.05218	0.05218	0.05218	0.05218	0.05218
	Viscosity	0.05321	0.05321	0.05321	0.05321	0.05321	0.05321	0.05321	0.05321	0.05321	0.05321	0.05321	0.05321	0.05321
	Sulfur Content	0.09698	0.09698	0.09698	0.09698	0.09698	0.09698	0.09698	0.09698	0.09698	0.09698	0.09698	0.09698	0.09698
	API Gravity	0.06957	0.06957	0.06957	0.06957	0.06957	0.06957	0.06957	0.06957	0.06957	0.06957	0.06957	0.06957	0.06957
	Alkane Content	0.05452	0.05452	0.05452	0.05452	0.05452	0.05452	0.05452	0.05452	0.05452	0.05452	0.05452	0.05452	0.05452
Objective	**Selection of Best Crude Oil Source**	0.16667	0.16667	0.16667	0.16667	0.16667	0.16667	0.16667	0.16667	0.16667	0.16667	0.16667	0.16667	0.16667

Table 13. Limit Supermatrix

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FORCE SENSITIVE RESISTOR; A NOVEL CONTROL SYSTEM FOR UPPER LIMB HAND PROSTHESIS

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Abstract

In field of trans-radial prosthesis, one of the critical tasks is to consider amputee determination to perform various tasks with prosthetic limb. The prosthetic limbs are generally operated through translation of amputee's biological signals into control signals that are fed to micro-controller for appropriate functioning of limb. Unfortunately, the most widely used approach for signal acquisition depending upon surface electromyography (EMG) still fails to provide reliable results. This is due to the fact that EMG signals are unstable and require a number of pre-processing operations which mostly results in delay in activation of motors for the control of limb. To address these issues researchers are looking for alternate techniques and solutions to control trans-radial prosthesis. This research work proposes application of Force Sensitive resistor (FSR) in controlling active upper limb prosthesis. EMG sensors are replaced by FSR sensors to acquire signals from amputees by detecting muscle movement. Experiments reveal that FSR signals can be fed to controller directly without requiring any pre-processing operations which resulted in lag removal along with precise actuation of motors

Index Terms— Trans-Radial prosthesis, EMG, FSR

1. INTRODUCTION

Limb amputation, for example hand loss can be extremely devastating as it renders a person impaired from performing day-to-days tasks. It has physical as well as psychological complications. The main causes of amputations in developed countries such as United States are vascular diseases and other medical conditions including congenital amputation and acquired amputation (Ziegler-Graham et al., 2008, Belter, 2013 #57) . Contrary to developed countries, the major cause of amputation in developing countries including Pakistan is war on terror and unstable security conditions. About 80-85% of the amputees in these countries are victims of land mines and IEDs which have affected more than 0.3 million peoples. This number is increasing by 26,000 every year.

Upper limb amputation generally results in loss of sensory-motor function of wrist and hand. There are two main types of prosthesis generally used to restore functionalities of upper limb i.e. passive prosthesis and active prosthesis. Passive prostheses are mainly used for cosmetic purposes and provide very little or no functionality, whereas active prosthesis in addition to cosmetics provide functionalities of real limb. Active prosthesis (myoelectric prosthesis) utilizes EMG electrodes placed on residual muscles of amputee and acquire EMG signal from motor neurons. These signals are then used to control various functionalities of limb. However, there are certain key limitations associated with this approach. These limitations include high cost, various pre-processing operations to remove noise and requirement of implantation to acquire best signal. Hence, there is a need to explore other technologies that are cost-efficient effective and provide efficient muscle signal acquisition without requiring specific pre-processing operations. (Blum, 2008 #53, Akhtar, 2016 #58).

State-of-the-art control method for upper limb prosthesis include passive control, cable control and experimental natural control. In passive control a prosthesis is locked into one of the limited number of chosen position. Passive models are generally used in strictly cosmetic devices with limited manipulated abilities (Meier, 2004 #54). Cable or body powered allow for simple direct control. The Otto bock hand make use of cable connected to existing residual limb to control limb (Blum, 2008 #55).

Neural control is potential future control that is in its growing stage. It works by using electrodes on the surface of the body receiving signal from the brain, these signal reconverts into movement through controller. Neural control still not working efficiently for below elbow amputation (Akhtar, 2016 #59). Currently the most effective and accurate type of the control is myoelectric control. By the muscle activity, a small electric impulse of the signal is generated, which is called electromyogram. Electrodes are used to extract this signal from muscle(Outten et al., 1996). The strength of the signal is low, its amplitude ranges

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from few hundred micro volt to few milli-volts and is disturbed by the slight movement of the limb, increases signal to noise ratio(De Luca, 1997). Ambient noise is another issue which originates from the surrounding and adds noise into the signal. While calculating Averaging, Integrating and RMS value of the signal(Fridlund and Cacioppo, 1986, Reaz et al., 2006), it causes time lag between onset of the motor activity and motion of the bionic hand. All these factors make the acquisition of high fidelity signal very challenging.

To address these issues Force-Sensitive Resistor (FSR) is emerging as are placement of EMG. FSR are ultra-thin low-cost pressure sensors, which exhibits changes in their electrical resistance when force is applied on their surface. Voltage divider circuit can be utilized to interface FSR with microcontroller. . When force is exerted on FSR, its resistance varies, resulting in variation of voltage drops across FSR which can be used to send commands to the microcontroller. FSR has wide range of applications in automotive industry, musical instruments, touch buttons, portable electronic devices etc. FSR is also proving to be promising sensing mechanism for developing applications in healthcare. It is a noninvasive sensing technique used for the acquisition of signals from the body. Comparing with the EMG the signal obtained through FSR does not require any pre-processing operations including amplification, filtering and noise removal. Due to all these characteristics FSR is a best choice to develop control model of the prosthetic hand.

Rest of the paper is organized as follow. Section-II presents Background of the study, Proposed Methodology is presented in section-III followed by discussion of Experimental Setup in section-VI. Results, Discussion and Conclusion is presented in section-V.

Background:

This section presents discussion of different control techniques that have been tested and applied with the passage of the time to give reliable prosthesis to amputees.

Body-powered: Body powered operates by using cables connecting to the movement of the body to control prosthesis. To open close or bend the prosthetic hand, cable is pulled by moving the body in a certain way. Ranging between 16 and 58 % for body powered prosthesis (Montagnani, 2017 #60), there are high rate of rejection among prosthesis users. This is due to distinct factors, like an unattractive cosmetic look of the prosthesis, pain and discomfort during wearing and dissatisfaction about the received preparation and training (Biddiss and Chau, 2007, Childress, 1985).

Pneumatic Prosthetic hand: A type of Prosthetic hand(Komatsubara et al., 2009, Mosadegh, 2017 #61) . The amputee uses headset which are used to detect the brain signals. Those signals are sent to the controller of the prosthetic hand that compares them to onboard database of established command signals, If there's a match, it actuates the arm accordingly, the artificial muscle operated (AMO) is pneumatic using compressed air to simulate the contraction and expansion of the muscle. That air comes from a refillable tank located in the user's pocket(INDULGENCE). The relatively simple technology keeps the production costs of the arm down but enlargement of the control system is a major problem(Komatsubara et al., 2009).

Ultra Sound Imaging: In the control of prosthetics the idea of using Ultra Sound Imaging is not new(Zheng et al., 2006, McIntosh, 2017 #62)). It is used to find the thickness of the extensor muscle in the forearm and to drive one degree of freedom prosthetic wrist, the approach was then extended to multiple degree of freedom and to a better accuracy(Chen et al., 2010, Chen et al., 2011). An attempt comparing sEMG and ultrasound imaging in a distinct tracking task appear, from which it seems that seems that ultrasound imaging obtain best result than sEMG, but as far as the cost is concerned a hand-held ultrasound machine cost is 8000 USD(Ravindra and Castellini, 2014), this kind of remains prohibitively expensive. The wearability is also an issue, the ultrasound interface has so far been realized that cannot be embedded into a prosthetic socket not an array of ultrasound transducer has been built yet(Ravindra and Castellini, 2014).

EMG: Currently used technology is EMG. EMG signals are not only used to control the prosthetic hand but it also has various applications in the detection of various diseases. Many researchers have contribution in picking up the EMG signal from the body and to generate various movement of the limb. Various methods have been developed for this purpose including RLD circuit, DC coupled, DSP technique and AC coupled technique. Literature review pertinent to this purpose is given below.

By muscle activity an impulse is produced, this impulse is called Electrographic signal or electrogram and the process is called electromyography (EMG) (Szabo et al., 1990, Geethanjali et al., 2009, Poo and Sundaraj, 2010, Konrad, 2005) . Various digital signal processing technique are used to clean this signal from various noises to prepare for processing. First step used in each technique is amplification by using differential amplifiers (Szabo et al., 1990) (Poo and Sundaraj, 2010) . Electrical activity of the skeletal muscle is used by EMG. There are different specially designed differential amplifiers available in the market. The value of the acquired signal is in milli-volt and is full of noise (Aagaard et al., 2002).

At the time of acquisition the bandwidth of the signal is between 10 Hz and 1000 Hz (De Luca, 1997). The most significant range of the PSD is 50-150 Hz. Several kind of noise such as Power Line Interference, Muscle Artifacts, Baseline Wandering or noise from the motion of other electronic components(De Luca, 2002). Further improvement will be made to make it able for the further processing through microcontroller. De-noising the signal is an important process for rest of the analysis. Some of the important methods for de-noising are Adaptive Digital notch filter (Ferdjallah and Barr, 1994), adaptive Wavelet transform (Zhang et al.,

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2006) and artificial Neural Network approach (Kale and Dudul, 2009).
Different type configuration filters are used for amplification (Ramesh, 2009 #51). The most suitable filter are Butterworth (Selesnick, 1998 #48;Haque, 2005 #49;Kaszynski, 2006 #50) configuration filters and second order filters. For amplification (Ramesh, 2009 #51), different type configuration filters are used. The most suitable filter are Butterworth (Selesnick, 1998 #45)O configuration filters and second order filters. The signal cannot be amplified unless the noise is removed otherwise the noise also amplified. For developing EMG signal that has the range of 20-500 Hz frequency (De Luca, 1997), cascading low pass filter and high pass filter giving 20-500 Hz band output are used. To remove the noise of power lane which is at 50 Hz, a Notch filter will have to be designed {Herrera, 2004 #46(Instruments, 2001 #47).
FSR: The difficulty and resilient/robust control using just EMG has led to search for alternative sensors/devices either substitute or augment them. Force sensor resistor (FSR) also called pressure sensor is one such device that is best replacement of the EMG(Blum, 2007, Ravindra and Castellini, 2014).
Force sensor resistors (FSR) is a polymer thick film (PTF) device which exhibits a decrease in resistance with an increase in the force applied to the active surface. The FSR has vide range applications in automotive industry, musical instruments, touch buttons, portable electronic devices etc. The FSR is also proving to be promising device for developing applications in healthcare. FSR is a noninvasive technique used for the acquisition of signals from the body(Ravindra and Castellini, 2014).
Force sensor resistors are piezoelectric. Different amount of pressure are applied to the sensing area to calculate output voltage of the force sensing resistors. The resulting signal produced due to the muscle contraction can be efficiently calculated by force sensing resistor. By carrying out research on this unexplored control method, it has the potential to make non-invasive, multifunction, and less expensive with possibility to minimize signal processing control for trans-radial prosthesis.

Comparison of FSR with EMG:
A comparison between FSR and EMG has been shown in the following table 1. From the table it is quite evident that EMG signal needs extensive signal processing and remove excess noise before reach it finally to the microcontroller, the block diagram is also shown below.

Issues	FSR	EMG
Acquisition of High Fidelity EMG Signals EMG	The FSR signal is enough, it does not needed any type amplification.	The amplitude of the EMG signal is very small ranging from few hundred micro volt to few hundred milli-volts, therefore amplification is need to obtain acquire signal
Motion Artifact	The FSR signal is not effected by the motion artifact	EMG Signals are Highly sensitive and disturbed even by slightly movement of the limb reducing signal to noise ratio.
Ambient Noise	FSR signal is not disturbed by the Ambient noise	The noise originates from the surrounding adds into the signal.
Reliable Signal Classifiers	Reliable Classifier is needed	It is difficult to detect the onset of the different activities such as Grasping, un Grasping, wrist movement etc. without a reliable classifier.
Skin Electrode Interface	Does not depend upon factor like hair and sweat	The skin Electrode interface depends upon factors like hair, sweat etc. the factors increase skin resistance

Table 1

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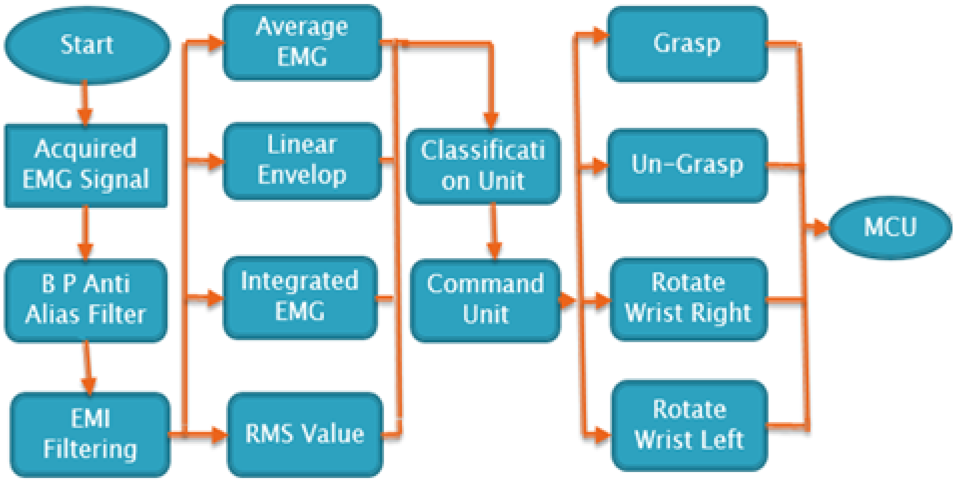

Figure 1. GMG Architecture.

All the processing of EMG shown in the block diagram take some time. This causes a delay in the activation of motors for the control of limb. This occurs as the time lag between onset of muscle activity and motion of the bionic hand. While in FSR the signal obtain from the muscle activity do not requires any type of preprocessing and is given directly to the microcontroller and gives promising results. The block diagram of the FSR is shown below.

Figure 2. Proposed FSR Architecture.

2. EXPERIMENTAL SET UP

The test bench was developed at Automation lab, Mechatronics department UET Peshawar. Experimental set-up consisted of number of FSR sensors, associated controlling mechanisms and prosthetic limb already developed in above mentioned limb. The test bench is shown in figure 1. Initially the required signal is acquired through FSR. FSR produces pulse in response to muscle movement of amputee. The pulse (or signal) is then classified as standard, extended or false pulse. This signal is then fed to command unit for opening/closing of hand and/or rotation of wrist.

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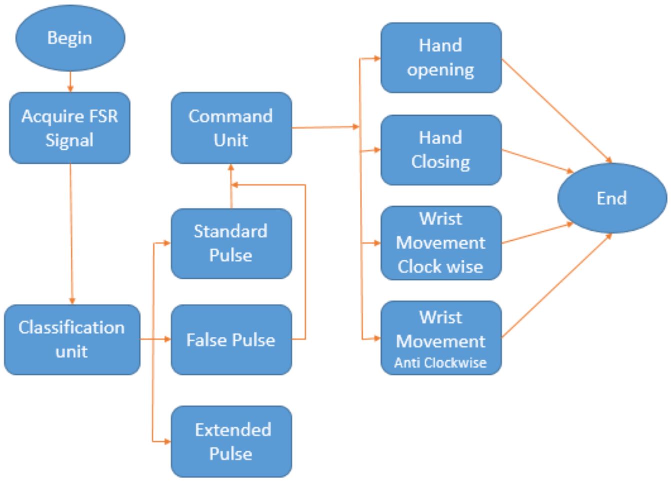

Figure 3. Flow Chart of Proposed Architecture.

The standard model of FSR-408 Strip was cut into a square shape having a 5.6 mm sensitive area. The resistance of FSR-408 changes appreciably with application of force. The sensitivity of FSR-408 ranges from 0.2 N to 40 N. The sensor works perfect when a rigid surface supports its backside, therefore a special casing of dimensions 3cm × 1cm × 1cm was manufactured from Teflon. The casing is designed and manufactured in a manner such that casing is not applying any extra force and at the same time it is capable of capturing muscle movement of amputees. The voltage divider circuit was used to interface the FSR with controller. FSR was connected in series with measuring resistor (RM). When voltage is applied to the circuit, all of the voltage drop is across the FSR in case when there is no force acting on the FSR, hence behaving as open circuit. As the force applies on the FSR, voltage begins to drop across the RM as shown in figure-2.

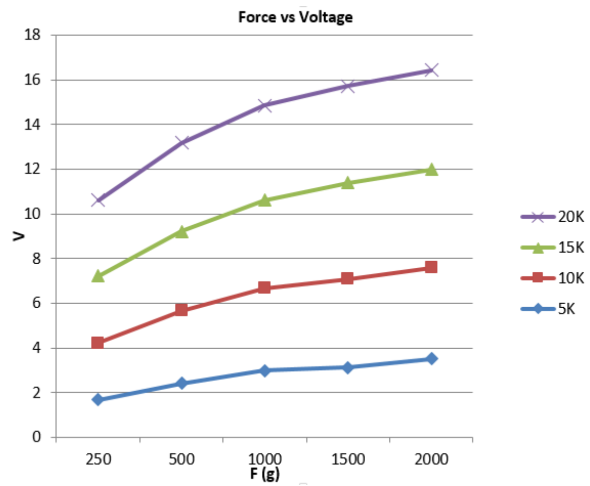

Figure 4. Force vs. Voltage Graph.

By selecting the high value of RM, more precise value of voltages can be obtained when force is applied across FSR. In this study different value of RM has been tested and finally 10K has been selected on basis of experimentation, as it provides precise results.

Control Software Design:

The Control software design based on FSR is shown in figure 3. Due to muscle contraction a small electric impulse is produced, FSR are used to obtain this electric impulse, after detection the signal, it is processed and compared with predefined templates. The signal is then classified and compared with predefined pulses named as standard, extended or false pulse. If the signal is classified standard, following situation may occur,

- If already hand is opened or closed or the wrist is rotated, the control unit stops their rotation immediately.

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- If there is no hand opening or closing occurs and nor the wrist is rotating, the previous motion of the hand is checked by the controller and the reverse execution is done after the conformation i.e. if the hand is already open then after the new muscle activity it will be close because controller will assume that amputee want to grasp some object for which he had opened his hand.
- The controller checks the previous motion of the wrist if the signal is classified as extended pulse and perform its opposite i.e. if the wrist rotated clockwise previously then after new extended muscle activity it will be rotated anticlockwise.

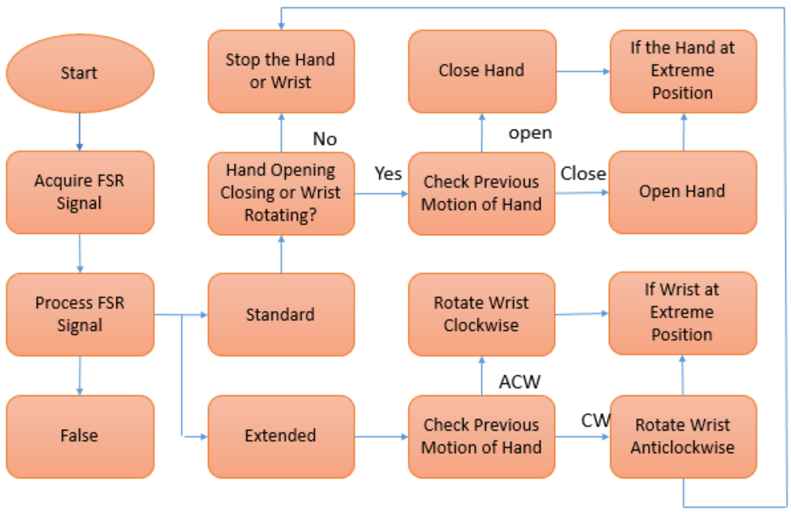

Figure 5. Block diagram of control software of limb.

3. RESULTS AND DISCUSSIONS:

Results were measured qualitatively and were used to demonstrate that a prosthesis could be controlled accurately and efficiently using force-sensitive resistor. The experiments were conducted on a volunteered, having right hand amputation. The patient was given initial training about working of FSR control. Due to changing factor of muscle strength person to person, the threshold value of FSR was adjusted according to amputee. While testing on amputee the amplitude of the FSR signal crossing pre-defined threshold value was provided to the microcontroller. Unlike the EMG signal it was not disturbed by the surrounding noise. It was easy to detect the onset of different activities such as hand grasping, ungrasping and the rotation of the wrist left or right. The FSR signal was not disturb by the factors like hair and sweat, which increases the resistance of the skin. The processing of FSR signal do not requires averaging, integrating and taking RMS value of the signal. Due to all these factors it was easy to obtain high fidelity signal. Following is the graph of the signal obtained which shows three types of impulses, first one is for hand opening/closing, the second one is to rotate the wrist right/left and the third one defines the false signal. These signals serve as pre-defined templates for classification unit.

The cost of the control was less than that of an ordinary intelligent prosthetic device: the force sensors alone cost is several times less than myo-electrodes. The potential for low-cost-of-manufacture indicates that force sensor-based control methods could be applied to create more accessible prosthetic options for a wider socioeconomic group.

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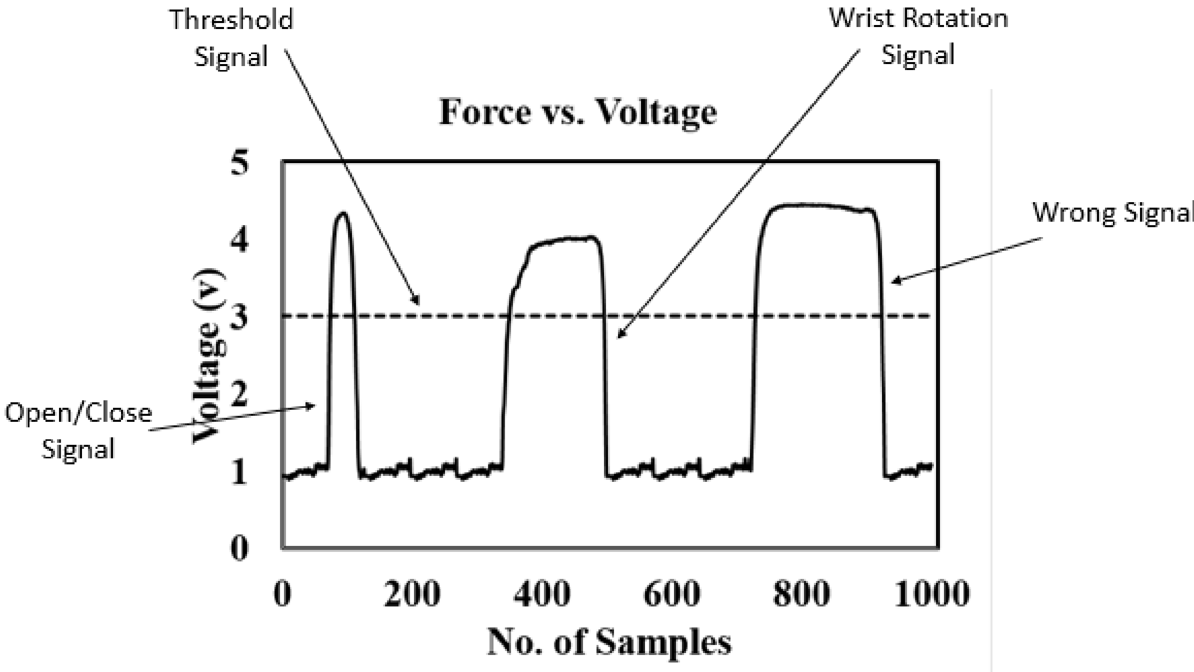

4. CONCLUSION:

In the proposed research work Force Sensitive resistor (FSR) is utilized to acquire signals from amputees by detecting muscle movement in controlling active upper limb prosthesis. The experimental work show that FSR signals without requiring any pre-processing operations can be fed to controller directly which resulted in lag removal along with precise actuation of motors. As for as the cost is concern FSR sensor are cheaper than EMG and unlike EMG their performance is not effected by the hair, sweat and the factor which increases the skin resistance. FSR signal does not require any type of processing like averaging, integrating and taking RMS value of the signal. The signal obtained from FSR is certain enough then it does not requires any type of amplification. FSR signal are not disturb by the ambient noise. Very simple classification is done to detect the onset of different activities such as hand opening, closing and wrist movement. Due to all these factors that are not found in FSR, the acquisition of high fidelity signal become very easy and promising results have been obtained.

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NUMERICAL ANALYSIS OF LOADING CONDITIONS ON TOTAL SURFACE- BEARING PROSTHESIS

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ABSTRACT

Finite element analysis (FEA) has been sorted as a helpful tool to understand the biomechanics of prosthesis. Previously, a lot of work has been carried out to study the response of prosthetic sockets using FE analysis but most of the work was done on Patellar tendon bearing (PTB) sockets. In this work, load transfer mechanism between residual limb and Total Surface Bearing (TSB) prosthetic socket was analysed using finite element method. Computer Tomography (CT) scan of residual limb of trans-tibial amputee were taken and images were converted into 3D CAD model using Geomagic studio® and Slicer 3D. Both CAD models of stump and liner were meshed and investigation was carried out using ANSYS 15.0®. Residual limb was subjected to single downward force based on amputee‟s weight. Maximum normal and shear stresses were found near patellar tendon region which is considered to be pressure tolerant area. Moreover, maximum slip at the stump/liner interface was found in a region of fibula head. FEA results showed that stresses were distributed all over the residual limb. Both the pressure tolerant and sensitive areas experiences almost same amount of stresses.

Keywords: Finite element analysis, Total surface bearing (TSB), Slip, Shear stress, Normal stress

1. Introduction

Prosthetic socket is an important part of every prosthetic limb as it forms an interface between the amputee‟s residual limb and prosthetic components. The socket is intended to provide ease, appropriate load transmission, and effective movement control. Attaining these objectives is quite challenging as about 55% of the lower limb amputees experiences discomposure in socket, residual limb pain or other skin/tissue disorders (Ischemia) (Rogers et al., 1991, Rogers et al., 2001). Therefore, it is required to provide an effective prosthetic fit to an amputee. Presently, there are number of prosthetic sockets in market but most important among them are Patellar tendon bearing (PTB) and Total surface bearing (TSB) sockets. In PTB socket design, weight bearing of the prosthesis is not uniformly distributed overall the residual limb. In fact weight is concentrated on specific areas i.e. pressure tolerant areas of residual limb(Michael and Bowker, 2004). In 1993, a new concept of prosthetic socket called “Total surface bearing” was proposed by kristinsson (Kristinsson, 1993). Total surface bearing (TSB) socket works on the principle of even distribution of load of residual limb. In such type of socket, no relief is given to pressure sensitive areas such as fibula head, tibial bone. Instead of concentrating weight on pressure tolerant areas, some weight is distributed to pressure sensitive areas so that to give relief to pressure tolerant areas (Wenger, 1993).
Evaluation of prosthetic socket is necessary to attain good and comfortable fit for the patient. For a past few decades, several techniques have been developed to understand the mechanical and bioengineering of prosthesis

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(Zhang et al., 1998, Reynolds and Lord, 1992, Sanders and Daly, 1993, Simpson et al., 2001). The influence of socket modifications (Silver-Thorn, 1996), material properties of socket (Quesada and Skinner, 1991), liners (Simpson et al., 2001), residual limb geometry (Reynolds and Lord, 1992) and frictional properties at the interface (Zhang et al., 1995) on the stress over the residual limb have been e xtensively studied using FE methods. The first FE model for trans-tibial amputee was developed by Steege et al. to predict the interface stress at residual limb. In their developed FE model, they did not consider interface contact, socket rectification and nonlinear material properties. Another 3D linear FE model for PTB socket was developed by Quesada and Skinner (Quesada and Skinner, 1991) with assumption of no slip between stump and socket interface. The high ratio of normal to shear stress was found at the pressure tolerant areas of residual limb. All the above FE models assumed that there will be small deformations in soft tissue and there is no slip/sliding between the residual limb and socket. But these models are not considered to be more accurate because of above mentioned limitations. To get the real insight of the problem, it is necessary to include non-linearity of materials including soft tissues, bone, liner and socket.

Reynolds (Reynolds, 1988) considered the non-linear 3D FE model for the simulation of interface stresses and slip in the model. Zhang et al (Zhang and Roberts, 1970, Zhang et al., 1995, Zhang et al., 1998, Zhang et al., 1996) in series of research work developed non-linear 3D models considering the donning effect, influence of coefficient of friction on interface stresses and slip at limb/liner interface. Limitation of their work was use of point to point contact instead of surface to surface contact. An automatic surface to surface contact was proposed and studied by Lee and Zhang et al. (Lee et al., 2004) between contact interfaces and found that it shows better results as the maximum normal and shear stresses were in a region were socket undercuts were made.

From the literature review, it was found that previous models well describe different factors that affect the model and its numerical approximations but most of them used PTB socket in their study. Therefore, it is required to study the interface stresses and slip in TSB sockets as they are different from traditional PTB sockets in their load distributions. The purpose of the study is to develop a non- linear 3D FE model of TSB socket with residual limb and to establish a surface to surface contact between interfaces. The non-linear model will simulate the interface stresses and slip/sliding at the stump and liner interface.

2. METHODS AND MATERIALS

2.1 Generation of FE model

A unilateral, right leg male amputee for 6 years having height of 166 cm, weight 55 kg participated in this study. Patient was using PTB socket with SACH foot since his amputation and never used TSB socket. Computer tomography (CT) scans of patient were taken with interval of 3 mm lying in supine position with knee extended in horizontal direction. The Dicom images of CT scans were converted into .STL format using Slicer 3D (Pieper et al., 2004) software. The boundaries of bone and limb geometry were identified and extracted. The bone was subtracted from the limb geometry in Autodesk Meshmixer to get the actual geometry of soft tissues. The outer surfaces of the soft tissue in contact with liner were selected and extracted. These surfaces were then extruded in uniform thickness of 4 mm to get the liner thickness for model. These .stl files containing bone, soft tissue and liner were processed in Geomagic studio® software to construct a CAD model by converting them into Non- Uniform Rational B Splines (NURBS) patches. These NURBS patches were then organised into solid model using Rhinoceros (McNeel, 2015) and exported in .IGES format for further use in FE analysis using Ansys 15.0®. The model was meshed into 3D tetrahedral having element size of 5mm using Ansys auto meshing tool as shown in Figure No 1(a) and (b) . Total number of elements in bone, soft tissue and liner were 13089, 17709 and 3993 respectively. Whereas total number of elements in FE model were 34791.

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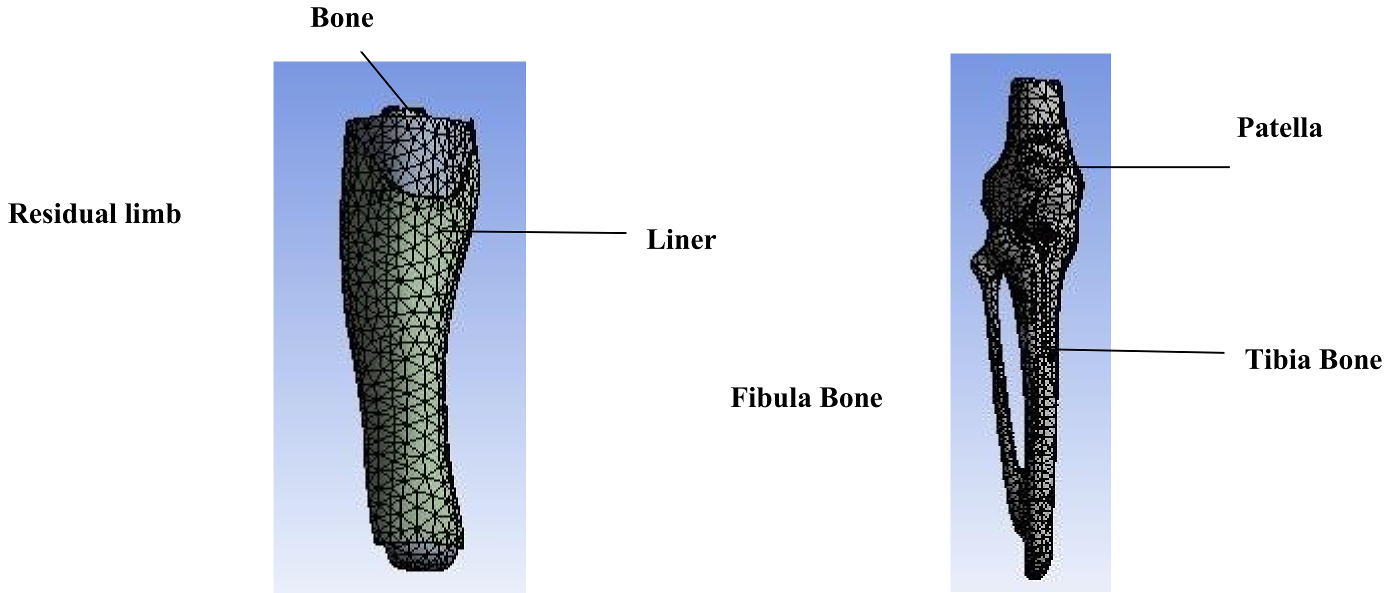

(a) (b)

Figure No. 1 (a) Stump, liner and bone assembly (b) Bone having element size of 5mm

2.1 Material properties

The mechanical properties of bone, soft tissue and liner were assumed to be linearly elastic, isotropic and homogenous as shown in Table No. 2.

Table No.2 Material Properties of FE model adapted from (Lee et al., 2004, Zhang et al., 1998, Colombo et al., 2013)

Geometry	Young"s Modulus (MPa)	Poisson"s Ratio	Density (kg/dm³)
Soft Tissue	0.20	0.4	1.48
Bone	10 000	0.3	2
Liner	1.5	0.39	1.78

2.2 Boundary Conditions and load analysis step

An assembly of lower limb prosthesis containing Bone, soft tissues and liner were created in Ansys 15.0®. The most important parameter to taken care of while making FE model of lower limb prosthesis is to establish the contact between surfaces. The bone and soft tissues was modelled as single body by creating a bonded contact between outer surfaces of bone and inner surfaces of soft tissues. The residual limb and liner were modelled as two separate bodies. Surface to surface contacts were established between the outer surfaces of residual limb and inner surfaces of liner. The inner surfaces of liner and outer surfaces of residual limb were defined as contact and target surfaces, respectively. Both surfaces were potentially in contact according to contact and target formulation in Ansys. Coefficient of friction was assigned to be 0.6 between the residual limb and liner. The external surface of the liner was given fixed rigid boundary to represent the „Hard Socket". A single downward force of 700 N was applied on top of the bone with certain assumptions that the direction of load does not affect the knee angle and the soft tissues of femur bone are not in contact with socket.

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3. RESULTS AND DISCUSSIONS

Three indexes from FE model i.e. interface stresses (normal stresses), shear stresses and sliding distance were studied. Figure No. 2(a) and (b) shows anterior and posterior view of the normal stresses distribution in liner/stump interface. The maximum magnitude of normal stress was found to be 42 kPa in patellar tendon (PT) region. A minimum stress of 10.1 kPa was found at stump end as no support was applied at distal end. The average normal stresses at other regions of stump were 29 kPa (popliteal depression, PD), 15 kPa (fibula head, FH), 22 kPa (anteromedial tibial, AMT) and 32 kPa (anterolateral tibial, ALT) and 17 kPa at (mid tibial, MT).

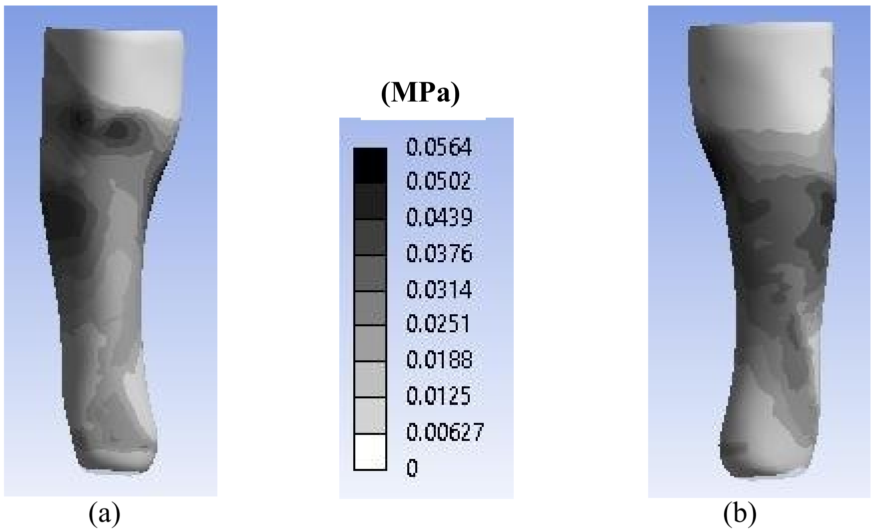

Figure No. 2 anterior and posterior view of normal stress map (a, b)

The shear stress distribution at stump/liner interface is shown in Figure N0. 3(a) and (b). The maximum and minimum shear stresses were found at patellar tendon region (14 kPa) and stump end (2 kPa) respectively. The other regions of stump i.e. PD, FH, AMT, ALT and MT displays stresses with magnitude of 10 kPa, 8 kPa, 7 kPa, 10 kPa and 6 kPa respectively.

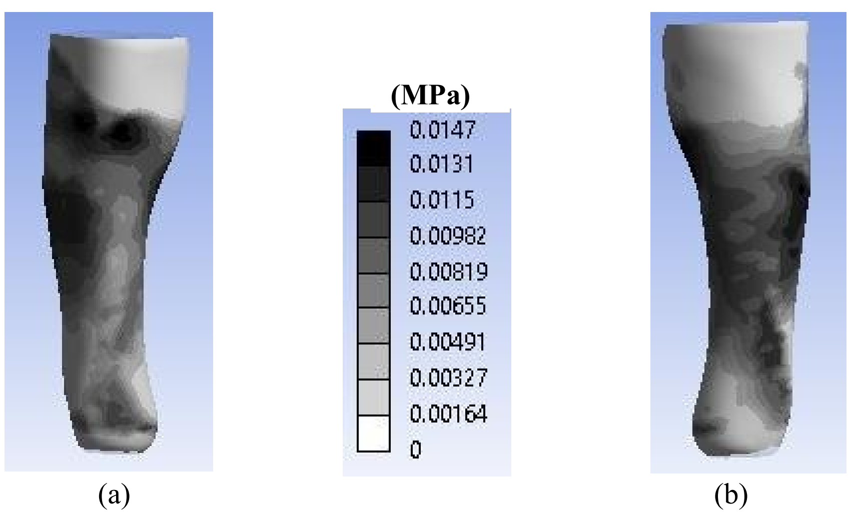

Figure No. 3 anterior and posterior view of Shear stress map (a,b)

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The uniform and local slip constantly exists between stump and liner. Slip is an important index in evaluating lower limb prosthesis because a large slip may create large soft tissue deformation, irregular stress distribution and burning and /or sweating due excessive rubbing while walking. As in the model, minimal space was left at stump end so that to allow the slip between the residual limb and liner. The slip at the stump and liner interface is shown in Figure No.5. The maximum slip of 0.7 mm found in a region of anterolateral tibial. Whereas minimum slip occurs at fibula head. The average slip between the stump and liner were 0.59 mm.

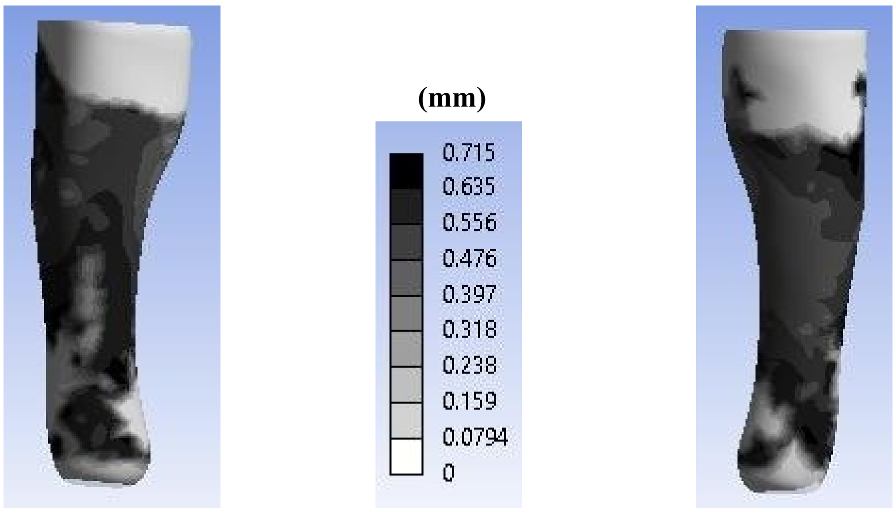

Figure No.5 Sliding distance at stump/liner interface

The main objective and significance of FE analysis is its capability to solve complex problems. For lower limb prosthesis, it is difficult to find the interface stresses and specially slip in the model. FE had capability to solve such problems. In this study FE method is used to simulate the different indexes of biomechanics. The interface stresses (normal and shear stresses) were distributed all over the residual limb except the stump end which was intentionally excluded from any loading so that to observe slip in model. The difference in magnitude of the interface stresses was not that large and all areas of the stump contribute in weight bearing. From the literature of TSB sockets, it was found that the slip of residual limb in TSB fit must be minimal or no slip. A larger slip may damage the soft tissues because of large amount of tissue deformation and frictional contact stresses. So, a small amount of slip i.e. 0.59 mm was found at the stump/liner interface in this model. This amount of slip was found to be in acceptable range as it will not create any significant skin deformation and/or sweating due to frictional rubbing.

4. CONCLUSION AND FUTURE RECOMMENDATIONS

In this study, FE method was used to find the biomechanics of lower limb prosthesis having TSB sockets. Surface to surface contact was established between the residual limb and liner with coefficient of friction 0.6. The normal, shear and shear stresses were found at the stump and liner interface. Maximum normal and shear stress of 42 kPa and 14 kPa respectively were found at patellar tendon region. The maximum slip of 0.7 mm occurs at fibula end whereas the averaged slip was about 0.59 mm. Based on the outcomes of the study, it was found that the results were accurate and well defined the principle of Total surface bearing socket.

Future FE analysis can be performed on TSB sockets to model stump-socket assemblies. Pre-stresses that develop from donning of residual limb in TSB socket can be studied. Moreover, accurate description of material properties at different regions of stump could provide optimal stress pattern at stump interface. The effect of TSB socket

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shape and material, rectification and stiffness of shank and prosthetic foot on stump/ socket interface could be evaluated using FE analysis.

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ASSESSMENT OF COMFORT LEVEL OF DIFFERENT CHAIRS FOR CLASS ROOMS BASED ON ERGONOMIC FACTORS

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ABSTRACT

Prolonged sitting in awkward posture in classroom may result in muscular pain and loss of attention among students during lectures. Such muscular skeletal disorders are associated with mismatch between anthropometry and classroom furniture design. This paper proposes alternatives of chair design based on perceptual (or physiological) assessment. A cross-sectional study was designed based on a questionnaire for perceptual assessment. A comfort rating scale was used to assess the level of comfort between the current available classroom chairs. Descriptive statistics for the comfort rating scale and the important anthropometric factors that may cause muscle fatigue in lower back shoulder or neck pain were found. Comparison between the current available chairs was made. This study helps in forming basis for developing a mechanism that will help educational institutes in selecting ergonomically suited chair for students and help in reducing muscle fatigue and increase attention during the lectures.

Key words— ergonomics, musculoskeletal diseases, student, chair

1. INTRODUCTION

Musculoskeletal Disorders (MSD's) are most commonly found injuries among students and occupational population that account for one third of work-related injuries every year (Mohseni-Bandpei, Fakhri et al. 2006) (Alexopoulos, Stathi et al. 2004). Computer use commonly associate with increased risk for musculoskeletal disorders among students due to the static posture adopted all day (Blatter and Bongers 2002). Occupational population cause economic losses due to disorders that greatly affect organizations and society (Cheng, Cheng et al. 2013) and estimates about one percent of GDP of industrialized country (Yu, Ignatius et al. 2013). MSD's closely relate to improper use of body mechanics. Bending and sitting contribute to be the most important factors that cause MSD's (Bot, Terwee et al. 2007). Important risk factor of MSD at schools could be sitting in bad posture using inappropriate furniture and equipment. (Dianat, Karimi et al. 2013). Failure to observe principles of ergonomics originates spinal disorders (Mirmohammadi, Mehrparvar et al. 2010, Yektaee, Tabatabaee Ghomshe et al. 2013). Research has shown that sitting for longer durations per day increase the risk for MSD's which include neck pain, shoulder strain, forearm tenosynovitis, carpal tunnel syndrome and de Quervain's syndrome. The causes of MSD's are not completely understood but these are multifactorial in nature. Students complain about neck and shoulder pains after long lectures at universities. Factors such as static neck and arm postures are related to chair design. 60-80% of people suffer from back pain due to poor design of chairs (Mohseni-Bandpei, Fakhri et al. 2006). Longer sitting durations cause lumber disorders that leads to absenteeism (Khosroabadi, Razavi et al. 2010). Research studies on relation to musculoskeletal disorders and prolonged sitting are limited in context of extensive usage of non-ergonomic chairs. Many research works used anthropometric data to design a chair that adjusts many body sizes using statistical data modeling having multivariate and co- related variables (Reed and Parkinson 2008). (Reed and Parkinson 2008). (Reed and Parkinson 2008) used PCA and regression analysis to analyze the anthropometric data in order to design chair and other applications. Principal component analysis (PCA) is a dimension reduction tool with linear combination of variables so that maximum variance is extracted from variables. It analyzes the common and unique variance which represents the whole data set. The main application of PCA analyzed by (Allen, Curless et al. 2003) is to compress data for body features of individuals editing to make them taller, shorter, gain or lose weight. SPSS software used by (Aghahi, Darabi et al. 2018) to implement regression analysis and chi- square test in many ergonomic improvements by testing the reliability and significant factors. Results were analyzed which showed that working environments needs to be improved and training is necessary to make workers aware of the right posture for sitting. A questionnaire developed by (Mowatt, Gordon et al. 2018) to study the ergonomic symptoms and results were analyzed using SPSS and AHP which concluded with advanced ergonomic practices that the musculoskeletal disorders can be reduced. The chair design flaws results in many disorders that can be clearly understood from above mentioned work till date. Limited work has been done on chair design available in university for students that cover many tasks like lab work,

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class work and paper attempting. The same chairs for all these tasks produce fatigue among students reducing their productivity and attentiveness. This paper covers the gap between the type of chairs and the effective fatigue it produces in neck, shoulder, wrist and back, with the help of a survey among students using those chairs. The specific chairs results in disorders which will be covered in this paper.
Since prolonged sitting in uncomfortable chairs causes fatigue therefore the primary objective of the study is to find significant factors that results in improper seating of students in university. The secondary objective is to find the chair which gives maximum rise to pains in shoulder, back, wrist and legs.

2. METHODOLOGY

2.1. Study Design and Participants

A survey was carried out on engineering students from 7 different departments in which tablet, revolving with arm rest and without arm rest chairs were analyzed in terms of Musculoskeletal Discomforts from a population of 400 students during attending class using white board, multimedia, and lab work and attempting paper. Target group were the students who visited university daily and had height from 5 to 6 feet. They used all three chairs to know about the variables being asked in questionnaire.

2.2. Questionnaire Design

The questionnaire consisted of the following parts:
(1) Personal information as name, gender, height and department the student is enrolled.
(2) How often the student visit university, students visiting university seldom data was omitted from results.
(3) Comfort level in usage of Tablet, revolving with arm rest and without arm rest chairs.
(4) Subjective discomforts in prolonged usage of these chairs during class, lab work and attempting paper.

Data was collected by means of structured questionnaire for comfort level and cause of pains. Students responded among which 22% were females and 78% males.

2.3. Data Analysis

The data has to be reliable in order to apply further tests to get results. Sampling adequacy with Kaiser-Meyer-Olkin (KMO) and Bartlett's test values are shown in table 1.

Table 1. Reliability test of Data

KMO and Bartlett/'s Test[a]		
Kaiser-Meyer-Olkin Measure of Sampling Adequacy		0.549
Barlett's Test of Sphericity	Approx. Chi-Square	187.258
	df	66
	Sig.	.000

Table shows that KMO measure of sampling adequacy gives value above 0.5 while Bartlett's test significance is 0.00 that is both the values are within the accepted region. Scree plot is used to select the factors to use based on size of eigenvalues, the steeper the plot, and then a straight line at the end is the ideal curve. Figure 1 shows the Scree curve for data collected.
The factors showing eigenvalues greater than 1 are considered to be important.

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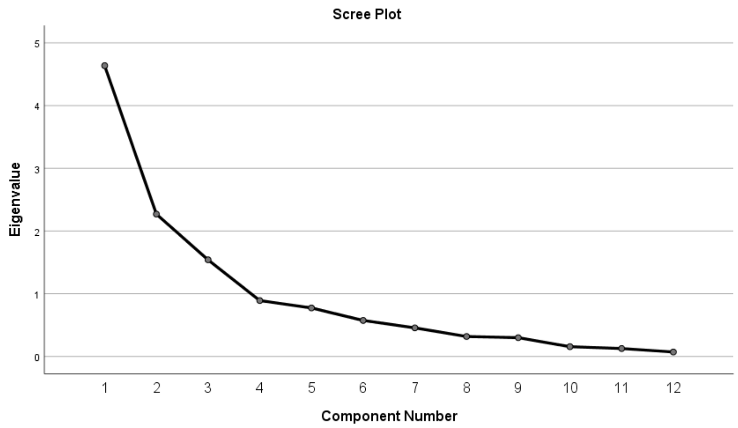

Figure 1. Scree Curve for Eigenvalues and Component number

All together 15 variables were identified which included 5 types of pains using 3 types of chairs daily. The targeted disorders are as follows,

1) Shoulder Fatigue
2) Back Pain
3) Wrist Pain
4) Neck pain
5) Leg pain

The chairs used to analyze the above mentioned disorders are,

1) Tablet chair
2) Revolving chair with arm rest
3) Revolving chair without arm rest

The possible combination of 5 disorders and 3 chairs are given in table 2 with abbreviated names;

Table 2. Variables to be used for disorders for each of three chairs

Shoulder fatigue [Tablet chair]	ST
Shoulder fatigue [Revolving chair with Arm rest]	SRA
Shoulder fatigue [Revolving chair without Arm rest]	SR
Neck pain [Tablet chair]	NT
Neck pain [Revolving chair with Arm rest]	NRA
Neck pain [Revolving chair without Arm rest]	NR
Back pain [Tablet chair]	BT
Back pain [Revolving chair with Arm rest]	BRA
Back pain [Revolving chair without Arm rest]	BR
Wrist pain [Tablet chair]	WT
Wrist pain [Revolving chair with Arm rest]	WRA
Wrist pain [Revolving chair without Arm rest]	WR
Leg pain [Tablet chair]	LT
Leg pain [Revolving chair with Arm rest]	LRA
Leg pain [Revolving chair without Arm rest]	LR

Analytical Hierarchy Process was applied on the data to get the alternatives, rank them according to priority. Finally when the difference between iteration values is zero, results are displayed in descending order with the most significant factor on top.

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The data from questionnaire was quantified according to a scale and plotted against 15 variables. Average values were calculated which are given in table 3 below,

Table 3. Average of values obtained from Questionnaire for each chair

ST	SRA	SR	NT	NRA	NR	BT	BRA	BR	WT	WRA	WR	LT	LRA	LR
3.02439	1.972973	2.472222	2.717949	1.8	2.057143	3.475	1.777778	2.027778	2.410256	1.742857	2.138889	2.525	1.777778	1.972222

Above table shows the average values for 15 variables each from questionnaire. These values were used to generate a From/To chart by cross multiplication. The matrix obtained is shown in table 4 as follows,

Table 4. From/To for each variable

	ST	SRA	SR	NT	NRA	NR	BT	BRA	BR	WT	WRA	WR	LT	LRA	LR
ST	1	1.53291	1.223349	1.112747	1.680217	1.47019	0.870328	1.70122	1.49148	1.2548	1.735306	1.414001	1.197778	1.70122	1.533494
SRA	0.652354	1	0.798056	0.725905	1.096096	0.959084	0.567762	1.109797	0.972973	0.818574	1.132034	0.922429	0.781375	1.109797	1.000381
SR	0.817428	1.253044	1	0.909591	1.373457	1.201775	0.711431	1.390625	1.219178	1.025709	1.418488	1.155844	0.979098	1.390625	1.253521
NT	0.898677	1.37759	1.099395	1	1.509972	1.321225	0.782144	1.528846	1.340358	1.12766	1.559479	1.270729	1.076415	1.528846	1.378115
NRA	0.595161	0.912329	0.72809	0.662264	1	0.875	0.517986	1.0125	0.887671	0.746809	1.032787	0.841558	0.712871	1.0125	0.912676
NR	0.680184	1.042661	0.832103	0.756873	1.142857	1	0.591984	1.157143	1.014481	0.853495	1.180328	0.961781	0.81471	1.157143	1.043058
BT	1.148992	1.761301	1.405618	1.278538	1.930556	1.689236	1	1.954688	1.713699	1.441755	1.993852	1.624675	1.376238	1.954688	1.761972
BRA	0.587814	0.901065	0.719101	0.654088	0.987654	0.864198	0.511591	1	0.876712	0.737589	1.020036	0.831169	0.70407	1	0.901408
BR	0.670475	1.027778	0.820225	0.746069	1.126543	0.985725	0.583533	1.140625	1	0.841312	1.163479	0.948052	0.80308	1.140625	1.028169
WT	0.79694	1.221637	0.974935	0.886792	1.339031	1.171652	0.693599	1.355769	1.18862	1	1.382934	1.126873	0.954557	1.355769	1.222102
WRA	0.576267	0.883366	0.704976	0.64124	0.968254	0.847222	0.501542	0.980357	0.859491	0.7231	1	0.814842	0.69024	0.980357	0.883702
WR	0.707213	1.084094	0.865169	0.78695	1.188272	1.039738	0.615508	1.203125	1.054795	0.887411	1.227231	1	0.847085	1.203125	1.084507
LT	0.834879	1.279795	1.021348	0.929009	1.402778	1.227431	0.726619	1.420313	1.245205	1.047606	1.44877	1.180519	1	1.420313	1.280282
LRA	0.587814	0.901065	0.719101	0.654088	0.987654	0.864198	0.511591	1	0.876712	0.737589	1.020036	0.831169	0.70407	1	0.901408
LR	0.652106	0.999619	0.797753	0.725629	1.095679	0.958719	0.567546	1.109375	0.972603	0.818262	1.131603	0.922078	0.781078	1.109375	1

Table 4 shows From/To chart. The first value in first column is obtained by dividing ST by ST from Table 3; second value from first column was calculated by dividing SRA by ST from Table 3, third value was obtained by dividing SR/ST and vice versa. For second column ST is divided by SRA for first value, ST divided by SR. The last value from second column was calculated by dividing LR by SRA and so on. In the same way all values are generated by dividing the value from row by column.

After calculating FROM/TO chart, AHP is calculated by multiplying the matrix with itself given in Table 4, in this way Table 5 is generated given below.

Table 5. Multiplication of Table 4

	ST	SRA	SR	NT	NRA	NR	BT	BRA	BR	WT	WRA	WR	LT	LRA	LR	SUM	R.W
ST	15	22.99365	18.35023	16.69121	25.20325	22.05285	13.05492	25.51829	22.3722	18.822	26.02959	21.21001	17.96667	25.51829	23.002405	313.7856	0.089235

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SRA	9.78531	15	11.97085	10.88858	16.44144	14.38626	8.51643	16.64696	14.59459	12.27861	16.98051	13.83643	11.72063	16.64696	15.00571	204.6993	0.058213

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SR	12.26142	18.79566	15	13.64387	20.60185	18.02662	10.67146	20.85938	18.28767	15.38564	21.27732	17.33766	14.68647	20.85938	18.802817	256.4972	0.072944
NT	13.48015	20.66386	16.49092	15	22.64957	19.81838	11.73215	22.93269	20.10537	16.91489	23.39218	19.06094	16.14623	22.93269	20.671723	281.9918	0.080194
NRA	8.927419	13.68493	10.92135	9.933962	15	13.125	7.769784	15.1875	13.31507	11.20213	15.4918	12.62338	10.69307	15.1875	13.690141	186.753	0.05311
NR	10.20276	15.63992	12.48154	11.3531	17.14286	15	8.879753	17.35714	15.21722	12.80243	17.70492	14.42672	12.22065	17.35714	15.645875	213.432	0.060697
BT	17.23488	26.41952	21.08427	19.17807	28.95833	25.33854	15	29.32031	25.70548	21.62633	29.90779	24.37013	20.64356	29.32031	26.429577	360.5371	0.102531
BRA	8.817204	13.51598	10.78652	9.811321	14.81481	12.96296	7.673861	15	13.15068	11.06383	15.30055	12.46753	10.56106	15	13.521127	184.4474	0.052454
BR	10.05712	15.41667	12.30337	11.19104	16.89815	14.78588	8.752998	17.10938	15	12.61968	17.45219	14.22078	12.0462	17.10938	15.422535	210.3854	0.05983
WT	11.95409	18.32455	14.62403	13.30189	20.08547	17.57479	10.40398	20.33654	17.82929	15	20.74401	16.9031	14.31835	20.33654	18.331528	250.0682	0.071115
WRA	8.644009	13.25049	10.57464	9.618598	14.52381	12.70833	7.523124	14.70536	12.89237	10.8465	15	12.22263	10.35361	14.70536	13.255533	180.8244	0.051423
WR	10.6082	16.26142	12.97753	11.80425	17.82407	15.59606	9.232614	18.04688	15.82192	13.31117	18.40847	15	12.70627	18.04688	16.267606	221.9133	0.063109
LT	12.52319	19.19692	15.32022	13.93514	21.04167	18.41146	10.89928	21.30469	18.67808	15.7141	21.73156	17.70779	15	21.30469	19.204225	261.973	0.074501
LRA	8.817204	13.51598	10.78652	9.811321	14.81481	12.96296	7.673861	15	13.15068	11.06383	15.30055	12.46753	10.56106	15	13.521127	184.4474	0.052454
LR	9.781586	14.99429	11.96629	10.88443	16.43519	14.38079	8.513189	16.64063	14.58904	12.27394	16.97404	13.83117	11.71617	16.64063	15	204.6214	0.058191
															Grand sum	3516.376	0.089235

Table 5 shows the cross multiplication of table 4 with itself. Sum is calculated in the last column of Table 5 for each variable horizontally. Grand sum is calculated by taking summation of the whole column. Relative weights (R.W) of nodes are calculated by dividing each value from "Sum" column by the grand sum shown in last column of table 5 which shows the weights of each variable calculated from first iteration of AHP. The same matrix given in table 5 is multiplied with itself for second iteration in Table 6 and again the weights of nodes are calculated by dividing sum of each variable by grand sum shown in Table 6.

Table 6. Multiplication of Table 5

	ST	SRA	SR	NT	NRA	NR	BT	BRA	BR	WT	WRA	WR	LT	LRA	LR	SUM	R.W
ST	3375	5173.572	4128.802	3755.522	5670.732	4961.89	2937.357	5741.616	5033.745	4234.951	5856.657	4772.252	4042.502	5741.616	5175.5411	70601.76	0.089235
SRA	2201.695	3375	2693.441	2449.93	3699.324	3236.909	1916.197	3745.566	3283.784	2762.687	3820.614	3113.198	2637.142	3745.566	3376.2847	46057.34	0.058213
SR	2758.821	4229.024	3375	3069.87	4635.417	4055.99	2401.079	4693.359	4114.726	3461.769	4787.398	3900.974	3304.455	4693.359	4230.6338	57711.87	0.072944
NT	3033.033	4649.368	3710.458	3375	5096.154	4459.135	2639.734	5159.856	4523.709	3805.851	5263.241	4288.711	3632.902	5159.856	4651.1376	63448.15	0.080194
NRA	2008.669	3079.11	2457.303	2235.142	3375	2953.125	1748.201	3417.188	2995.89	2520.479	3485.656	2840.26	2405.941	3417.188	3080.2817	42019.43	0.05311
NR	2295.622	3518.982	2808.347	2554.447	3857.143	3375	1997.945	3905.357	3423.875	2880.547	3983.607	3246.011	2749.646	3905.357	3520.3219	48022.21	0.060697
BT	3877.848	5944.392	4743.961	4315.065	6515.625	5701.172	3375	6597.07	5783.733	4865.924	6729.252	5483.279	4644.802	6597.07	5946.6549	81120.85	0.102531
BRA	1983.871	3041.096	2426.966	2207.547	3333.333	2916.667	1726.619	3375	2958.904	2489.362	3442.623	2805.195	2376.238	3375	3042.2535	41500.67	0.052454
BR	2262.853	3468.75	2768.258	2517.983	3802.083	3326.823	1969.424	3849.609	3375	2839.428	3926.742	3199.675	2710.396	3849.609	3470.0704	47336.71	0.05983
WT	2689.671	4123.024	3290.406	2992.925	4519.231	3954.327	2340.897	4575.721	4011.591	3375	4667.402	3803.197	3221.63	4575.721	4124.5937	56265.34	0.071115
WRA	1944.902	2981.36	2379.294	2164.185	3267.857	2859.375	1692.703	3308.705	2900.783	2440.464	3375	2750.093	2329.562	3308.705	2982.495	40685.48	0.051423
WR	2386.845	3658.818	2919.944	2655.955	4010.417	3509.115	2077.338	4060.547	3559.932	2995.013	4141.906	3375	2858.911	4060.547	3660.2113	49930.5	0.063109
LT	2817.717	4319.307	3447.051	3135.407	4734.375	4142.578	2452.338	4793.555	4202.568	3535.672	4889.6	3984.253	3375	4793.555	4320.9507	58943.93	0.074501

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LRA	1983.871	3041.096	2426.966	2207.547	3333.333	2916.667	1726.619	3375	2958.904	2489.362	3442.623	2805.195	2376.238	3375	3042.2535	41500.67	0.052454
LR	2200.857	3373.716	2692.416	2448.998	3697.917	3235.677	1915.468	3744.141	3282.534	2761.636	3819.16	3112.013	2636.139	3744.141	3375	46039.81	0.058191
															Grand sum	791184.7	

Relative weights generated the same values as in table 5 which means the difference is zero and that's where the iterations are stopped. The values in table gives significance level of each factor studied. After sorting them in descending order, gives factors contributing to disorders ranging from largest to smallest as shown in Table 7.

Table 7. Significance of disorders in descending order

S. No	Disorders	Significance Level
1	BT	0.102531
2	ST	0.089235
3	NT	0.080194
4	LT	0.074501
5	SR	0.072944
6	WT	0.071115
7	WR	0.063109
8	NR	0.060697
9	BR	0.05983
10	SRA	0.058213
11	LR	0.058191
12	NRA	0.05311
13	BRA	0.052454
14	LRA	0.052454
15	WRA	0.051423

Table 7 shows that back pain using tablet chair is the most common pain student suffer while in university having highest value of 0.102531. Second value shows shoulder fatigue using tablet chair while third is neck pain using the same chair and vice versa.

3. RESULTS

Results of AHP showed that tablet chair was selected by all the students that caused all the disorders studied in this paper. Graph shows that tablet chair gives maximum disorders and then revolving chair without arm rest and lastly the most comfortable among the 3 chairs was revolving chair with arm rest.

The graph shows clearly that tablet chair is worst of all in assessment of three chairs. While revolving chair with arm rest cause the least disorders among university students. The most common of all disorders was back pain caused by tablet chair having the highest value of 0.102531 among all. The reasons most students expressed in survey were the non-ergonomic design and not fit for most of student's height. Second highest value was 0.089235 for shoulder pain caused by tablet chair. Since there is no back rest, students sitting for 3 hours straight feels shoulder pain with chair made of wood with no cloth or resin. The third highest value was 0.080194 for neck pain. The discomfort reaches its maximum level when students attempt paper and have to bend their heads for long period of time.

The lowest value was obtained for wrist pain using revolving chair with arm rest. Since students have arm rest in chairs and they can change their posture time to time while sitting in class that account for less pain usually. Second lowest value was obtained for leg pain using revolving chair with arm rest. Since the revolving chair have height adjustment lever. Therefore students can adjust the seat according to their height so that their feet touch the ground comfortably. Third lowest value was for back rest using revolving chair with am rest. Since the chair got adjustable back rest that can be moved up and down as well as back and forth that helps students sit in comfort zone.

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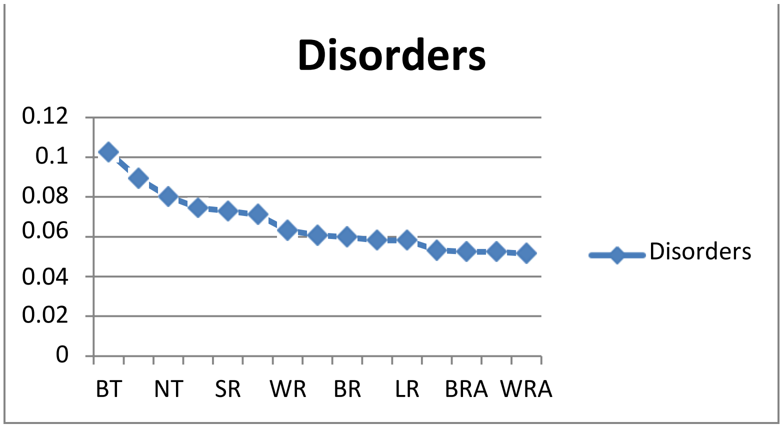

Figure 2. Significance plotted on Line Graph

4. CONCLUSION AND FUTURE WORK

A questonnaire was designed to investigate from students about the comfort level and disorders caused by chairs including Tablet chair, revolving chair with Arm rest and revolving chair without Arm rest. Reliability of data was checked with help of SPSS software and then AHP tool was applied. In the second iteraton the difference between weights was zero and gave the significance level of disorders. The factors shows that tablet chair is reason to most disorders. For future work the same data collected from students can be used and apply Principal component analysis to get more correlations between factors to get better idea. Visual data can be collected to apply software like Multimedia video task analysis in order to analyze stress factors and fatigue areas repeatedly. Tablet chair can be redesigned to lower the disorder level it caused in the present study for future work.

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EXO SKELETAL ANKLE SUPPORT FOR LEG BELOW KNEE

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Abstract

this paper deals with the exoskeletons that are widely in demand due to world that is getting smarter day by day and requires much more stamina and endurance. Exoskeletons are being prepared for warzones, maintenance engineers, workers who have to stand for long hours and for medical purposes. In order to help the patients with amputees or the one paralyzed so they may live up to the mark and enjoy life as we do, there is a need for such portable structures that are lightweight, strong and durable. We have presented in the paper that our exoskeleton for leg below knee, how it differs from other prosthetics used for the purpose, how we have achieved much needed walking efficiency and cut down cost so a layman patient may also benefit from it.

Index Terms—Exoskeletal prosthetics, Exoskeletal ankle support, Lightweight, Walking Efficiency

1. INTRODUCTION

Exoskeletons are structures similar to the human skeletons. The word Exo means 'external'. Therefore, an external structure that helps the body in being firm and in form. If we closely observe exoskeletons have been all around us. Some insects with exoskeletons or shells include grasshoppers, cockroaches, crabs, snails, lobsters and many more. Some animals like tortoises have both exoskeleton as well as an endoskeleton! Exoskeletons may be of any kind and its place of application

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is not restricted. Exoskeleton may be for any limb for example, Exoskeleton of arm,

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Exoskeleton of hand, Exoskeleton of upper leg, Exoskeleton of leg below knee. [1] [2]

1.1 Classification of exoskeletons

Exoskeletons are classified according to place of application, the power source used, the portability and the way of control. Mainly there are three types of exoskeletons. Full body, Upper Extremities, and Lower Extremities. Upper Extremities include the torso and arms. If we further divide
the category, upper body includes shoulders, hands, fingers and the joints. Likewise the lower body includes the hip, leg, ankle and the joints.

Is the structure powered? If yes, then it is further categorized into electrically driven, hydraulically driven, elastically driven or it is mechanically driven.

The portability factor also divides it further. If the structure is mobile and easy to carry it is portable, otherwise if it is fixed, supported and heavy.

An exoskeleton may be controlled in many ways. It may be fully Automated, Joystick controlled, using buttons, using gesture movements or controlling with brain. [3] [4] [5]

2. LITERATURE REVIEW

Work on exoskeletons has been progressing day by day. These exoskeletons have existed around us since the start but due to lack of awareness and research, exoskeletons for humans has been delayed. When scientists found out about the exoskeletons in insects, the idea came up and the imagination went to new heights. Movies like Iron Man, Robocop started emerging. People started becoming curious and awareness spread.

Around 1965, General electric started in the US for developing full body exoskeleton called Hardiman. It was made to add strength to human for lifting heavy objects. In the late 60s, an institute of Serbia developed exoskeleton for walking gait followed by Madison institute who developed in 70s. But the knowledge, awareness and skillset which we have nowadays was not there to mature the technology. [6] [2]

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Research started again in the 21st century and the idea was to develop these skeletal supports for the soldiers for the warfare so they have enhanced strength and endurance in the field. Similarly to help wounded soldiers returning from field to live and enjoy life once more, scientists worked tirelessly on the application of

Fig. 1 Rehabilitation of paralyzed child

exoskeletons in the field of medical. In 2010, exoskeletons for medical purposes emerged in the market. [7]

For example, ReWalk device by ReWalk Robotics and Indigo Exoskeletons. As these structures emerged in the market, some standards and certifications came up as well certifying these exoskeletons. Wheelchairs and heavy walkers were replaced by these structures as they were light and portable. Gradually exoskeletons made their way in many more fields. Researches were done on how to use them in homes and industries. [1] [6]

Around (2014-2015) companies started emerging who showed different approaches towards exoskeleton structures. In 2014, a paralyzed exoskeleton user executed a symbolic kicked off in the world cup that took place in Brazil. His exoskeleton was mind controlled with the help of EEG sensors. Another example like this was of Claire Lomas. She was paralyzed and used ReWalk exoskeleton for participating in marathon. The 2012 marathon she participated in was her first with the structure and she crossed the finish line after 16 days. Soon in 2016 she again participated and completed half-track in just 5 days! [5]

In 2016, Zurich hosted its first Cybathlon. This event was for the people with amputees and disabilities using robotic assistive devices. Amongst the

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modules was the Exoskeleton race. In this race, patients had to show skills of sitting on couch, lifting objects, avoiding stones and hurdles and walking on the slopes.

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Due to the overwhelming support and success, Zurich authorities have pre informed about the second Cybathlon that would take place in 2020. This platform would show what progress would have been made then. [2] [8]

Lockheed Martin has taken initiative of developing exoskeletons for military. Exoskeletons are a part of Pentagon’s third Offset strategies. It seeks usage of robotics and artificial intelligence in soldiers to enhance their skills in battlefield.

Further companies who are in the making of exoskeletons include AlterG, Ekso Bionics, Myomo, Cyberdyne Inc, ReWalk and many more.

Most of these exoskeletons are way too much expensive and have complexities. We are developing cost effective exoskeletal ankle support that is fully automated and has increased walking gait efficiency. [8]

Fig. 2 Military Exoskeletal support showcase

3. BENEFITS AND DRAWBACKS

- One major advantage of exoskeleton is that it protects the inside of the body and acts as a support for being erect and firm.
- It is the latest innovation and a blessing in disguise for the one having amputee or limb paralysis.
- To enable disabled of living a quality life.
- Training sessions are necessary for its effective usage.
- Being an attachment to the body, getting used to it would require both time and patience.

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- It increases soldier effectiveness in field.

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- The increased stamina, strength and endurance would benefit most.
- It requires great care and maintenance
- It gives increased walking efficiency to the patient [5] [2] [4]

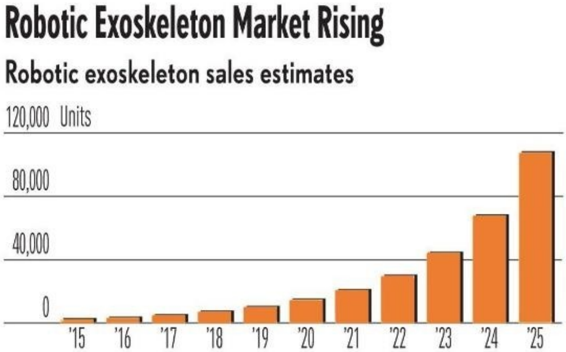

Fig. 3 Market Estimation for exoskeletons

Having said all this, Exoskeletons are of great value and have application in almost every field. The increased stamina and strength and the increased walking efficiency it gives is remarkable.

4. DETAILS OF DESIGN

Our objectives for exoskeletal support for leg below the knee constitute portability, being electrically powered and fully automated. The main motives behind it are that the people who wear this support are not dependent on anyone, must not feel any inconvenience in operating it as well as not being dependent on any button control. This support must be cost effective so an average person affords it without having making financial compromises. The weight consideration for our design is for the person of 80 kilograms.

4.1 Analysis

We have done stress analysis of the exoskeletal ankle support for PP

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(polypropylene) and PLA material as well. The analysis confirms the right choice

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of material and the pass percentage of the project for desired loading. It saves time and capital. This was done in PTC Creo.

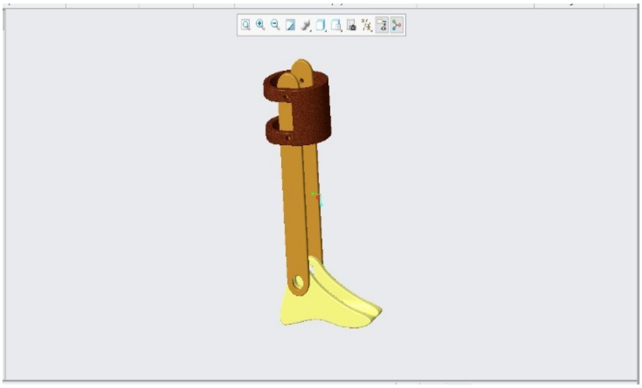

Fig. 4 Prototype on PTC CREO

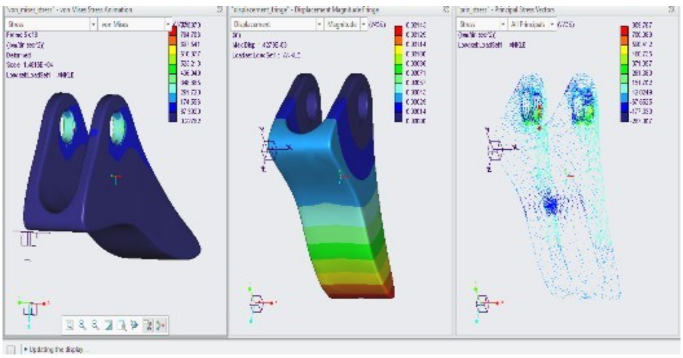

Fig. 5 Stress analysis for PP

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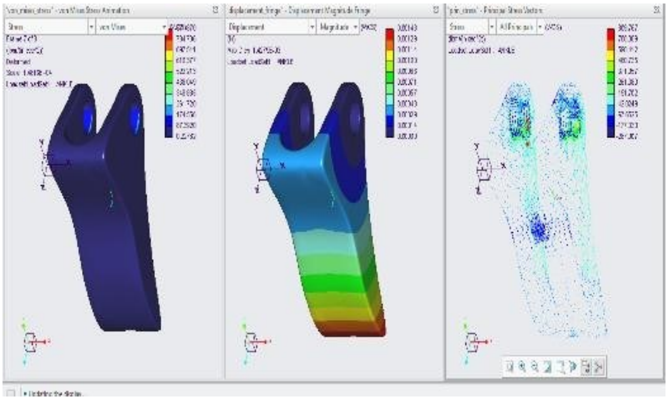

Fig. 6 Stress analysis for PLA

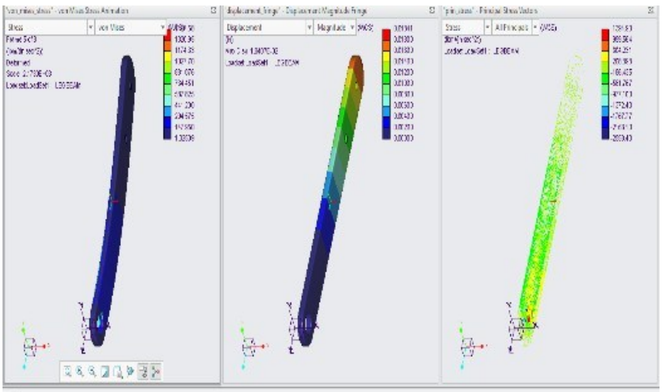

Fig. 7 Stress analysis for PP

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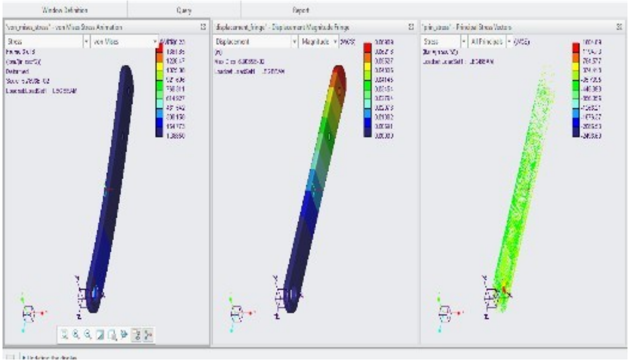

Fig. 8 Stress analysis for PLA

4.2 Material

We considered a wide range of materials for the design and fabrication of exoskeletal leg below knee which include 1) Glass fiber, 2) Thermoplastics, 2a) Polypropylene, 2b) Polyethylene, 3) Composite Carbon Fibers, 4) PLA.
Amongst all these we chose polypropylene and PLA. [6]

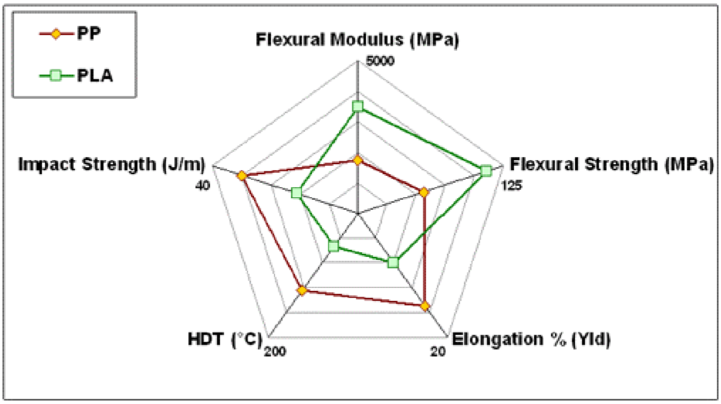

Fig.9 PLA Vs PP

4.3 Mode of fabrication

We had mainly two options. Injection Molding, Vacuum Forming and 3D Printing.

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4.4 Equipment Selection

Motor for ankle was selected after calculations of forces and moments on the ankle of a 70kg person. We did our homework and got to know about the desired torque needed for the motor. Servo was selected of high torque so it is able to move the ankle.

Our objective was to rotate the ankle automatically by the help of leg angles. Leg angles were measured by the accelerometer which was controlled by microcontroller.

Basic design was to make a cylindrical hollow leg support and shape it like the leg below knee. The cylindrical hollow leg had 3 brace so the person with disability or paralysis may also wear it. Then the foot was also made hollow and shaped it carefully so it slides into any shoe. The leg and foot were joined together through roller bearings because they can withstand maximum radial loads. At the outer side of ankle joint, a high torque servo motor was chosen to be placed which could turn the foot and act as ankle.

We chose Arduino as a microcontroller and sensors like accelerometer so the angles of leg may be measured. Main idea was to move foot with the changing angles of leg so it may get fully automated. And the user or patient may get increased walking efficiency when compared with the traditional prosthetic leg.

Tests for the project are being carried on a person of weight 70kgs. His leg was cut from below the knee and we are considering his walking gait for the calibration of sensor and actuator for achieving maximum efficiency while walk. [3] [9] [2]

5. APPLICATIONS

Exoskeletal support has a wide range of applications. It can fit in almost every field ranging from medical to military to industry.

5.1 Medical

Accidents happen most often in everyday life. Moreover some people have disability by birth. Due to these unfavorable conditions there is an opportunity for

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exoskeletons to creep in and make their way. Exoskeletal supports for leg below knee are crucial for such patients. This new technology enables their wearer to walk

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or run like normal people. Traditional prosthetics come as fixed ankle support but the latest exoskeletal support for leg below knee is a movable ankle which allows the wearer to walk effectively as if he has no disability. Furthermore, the cost factor is the main factor being stressed upon so the market for this new structure is diversified. [4] [1] [10]

5.2 Industry

In a country like Pakistan where labor is very much cheap, industrialists prefer human labor than machines. So where human labors are involved in lifting and transporting heavy packages, standing for many hours and operating machinery they require structures that enhance their stamina and endurance so they may lift heavier objects and do not feel stressed out. Such structures called exoskeletons have come to our help. These structures enable heavy lifting, provide support to stand for many hours and still not get exhausted. These exoskeletons can also form a chair like support whenever the wearer wants to sit. [11] [6]

5.3 Military

In a field which requires extensive stamina, strength and endurance, exoskeletons are ideal. Soldiers need to stand for many hours equipped with heavy guns and armor. In such cases exoskeletons provide hassle free solution to the problem. Soldiers when in the battlefield, need to run long distances. This is also solved by exoskeleton supports. Exoskeletons provide better running and enhances the fatigue threshold levels of soldiers. Soldiers face many accidents which result in some disability when returning from battle zones, exoskeletons provide solutions to the problem and enables them to not let their disabilities hinder them from the cause and target they plan to achieve. [3] [9]

5.4 Construction sites

At the construction sites, the workers who have to lift heavy bricks and sand bags need to have sound stamina, strength and endurance. Most often these laborers develop back pains and injuries. To cope with this problem exoskeletons have come to the rescue. Workers or laborers may wear these light weight structures and lift heavier objects easily without even feeling overburdened! These structures drastically improve the stamina and strength of a wearer. Moving to and fro about

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the construction site may make the person tired and exhausted but these structures if worn can considerably reduce the fatigue. [11] [12]

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6. FUTURE ASPECTS

Exoskeletons have a very bright future. Exoskeletons are such structures that are a need of an hour and the skills these structures enhance, the strength, stamina and endurance is prerequisite of almost every work we do! We see exoskeletons to emerge in every field and in future it would be a safety rule for the human workers and the soldiers. Rehabilitation would greatly be influenced by this. The joint pains resulted by lifting, fatigue would vanish because exoskeletons would take loads rather being transmitted to human joints.

7. CONCLUSION

The exoskeletal ankle support for the amputee and paralyzed is a great way to make the patient live up to the mark and increase hopes for a better quality life like the rest. The cost effective ankle support will benefit all class citizens ranging from laborer to a businessman. This may break barriers and open a new era in which we start caring for our amputee and paralyzed or even soldiers who return from warzones wounded.

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ANALYSIS OF REVERSED LOGISTICS PRACTICES IN PHARMACEUTICAL INDUSTRIES IN PAKISTAN

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Abstract: In recent years, closed loop supply chain or reversed logistics have gained a lot of importance in industry and in academics based on environmental, social and many other essential factors. In pharmaceutical industries, expire or damage products that are not properly disposed of, effect the environment and might turn into a peril to people's health if redistributed without any check to people. This research focuses the reversed logistics and order flow dynamics in downstream supply chain. The main focus is to analyze reverse logistics practices in pharmaceutical industries in Pakistan. Specifically, focus is to analyze some reverse logistics factors (product returns reasons, company receiving and disposing of drugs, theft and damage products with regard to returned drugs management) in pharmaceutical industries. The relation between these factors is analyzed and test by hypothesis. Proper management of reversed logistics will be helpful for safety and security of closed loop supply chain and also prevent access of fake medicines. Use of better flow management through advanced technology and its applications will improve reversed logistics and overall closed loop supply chain of a company.

Keywords: Supply Chain Management, Closed Loop Supply Chain, Reverse Logistics.

1. INTRODUCTION

Nowadays, a lot of concern is given to the study of downstream logistics in the pharmaceutical industry. Valuable Time, resources and other things are now being devoted to understand the downstream logistics practices by companies. Almost all pharmaceutical industries are dealing with some nature of return goods due to issues of marketing returns, quality defects, warehouse keeping problems, goods brought back for remanufacturing. Learning to manage reverse flow of goods is of key importance for various industries. Reverse logistics involves the returning of goods, sorting of the goods received, disposal of goods and retrieval of components at various stages in closed loop supply chain. There can be various reasons, such as product warranty claim, wrong or incorrect product orders or delivery, broken products, product recall for quality check, reusable packaging materials and product upgrading account for reverse flow.

Pharmaceutical sector is among the best structured and well known industrial sectors of Pakistan. There are total 759 pharmaceutical industries and manufacturer in Pakistan (PPMA, 2014). Multinational companies cover almost 40% of the total pharmaceutical business across Pakistan, (Memon, 2009). Competing with multinational companies is a good factor for the Pakistani companies to struggle for brilliance. The total sales of medicine in Pakistan is about Rs. 329,526 billion in 2014 and expect to increase by 15%.There are total 759 pharmaceutical companies that are registered and allow to manufacture in Pakistan. There are more than 30 multinationals companies that are producing pharmaceutical products on large scale. The top 100 pharmaceutical companies control 70% of the pharmaceutical market while the top 160 companies account for 85% of the pharmaceutical trade (PPMA, 2014). Pakistan meets 75% of its medicine demand from industries that are producing locally while 25% of medicines are produced in other countries. Raw material for local industries in imported from other countries. For high competition between pharmaceutical industries reversed logistics in very important. (Pervez, 2008).

2. LITERRATURE REVIEW

The success of any industry in today's competitive business environment depends to a large extent on supply chain effectiveness. Competition has stretched from business to competition between supply chains (Khan, A and Subzwari, M.2009). Supply chain defines all direct and indirect parties who comes together to accomplish

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a customer's requirements ((Pervez, 2008).Management understands that mistakes from any member of the

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supply chain can affect the operation and profitability of the organization. Reuse of material is a common practice in supply chains. Supply chain management also tackle returns of parts and customer service; closed loop supply chain as process can be been included as if it were an afterthought in the supply chain management processes. The international Body of Supply Chain (CSCMP, 2009), define logistic management as "Supply chain involves the scheduling and controlling of all activities involved in locating and obtaining, conversion, of all logistics management actions. Importantly, it also includes direction and collaboration with other partners that can be suppliers, supplier's supplier, mediators, third party, and customers. In principle, supply chain integrate both supplies and order from customer (CSCMP, 2009). The reverse logistics is stated as "The method of designing, applying and supervisory the efficient and effective stream of raw materials, complete products and flow of information from the customer to manufacturer for the purpose of recollecting value or proper dumping of wastes." (Rogers & Tibben-Lembke, 2005).

2.1. Reverse Logistics

Reverse logistics or closed loop supply chain can be defined as "the method of moving the material from their final endpoint or from end user to point where it was created or to work place to recover worth or for proper dumping. Downstream logistics is necessary from a customer service relation and its true potential for value removal, reducing user cost, competently and professionally meeting controlling requirements. (Khan, A and Subzwari, M.2009)

The nature of work in pharmaceutical industry differs from other manufacturing industries because products returned and retrieved in time. Reverse logistics goods are rarely refurbished or resold but instead demolished and disposed of properly (Kabir, 2013). Blumberg in 2008 indicated that the global pharmaceutical reverse logistics comprises recall management, discarding & scrapping, Asset recovery & liquidation, Rebalancing & restocking of products as well as Optimization of transportation & shipping costs. The ability to track, retrieve and manage return product in the entire supply chain is of prime importance in the pharmaceutical manufacturing sector. Lots of pharmaceutical products are unable to be recovered in times of reverse logistics. It was estimated that only 4-5 % of pharmaceutical products are returned to manufacturer for disposal (Sartori, 2010).

In sight of the importance of closed loop supply chain for the supply chains and manufacturing industry, main focus is to minimize costs, removal of residual value and sustainable environment for disposal of products, Reversed logistics has acquired great importance due to its implications on supply chain. Good inventory management and use of information technology have aided the supply chains and accomplish their products and systems for disposal.

2.2. Reverse Logistics & Pharmaceutical Industries

Pharmaceutical industries is one of most valuable and important sector with high monetary value, low inventory time and potential for compromising the life of products are major concern. In addition the infiltration of fake, forged and copy products and hazard of misuse of many products allow to track down, recall, receive and ensure efficient removal when necessary importance.

2.3. Expired, Damaged or Wrong shipment Product Return

In reversed logistics management return products are very important. Wrong delivered, expired and products with broken packing's need to returned as soon as quickly to avoid fall in sales. In order to avoid legal implications for expired products make sure the channel is completely operational. Forward channel is easy to implement but reversed logistics is difficult and time consuming to implement. Upstream supply chain follows one-to-more model while downstream supply chain follows more-to-one model (Chen, 2005). An efficient return policy can gave better results and ensure complete clearing of downstream channel.

2.4. Counterfeiting and Forged products Concerns

Counterfeiting or Forged products are a major alarm for pharmaceutical industry across world. World Health Organization (WHO) defines fake products as "a fake, forged or copy medicine are those which are intentionally and falsely printed with respect to uniqueness source. These medicines contain wrong ingredients, wrong quantities of the constituents or no active constituents at all" (World Health Organization WHO, 2009). Some medicines are very expensive. Pakistan Pharmaceutical Association (PPMA) claims that the figures are not true and percentage of false drugs is about 0.5% of the medicines that are produced in country.

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Counterfeiting concern undermining the patient confidence on medicine and also effects the profitability of medicine market. Tracking and tracing counterfeits medicine in downstream is very important and very effective for pharmaceutical industry. The material obtainable on reverse logistics proposes that 4- 5% of the products sent out in market eventually return to the pharmaceutical industry. Ability to follow medicine supply in market can protect end-user and also company reputation and ensure that only real products are return to company when outdated medicine are cleaned from market. (Khan, A and Subzwari, M.2009)

2.5. Downstream Logistics Model

Downstream logistics if managed well can help in improving the supply chain efficiency and overall firm efficiency. The factors that are essential for reversed logistics process impact the efficiency of reverse logistics, which in turn affects the overall supply chain. The factors include the concern and customer service reasons for returns, distribution system needs, ensuring safety of medicine, forged, copy and wrong medicine concerns and the role of technology in managing reversed logistics. The factors given below show that reversed logistics is dependent on the first four factors, while reversed logistics will result in supply chain performance. The model can thus be depicted as below.

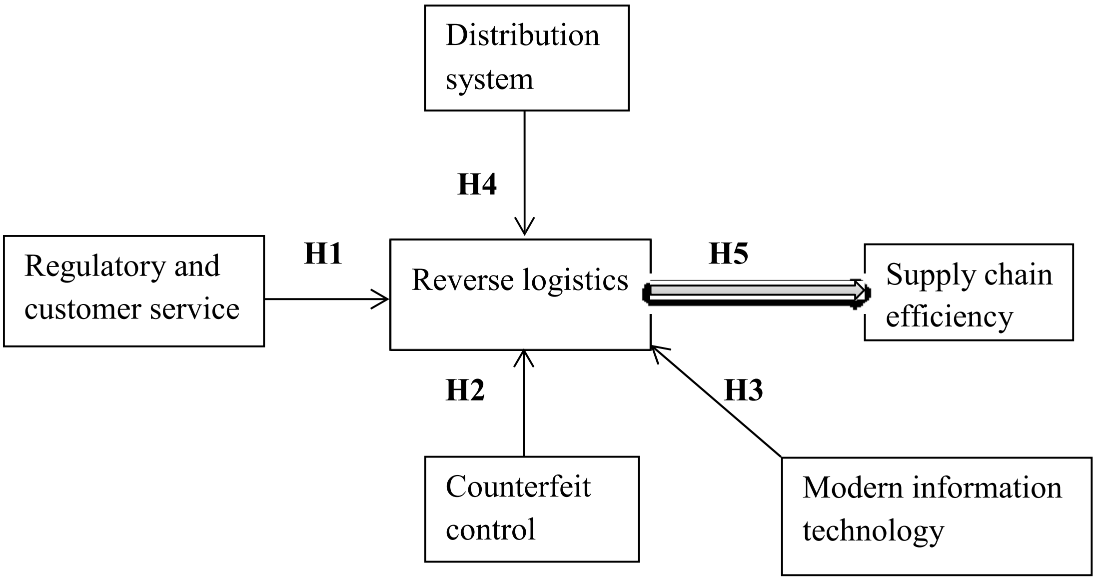

Figure 1 Reverse logistics model

3. METHODOLOGY

Reverse logistics if managed well can help improve the supply chain efficiency of a company. The factors that effects the reversed logistics process also effects the efficiency of reverse logistics, which in turn affects the overall supply chain efficiency of the company which affects the performance of whole company. These factors include the customer service and customer care, causes for returns, distribution system needs, ensuring safety of medicine, forged, copy and wrong medicine concerns and the role of technology in managing reversed logistics.

A comprehensive literature review leads to indicators and sub-indicators. These indicators are designed into five factors. These factors were verified and discussed with pharmaceutical stakeholders, supply chain experts, people from market and academic experts. A questionnaire was designed targeting the identified factors. A pilot study was conducted and the errors were removed and adjustable suggestions were incorporated in the final questionnaire. The questionnaire was then shared with around 150 top pharmaceutical industries of Pakistan. The list was taken from Pakistan Pharmaceutical manufacturers association. Upon

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receiving 40 questionnaires, the incomplete ones were discarded. So a total of 32 responses were analyzed with the SPSS software.

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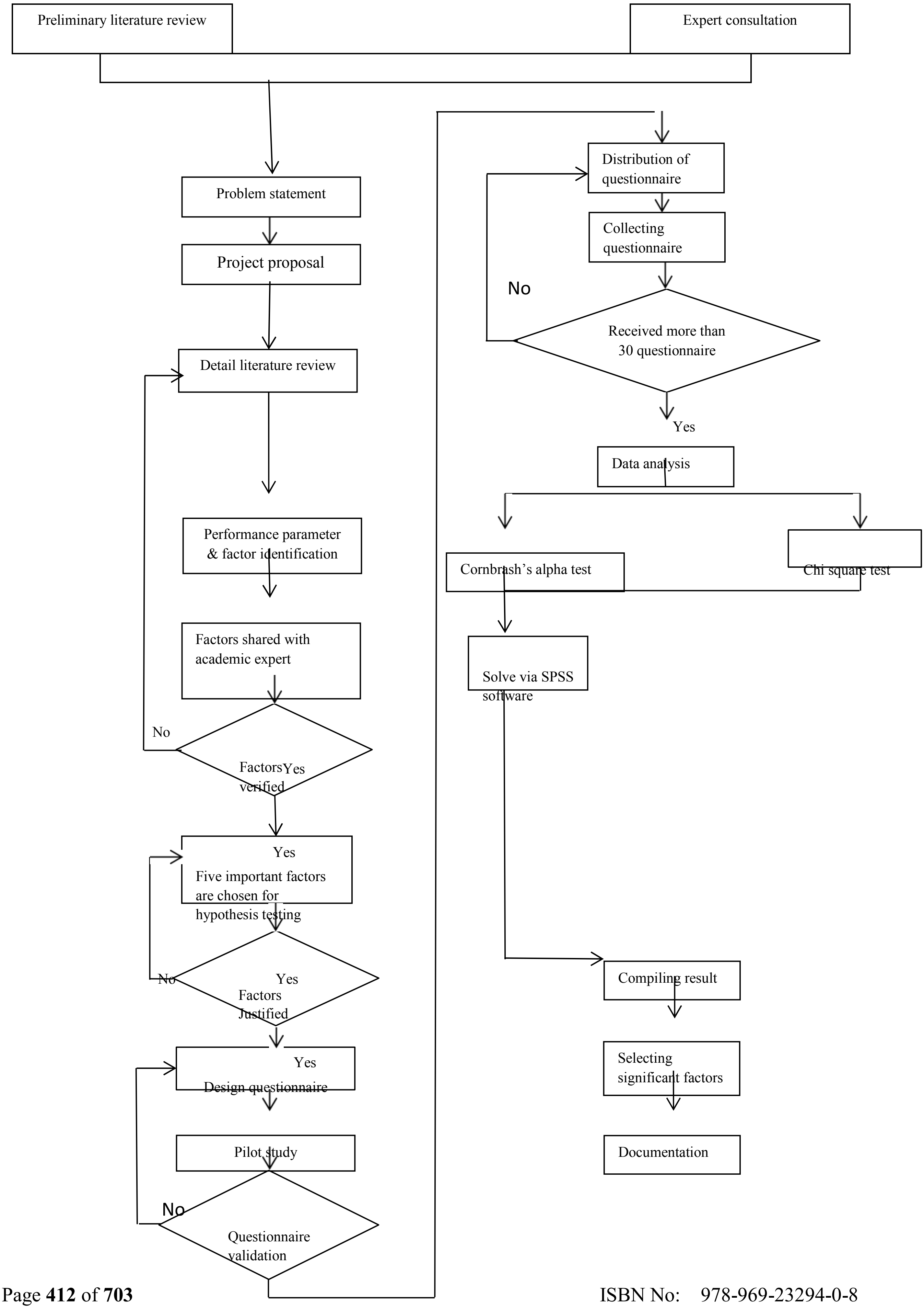

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Yes

Figure 2 Research methodology

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Literature review highlights the issue of availability of valid data related Pakistan pharmaceutical industry. A questionnaire was designed which is divided in to two sections;

- The first section contained information about the respondent profiles and the company and organization information.
- The second section contained series of questions related to factors that are to be test by hypothesis testing. These questions were given weights based on scale from 0 to 5 (highest). As shown in Table 1. H1, H2, H3, H4, and H5 shows number of hypothesis respectively.

Table 1 Twenty six different questions

H1: Respondents View on Product Returns		strongly agree	agree	uncertain/ not applicable	disagree	strongly disagree
1.	There is supply chain department present (for returned medicine)	☐	☐	☐	☐	☐
2.	Return medicine are handled in house	☐	☐	☐	☐	☐
3.	Return medicine are handled By third party	☐	☐	☐	☐	☐
4.	Products allowed to be returned to the organization	☐	☐	☐	☐	☐
5.	Products are returned on daily basis	☐	☐	☐	☐	☐
6.	Products are returned on weekly basis	☐	☐	☐	☐	☐
7.	Products are returned on monthly basis	☐	☐	☐	☐	☐
8.	Products are returned on quarterly basis	☐	☐	☐	☐	☐
9.	Products are returned on yearly basis	☐	☐	☐	☐	☐
10.	Products are returned on other basis	☐	☐	☐	☐	☐
11.	Reason account for the return of products is "damage to product/ package"	☐	☐	☐	☐	☐
12.	Reason account for the return of products is "wrong shipment "	☐	☐	☐	☐	☐
13.	Reason account for the return of products is "expired drugs "	☐	☐	☐	☐	☐
14.	Reason account for the return of products is "temperature excursion damages"	☐	☐	☐	☐	☐

H2: Theft and Damage Challenges with Regard to Returned Drugs Management	

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15	The company experience theft in the course of managing the returned drugs	☐ ☐ ☐ ☐ ☐
16	Drugs get damage when returning wrong shipments	☐ ☐ ☐ ☐ ☐

H3: IT Applications		
17	IT is used in handling of return medicine	☐ ☐ ☐ ☐ ☐
18	Computer based record keeping is used in handling of return medicine	☐ ☐ ☐ ☐ ☐
19	RFID is used in handling of return medicine	☐ ☐ ☐ ☐ ☐
20	2-D or 3-D Bar codes is used in handling of return medicine	☐ ☐ ☐ ☐ ☐
21	Other IT is used in handling of return medicine	☐ ☐ ☐ ☐ ☐

H4: Return System		
22	Product are sent to a central location point provided by the company	☐ ☐ ☐ ☐ ☐
23	Product are returned by wholesalers	☐ ☐ ☐ ☐ ☐
24	Product are returned by retailers	☐ ☐ ☐ ☐ ☐
25	Product are returned by other source	☐ ☐ ☐ ☐ ☐
26	It is very costly to collect and return drugs sold	☐ ☐ ☐ ☐ ☐

Sample or prototype survey is necessary to involve participants and tries to conduct survey in a more efficient way. To increase number of responses the questions are designed in such a way that the participants interest increases in the survey. To avoid any potential conflicts in data collection and after carefully considering the different angles of the research theme, only Pakistan pharmaceutical industries were considered for the survey.

The data was collected by distributing the questionnaire. In distribution process questionnaire was sent to different industries either by mail, by phone survey and some questionnaire was distributed by hand.

In the item analysis an indicator named as Cronbach's Alpha is used for validation process. Data will be valid if Cronbach's Alpha is equal to or greater than 0.7 otherwise data will not be valid (Akhtar, R., &Haq, I. U. (2015).

SPSS software was used to check the data validity. As shown in Table 2. R1, R2…R32 represents 32 different responses. After conducting an item analysis, overall Cronbach's Alpha value is calculated which is greater than 0.7, so data collected is accepted and validated.

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4. DATA COLLECTION

The data is collected for the research objective through the designed questionnaire. The questionnaire is filled by respondents at their own suitability.

In comparison of cost, time, and response rate among the various modes of data collection; we concluded that questionnaire is good mode of data collection having minimum cost and high response rate compared to other modes like interview, direct observation etc. And the data collected through questionnaire is simple and can easily be analyzed. In Pakistan, different pharmaceutical industries were surveyed for data collection for the research project.

These companies, are selected because these are the best due to their reputation. In these companies questionnaires were sent through mail and in some cases by hand. Some data is also collected through other ways of communication.

After questionnaire design, around 120 questionnaires were distributed with different respondents. 60 questionnaires were sent through mail in which 10 were received. Of these 10, 5 were rejected because of their response was incomplete. 40 questionnaires were shared and discussed by personnel meeting with companies' representatives. Out of these 40 questioner 20 response are received, 20 questions are asked to company representative through phone calls and only 7 response are received through this. The Figure 3, with the help of pie chart graphically summarizes the responses.

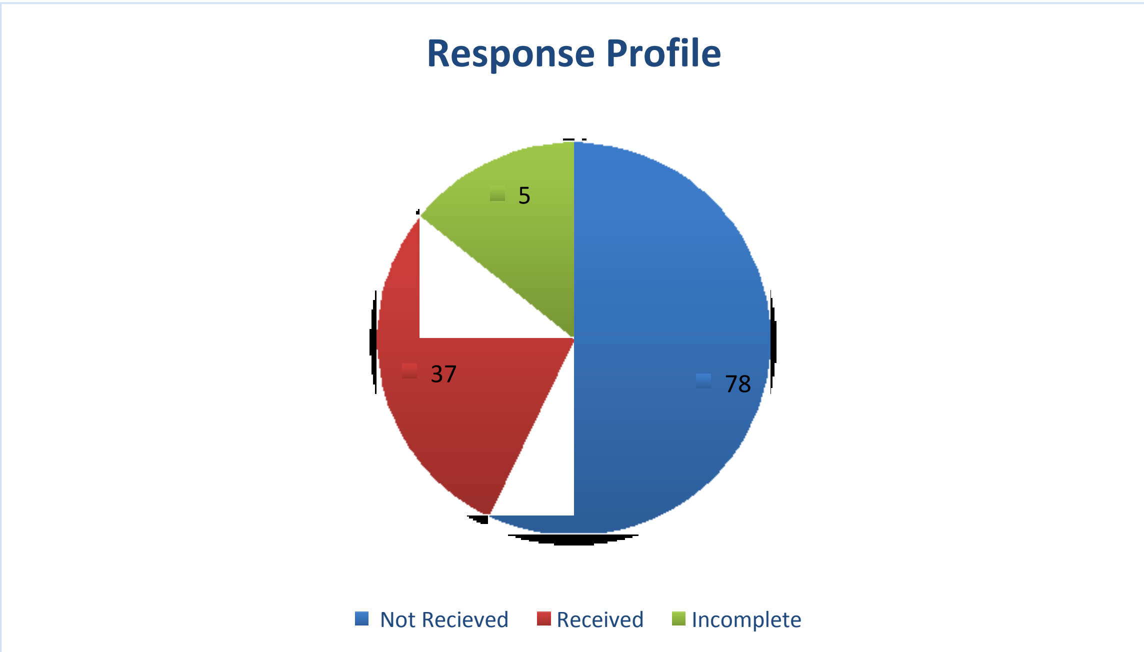

Figure 3 Statistics of Distributed Questionnaire

There are 26 questions and four factors and its representation is shown in Table 1. Table 2 shows the data being collected. Each respondent gives weight age based on his experience. A total of 32 responses are shown in table below.

Table 2 Questionnaire Data for Factors

S.N	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	R11	R12	R13	R14	R15	R16	R17	R18	R19	R20	R21	R22	R23	R24	R25	R26	R27	R28	R29	R30	R31	R32
1	5	5	4	4	4	5	5	5	5	4	5	5	5	4	5	4	5	5	5	5	5	4	5	5	5	5	5	5	5	5	5	5
2	5	4	3	3	3	4	5	4	4	5	5	5	5	5	5	5	5	5	5	5	5	4	5	5	5	5	5	5	4	3	5	5
3	3	2	3	2	4	3	5	2	2	5	3	3	2	2	5	3	3	3	4	1	3	2	3	2	1	2	3	4	2	2	3	1

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4	5	5	5	4	5	5	1	5	2	5	3	3	4	5	1	4	5	3	5	5	5	4	5	5	5	4	3	5	5	4	5	5
5	5	4	3	3	3	4	5	4	4	5	5	5	5	5	5	5	5	5	5	5	5	4	5	5	5	5	5	5	4	3	5	5
6	5	3	4	5	5	3	5	5	5	3	5	5	5	3	5	3	3	5	5	3	4	5	5	4	5	5	5	5	4	5	5	5
7	5	4	3	2	1	5	1	4	4	4	4	4	4	4	1	5	4	4	5	3	4	4	4	4	5	4	4	5	4	2	4	3
8	5	5	4	4	4	5	5	5	5	4	5	5	5	4	5	4	5	5	5	5	5	4	5	5	5	5	5	5	5	5	5	5
9	5	4	4	2	2	1	1	4	4	4	4	4	1	3	1	3	4	4	5	2	5	4	5	4	5	1	4	5	4	2	5	2
10	5	5	3	4	5	5	3	5	5	5	3	5	5	5	3	5	3	3	5	5	3	4	5	5	4	5	5	5	5	4	5	5
11	5	5	4	4	4	5	3	5	5	5	5	4	5	5	3	4	5	5	5	5	5	5	5	4	5	5	4	5	5	4	5	5
12	5	4	3	2	1	5	1	4	4	4	4	4	4	4	1	5	4	4	5	3	4	4	4	4	5	4	4	5	4	2	4	3
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14	5	3	2	2	2	1	4	3	4	5	4	4	5	2	4	1	3	3	5	4	4	5	4	4	4	5	4	5	3	2	4	4
15	1	4	4	3	4	1	2	4	4	5	4	4	2	2	2	2	4	4	1	1	4	4	2	4	4	2	4	1	4	3	2	1
16	3	4	5	4	4	2	4	4	4	4	5	5	3	3	4	3	4	4	3	1	5	4	2	4	4	3	5	3	4	4	2	1
17	4	5	5	5	5	5	5	5	5	5	5	5	5	3	5	4	5	5	4	5	5	4	5	4	5	5	5	4	5	5	5	5
18	4	2	5	5	5	5	5	2	5	5	5	4	5	4	5	5	5	5	4	5	5	5	4	4	5	5	4	4	2	5	4	5
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21	5	5	4	4	4	5	5	5	5	4	5	5	5	4	5	4	5	5	5	5	5	4	5	5	5	5	5	5	5	5	5	5
22	4	5	1	5	4	3	1	5	5	5	5	5	5	4	1	5	5	5	4	5	5	5	5	4	5	5	5	4	5	5	5	5
23	4	2	4	1	2	4	4	2	2	5	4	5	3	3	4	4	5	5	4	5	4	5	4	5	5	3	5	4	2	1	4	5
24	4	2	2	1	2	4	5	2	2	3	3	2	5	3	5	4	5	5	4	1	4	5	5	5	5	5	2	4	2	1	5	1
25	5	4	4	2	2	1	1	4	4	4	4	4	1	3	1	3	4	4	5	2	5	4	5	4	5	1	4	5	4	2	5	2
26	4	5	5	5	5	5	5	5	5	5	5	5	5	3	5	4	5	5	4	5	5	4	5	4	5	5	5	4	5	5	5	5

5. DATA ANALYSIS

The questionnaire was emailed to pharmaceuticals industries and upon personal contact for data collection. A total of 120 questionnaires were sent out to potential respondent. Follow-ups and personal approaches resulted in over 32 responses. The questions were valued on a scale of 1-5. Strongly disagree = 1, disagree = 2, undecided = 3, agree = 4, and strongly agree = 5 for statistical analysis using software SPSS.

First of all data has been tested for further analysis. Cronbach Alpha yield .773 or 77.3% as a reliability statistic of the data (Table-3.1).

Table 3.1. Reliability statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	No of Items
.777	.780	26

To test the hypothesis chi square test has been used as it has great scope to test the variances in a useful way. The tests have been performed on the basis of Asymptotic Significance. Asymptotic Significance is the p- value of the chi square. This value defines the statistical importance of the relationship. In all tests of significance, if $p < 0.05$, we say that there is a statistically important connection between the variables. The first hypothesis that Regulatory and customer service returns are positively related to RL was approved (table- 3.2).

Table-3.2 Test statistics (Hypothesis 01)

Test Statistics (Hypo 01)														
	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q13	Q14
Chi-Square	10.125	18.25	13.625	33.3125	18.25	15.4375	27.6875	10.125	10.5	15.4375	19.75	27.6875	10.5	10.5
df	1	2	4	4	2	2	4	1	4	2	2	4	4	4
Asymp. Sig.	0.001463	0.000109	0.008593	1.03E-06	0.000109	0.000444	1.44E-05	0.001463	0.032797	0.000444	5.14E-05	1.44E-05	0.032797	0.032797

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The asymptotic significance is less than 0.05 in every question related to first hypothesis. This significance means that reverse logistics in Pakistan's pharmaceutical industrial is mainly effect the regulatory and customer service.

Second hypothesis that counterfeit medicines are a major concern for the pharmaceutical industry was approved when chi square test was run for it (Table-3.3).

Table-3.3 Test statistics (Hypothesis 02)

Test Statistics (Hypo 02)		
	Q1	Q2
Chi-Square	19.5625	16.75
df	4	4
Asymp. Sig.	0.0006092	0.0021615

The significance value of asymptotic significance is also less than 0.05. These results show that concern for the counterfeiting is a major concern in RL. All the companies are sensible that counterfeiting is a real possibility and must be carefully monitored. Survey included companies producing generic medicine as well as proprietary medicine. It seems logical that the generic producer will be less concerned with counterfeiting of their product due to low margin. The trademarked products have higher boundaries and are more liable to copying of their products. But in both cases the counterfeiting has a significant role.

Third hypothesis the information technology advances such as RFID, 3-D bar coding is helpful in reverse logistics was also approved (Table-3.4).

Table-3.4 Test statistics (Hypothesis 03)

Test Statistics (Hypo 03)				
	Q1	Q2	Q3	Q4
Chi-Square	30.0625	13.9375	34.25	7.75
df	2	2	3	3
Asymp. Sig.	2.96E-07	0.000941	1.75E-07	0.05

However most local pharmaceutical industries presently do not have 2-D, 3-D or RFID expertise employed but their own path and trace system based on computer record for their goods is strong enough for tracing necessary material. With no doubt, the information technology has made considerable inroads into management of forward and reverse logistics and record keeping in most companies is computerized. This technology is still in early stages in the developing countries of the world.

Fourth hypotheses that distribution system organization and control is an important factor in managing reverse logistics was also approved (Table-3.5).

Table-3.5 Test statistics (Hypothesis 04)

Test Statistics (Hypo 04)				
	Q1	Q2	Q3	Q4
Chi-Square	34.25	12.0625	6.4375	10.5
df	3	4	4	4
Asymp. Sig.	1.75E-07	0.016893	0.048771	0.032797

This suggests that all the companies included in the survey have a strong supply chain network which allows

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them to completely ensure a complete recovery as well as they have a strong check over false products by

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advertising though incomplete distributions channels and openings. The acceptance of hypothesis 4 also shows that pharmaceutical companies identify the importance of checking and controlling distribution of medicine for both upstream and downstream logistic.

The last hypothesis that the effective reversed logistics is positively related to efficient supply chain was also approved by accepting the entire previous hypothesis. The acceptance of this hypothesis displays the pharmaceutical sector is dynamic and flourishing to carefully manage and control returns. They do not cater return costs importantly and not ignored or justified with marketing expenses.

6. RESULTS AND DISCUSSIONS

Table 4 summarizes the overall results. Each hypothesis is intrigued with respect to its result. The hypotheses which are conspired at the top have great significance according to the respondents.

Table 4 result of hypothesis testing

H1	Regulatory and customer service returns are positively related to RL	Accepted
H2	Anti-counterfeit measures are positively related to RL	Accepted
H3	IT applications are positively related to RL	Accepted
H4	Distribution system effectiveness are positively related to RL	Accepted
H5	Effective reverse logistics is positively related to efficient supply chain	Accepted

This study has been competent to fill a gap in our information on the Pakistani pharmaceutical industry. Reverse logistics is mainly ignorant area in supply chain management, Information about return management, managing returns to improve the effectiveness of the reverse logistics process. It is clear that reverse logistics has been familiar as a necessity for regulatory and customer service objectives. Reverse logistics has not established the attention it deserves and little or no attempt is being thru to manage RL for managing costs and efficiency.

The pharmaceutical industry is a superficial division where mishandling of expensive medicine not only conciliations the profitability of the sector but also theaters to the health of those who buying these pricey medicine expecting to be treated of their illness. Counterfeit or expired medicines, improper cleaning of network of expired medicine is not only risk the profitability of the sector but also creates problem of life and death for the buyers. Delayed responses, long return processing times, poor control of returned medicines create probable problems for the pharmaceutical industries. unsuitable control of returned medicine leaks pilferage and penetration of the expired medicine into the market with counterfeit packaging.

The regulatory bodies must have planned all the regulations and rules necessary to defend the industry and the consumers. Improper implementation of these regulations, the temptation of making high profits by producing subnormal and/or counterfeit medicines and existence of corrupt features in delivery systems has put the burden on the pharmaceutical industry to protect the truthfulness of their products.

The pharmaceutical sector in Pakistan comprises of multinational and large local companies on one hand and an collection of small local companies on the other. The larger companies accounting for 80% of market have the resources to securely regulate their distribution network and are better equipped to control both forward and reverse processes. It is clear that present RL focuses on retrieving the medicine that have a few months of shelf life, along this the damaged packaging and temperature/exertion based returns can be returned to the supply chain. If managed properly, even in this sensitive area 10 percent or more of the returned medicine could be used to add value to the supply chain resulting in value addition of nearly Rs 500 million at the present estimate cost of reverse logistics.

The budget associated with reverse logistics cost is considered a marketing and distribution expense and by many states that it is considered to be a very small amount of total costs (1-5%). Managing reverse logistics is therefore of slight importance and the medicines retrieved from the market are allowed to accumulate at local collection points for weeks and months until they are disposed of.

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The scope of information technology use in reverse logistics is limited to computerized tracking and recording of retrieved products. The emerging technologies like management information system, RFID, 3D bar coding and ERP application will add a whole new dimension to managing distribution and return of pharmaceuticals. The implementation of RFID, 3D bar coding, ERP is still in early stages in countries where the hardware required to implement the technology is already in place. Applications in advanced world are likely to introduce this technology in Pakistan as well through the international companies functioning in Pakistan.

7. CONCLUSION AND FUTURE RESEARCH

The effects of this study for Pakistan's pharmaceutical industry are frequent. Reverse logistics has not established the courtesy it earns and little or no effort is being made to accomplish RL for managing costs and efficiency.

Very rare of these companies have the logistics support to certify an efficient network of product delivery and reverse logistics. The questionnaire was sent out more than 150 survey forms to known addresses of all companies. The degree of reply from the smaller firms shows that some of these firms are either shipping common medicines or have little or no business in Pakistan. Deficiency of marketing organization in smaller companies can be challenging in ensuring efficient reverse logistics and can even create further risk of counterfeiting of their products.

Reverse logistics is a comparatively new extent for the industry. The pharmaceutical sector in Pakistan is awfully systematized and most of the business is well organized. The major manufacturers have achieved to control management of returns efficiently. The other economic sectors have rewarded little care to the management of reverse logistics for enlarged profitability and customer service improvements. In many sectors reverse logistics abilities to be profitable as renovation, enduring value recovery, income from extended warranty can increase the profitability of those sectors.

More prominently, a better return policy will assistance local producers to create a brand image that is normally reserved for large multinational companies. It is suggested that reverse logistics in other economic sector be planned to advance recommendations to improve reverse logistics to increase the profitability of these sectors. Better management and control of returned products is crucial to keep company image as poor control of returned medicine can effect in infiltration of expired medicine in new wrapping into the market distressing the status and effectiveness of decent manufacturers. Through this investigation, it is publicized that there is lack of conformity, control and effectiveness in the whole process of reverse logistics.

Appropriate management of medicines recovered approaching to expiry offers the opportunity to project the company as a responsible social citizen by distributing these medicines through charitable hospitals to poor who cannot manage to pay for these medicines anyway and decrease the cost of disposal after their expiry.

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COMPARATIVE ANALYSIS OF ENGINE OIL CHARACTERISTICS USING GASOLINE AND CNG AS FUEL

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ABSTRACT

Engine oil is one of very basic and important component that is used for lubrication purposes in internal combustion engines. It helps engine to improve the wearing on moving parts, remove the sludge, protection from corrosion, improves sealing and cool the engine by taking away the heat generating in it. Two different oil grades of SAE20W50 and SAE10W30 of Petron Company of Toyota were used in 1298 c.c Toyota Corolla engine to investigate the behavior of engine lubricating oil running in the same capacity of engine with Gasoline and CNG as fuel and were compared at different mileage in two different fuel driven engine in this research. Viscosity tests and Total Acid Number (TAN) tests are used to study and analyze the behavior of two different grades oil with the two different fuel driven engine. Viscosity result shows that engine oil used in Gasoline perform better than CNG in both the oil grades while TAN results also reveal that engine oil used in Gasoline driven engine perform better than that of CNG driven engine due to low acidity level. Moreover, SAE20W50 engine oil shows better characteristics and performance than SAE10W30 engine oil.

Index Terms— SAE10W30 engine oil, SAE20W50 engine oil, Viscosity test, TAN test

1. INTRODUCTION

Engine oil is one of very basic and important component that is used for lubrication purposes in internal combustion engines. The main function of engine oil is to reduce friction among the moving parts in internal combustion (IC) engine. It also helps to improve the wearing on moving parts, it helps to remove the sludge, protection from corrosion, improves sealing and cool the engine by taking away the heat generating in it. Engine life and its performance are dependent on engine oil, whereas engine oil performance itself depend on the fuel (either CNG or Gasoline) and its mileage. Specification of engine oil indicates that which kind of engine oil should be used in different conditions and when it need to change. Degradation of engine oil is due to continuous running providing lubrication to various parts of engine which results in oil loses its properties. All the commercial engine oil contains additives whether it is petroleum based or synthetic based. All lubricants contain additives (5% to 30%). The main and important additives are antioxidants, corrosion inhibitors, antifoam agent, demulsifying agent, pour point depressants and viscosity index improvers. Society of Automotive Engineers (SAE) used a rating system for motor oils to classify oil by viscosity. In SAE 0W20 oil, the 0 is the cold-temperature viscosity rating (W stands for winter), and the 20 is the high temperature viscosity rating. Multi-grade viscosity motor oil flows well at low temperatures as well as protects the engine at high temperatures.

Different researchers studied the performance of engine oil, its properties and its effect on engine running on both Gasoline and CNG driven engines. Different aspect of the oil was observed in different papers with different prospective explaining all the desired objectives.

Analytical lubricant technology was used for determining the condition of 2 and 4 cycle automotive and railroad diesel engines through used oil analysis. It is made from crude oil with the addition of different derivatives i.e. in ordered to improve its certain properties. It picks up several impurity and additional components from engine wear and hence the property of oil shows a variation with the number of kilometers it is driven (Frassa, 1968). Wear elements was investigated in lubricating oil (Adeyemo, 2004). Removal and recycling of elements and compounds from engine oil was studied and used the engine oil after purification using extraction by composite solvent and acid treatment method (Abro, 2013). However, his work was based on the recycling of oil using the mentioned methods without mentioning the mileage of lubricating oil driven in an engine. Analytical approach was developed to enable a more accurate wear determination from engine oil samples. The factors oil

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consumption and oil additives were considered and improved maintenance program for ICE based on oil analysis (Macia,

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2003). Analysis of kinematic viscosity of biodiesel fuel components and related components was studied (Knothe, 2005). Information on the relationship between oil viscosity and engine performance was summarize that may be of use in developing a new engine oil viscosity classification system (Stewart, 1977).
Number of research work has been carried out on engine oil to study the behavior of viscosity considering different engine oils driven with gasoline engine, however the aim of this research work focuses on the viscosity of two different types of engine oils grades SAE20W50 and SAE10W30 have been used for the analysis when driven in Gasoline engine and then in CNG engine. The research effort focuses mainly on comparing the performance of engine which is running in Gasoline and CNG as fuels. The properties of engine oil were investigated through viscosity and total acid number (TAN) tests.

2. METHODOLOGY

2.1. Engine Type and Specifications

Two type of Engine Oil SAE20W50 and SAE10W30 of Petron Company of Toyota were used in 1298cc Toyota Corolla engine and different samples were collected at various mileage. The same engine was first driven with Gasoline and then CNG. Gasoline and CNG both have different properties and operating condition, thus these 2 have different impact on an engine.

Table 1: Specifications of test engine

Engine Specifications					
Engine cylinder	Engine capacity	Cylinder bore	Engine stroke	Compression ratio	Fuel system
4	1298 c.c	75 mm	73.5 mm	10:1	Multiport Fuel Injection

The different samples were collected at different intervals for both Gasoline and CNG fuel. Viscosity test and Total Acid Number (TAN) tests are performed to study the effect on engine oil. All the tests are conducted to specify the properties of engine oil at any required time and mileage. After all the tests were performed, a comparison was made for both Gasoline and CNG fuel.

2.2. Viscosity test

This test was performed to investigate the effect on viscosity of the engine oil when same type of oil grade is used in Gasoline driven engine and then in CNG driven engine. Different samples were collected and analysed. Viscosity changed with respect to temperature after driving an engine. It is difficult to find absolute viscosity so, that is why relative viscosity was calculated. In this method, the viscosity of one fluid was found out by comparing with the other fluid. The reference fluid that used was water because the viscosity of water is known at normal temperature and pressure as well as its density. Total of 10 nos. of samples were then tested to determine the viscosity.
The Ostwald Viscometer (Optec Instrumentation) was used to find the relative viscosity. There are two level indicator lines on the Ostwald viscometer that is used for the detection and provide a base line for reading. Firstly measure the time taken by the water to cross the 2 level indicator lines. The experiment was performed thrice on water in order to avoid error because water is not that much viscous and it flow very quickly. Engine oil samples density was found out by knowing its mass and volume by the given formula:

$$\rho = {}^{m}/_{v}$$

The mass of oil sample was found out by subtracting the beaker mass from total mass by knowing the volume of a beaker exactly 25ml, indicating the volume of oil sample i.e. 25ml.
The oil samples were placed in Ostwald viscometer following the same procedure as for water. The below relationship was used to find the oil viscosity of unused oil relative to water which will be used as reference for other samples collected at different intervals. Thus, by comparing with the unused oil shows how the viscosity changes with respect to time.

$$\eta_o = \frac{(\rho_o * t_2)}{(\rho}$$

w

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$$* t_1)^{\eta_w}$$

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Where,

η_o= viscosity of engine oil sample η_w= viscosity of water
ρ_o= density of engine oil sample ρ_w=density of water
t_2= time taken for oil sample t_1=time taken for water

2.3. Total Acid Number (TAN)

Total acid number (TAN) covers determination of acidic constituents in lubricating oils and other petroleum products, titration methods of soluble or nearly soluble mixtures of toluene and ethanol is used to find out the acidity of oil samples. It is applicable for the determination of acids whose dissociation constants in water are larger than 10-9; extremely weak acids whose dissociation constants are smaller than 10-9 do not interfere.

In engine oil, the constituents considered to have acidic characteristics include organic and inorganic acids, esters, phenolic compounds, lactones, resins, salts of heavy metals, and addition agents such as inhibitors and detergents. Colour titration method was used to find the acidity of unused and used oil. The basic purpose of this test is to check the limit of acidity in engine oil.

The TAN test is performed according to standard (ASTM D664). The acidity of unused sample of both the 2 grades of engine oils and acidity of all other samples of engine oil at different mileage driven in both CNG and Gasoline for the same engine were examined. After getting a hand on the results of all samples, we compare the results of all given data and conclude which oil has lower acidity and which has higher acidity.

Firstly the solution was prepared by dissolving the oil grade sample in 10mL toluene containing in a beaker, call that solution 1. Then add 50ml ethanol and add few drops of phenolphthalein in it as an indicator, call that solution 2. Then 0.142g of potassium (K) was added to 25ml of ethanol making alcoholic KOH solution, call that solution 3. Solutions 1 & 3 were mixed and placed on a hot water bath so that they become dissolve in each other completely to become a 0.1N solution. Then solution 2 was added drop wise in the solution. After sometime the colour of the solution start changing. Keep dropping until the colour of another solution is changed permanently to pink. Note the decrease in volume of that 2nd solution and find the TAN by using the equation.

$$TAN = \frac{M.mass\ of\ KOH * volume\ used\ during\ titration * normality}{weight\ of\ oil\ sample}$$

3. RESULTS AND DISCUSSION

3.1. Viscosity Test

Viscosity was analysed on both type of oil grade driven by Gasoline and CNG fuels using Ostwald viscometer, the experiment was performed on specific engine oil to find the viscosity after specific intervals. The result shows that engine oil viscosity decrease when mileage increases.

The initial viscosity measured at 0km was 159.262 pa.s. In case of SAE20W50 engine oil during CNG driven engine different samples were collected at 1340km, 2680km and 3590km which shows the viscosity of 121.108 pa.s, 97.561 pa.s and 79.453 pa.s respectively. Similarly, when the same engine oil was driven with Gasoline fuel different samples was collected at 1340km, 2690km and 3570km which shows the viscosity of 138.589 pa.s, 106.815 pa.s and 90.143 pa.s respectively. Figure 1 shows the comparative analysis of viscosity of SAE20W50 operating on both type of fuel.

By analysing both samples of SAE20W50 oil by using two different types of fuels as shown in shows that viscosity decreases in both type of fuel used but decreases much when operating in CNG fuel. A decrease in viscosity may be due to water contamination or admixture with lower viscosity fuel or lubricants. CNG fuel may have more chances to mix with the engine that causes decreases in the oil viscosity. In Gasoline operating engine, the oil viscosity decreases but not much as in CNG operating engine.

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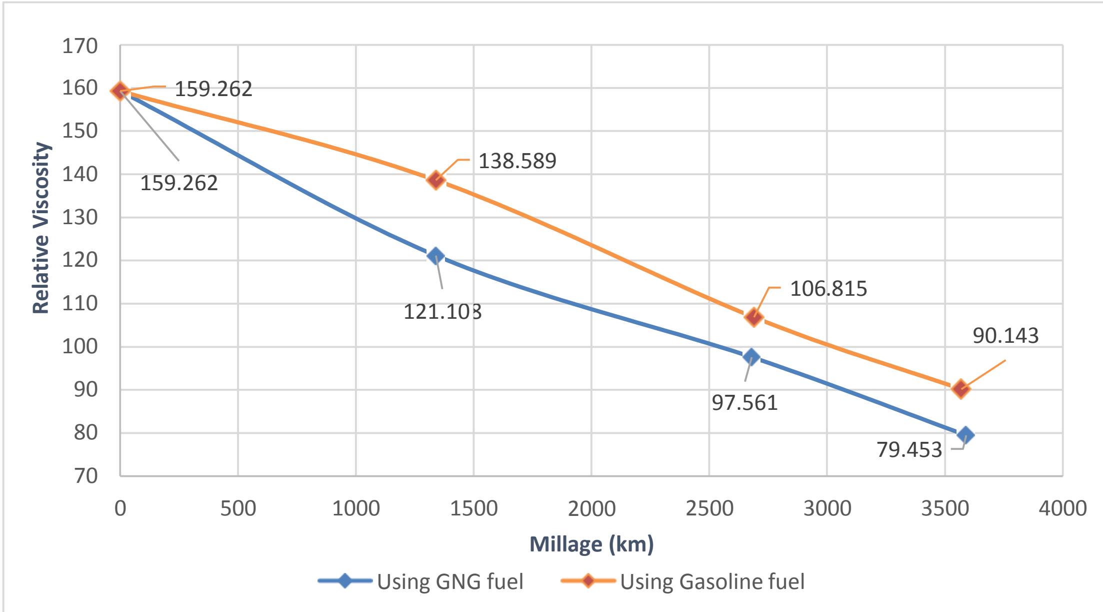

Figure 1: Comparative analysis of viscosity of SAE20W50 operating on both type of fuel

Considering the same case for SAE10W30 engine oil, the initial viscosity measured was 69.863 pa.s. During CGN driven engine different samples were collected at 1365km, 2685km and 3580km which shows the viscosity of 56.752 pa.s, 44.165 pa.s and 37.412 pa.s respectively. Similarly, when the same engine oil was driven with Gasoline fuel different samples was collected at 1350km, 2675km and 3565km which shows the viscosity of 61.745 pa.s, 50.452 pa.s and 46.412 pa.s respectively. Figure 2 shows the comparative analysis of viscosity of SAE10W30 operating on both type of fuel.

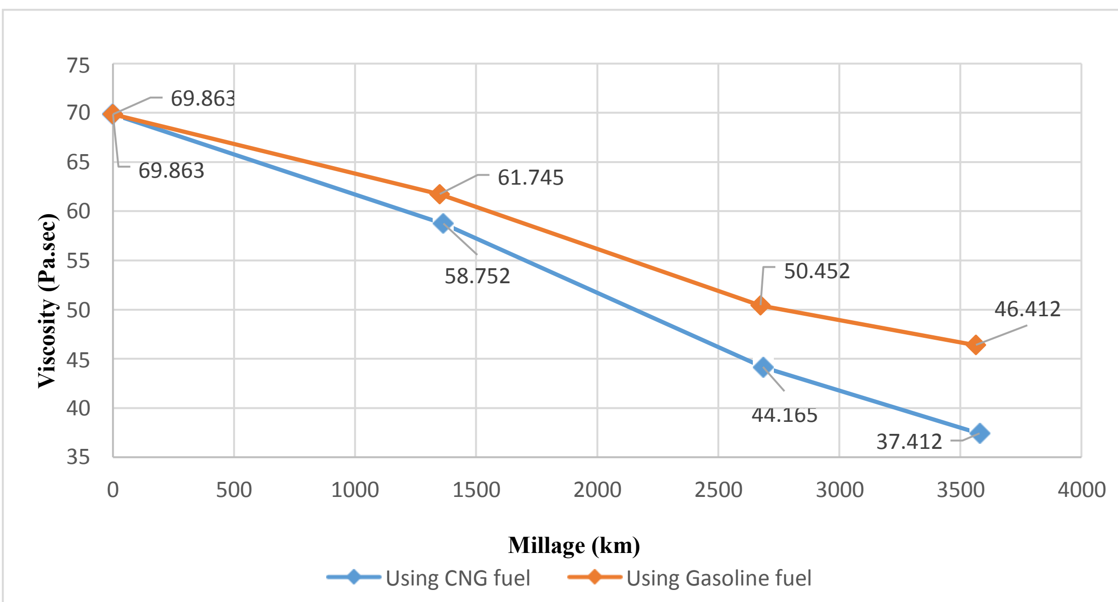

Figure 2: Comparative analysis of viscosity of SAE10W30 operating on both type of fuel

Same result can be drawn by analyzing the SAE10W30 engine oil by using two different types of fuels that viscosity decreases much when operating in CNG fuel than in Gasoline fuel.

From the comparison of viscosities of both type of engine oil the SAE20W50 engine oil perform better but it will degrade fast as compared to SAE10W30 engine oil. Moreover Gasoline fuel is better with respect to viscosity when running the engine.

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3.2. Acidity Analysis

Engine oil acidity was studied using colour. Acidity of engine oil increases depend on what type of fuel is used and which type of oil is used. Acidity in engine oil can be referred as TAN which show the milligram of KOH in sample of engine oil. The acidity of unused sample of both the two grades of engine oils and acidity of all other samples of engine oil at different mileage driven in both CNG and Gasoline for the same engine were examined. Each sample of engine oil was poured in two same engine size operating in two different types of fuel.
For acidity analysis the initial TAN measured was 1.31 mg KOH/g. In case of SAE20W50 engine oil during Gasoline driven engine different samples were collected at 1340km, 2680km and 3560km which shows the TAN of 2.39 mg KOH/g, 2.98 mg KOH/g and 3.15 mg KOH/g respectively. Similarly, when the same engine oil was driven with CNG fuel different samples was collected at 1360km, 2690km and 3580km which shows the TAN of 2.46 mg KOH/g, 3.02 mg KOH/g and 3.23 mg KOH/g respectively. Figure 3 shows the comparative analysis of TAN of SAE20W50 operating on both type of fuel.

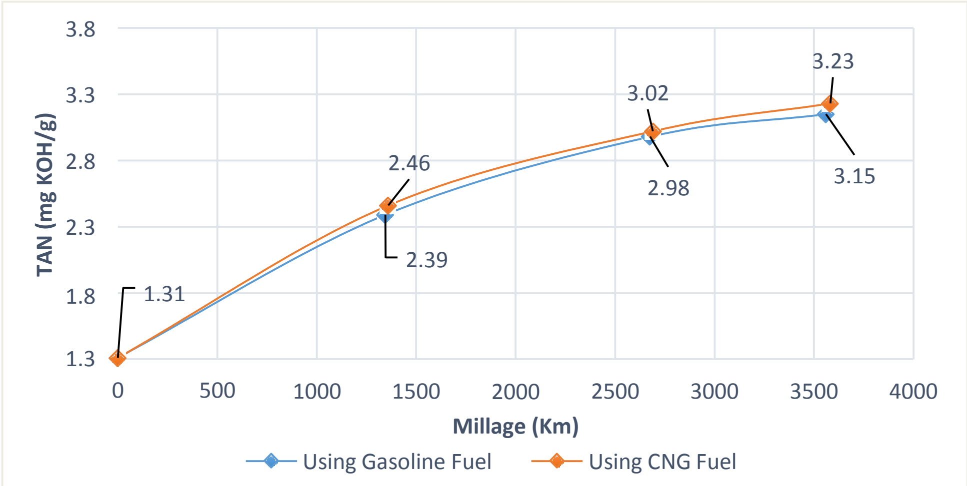

Figure 3: Comparative analysis of TAN of SAE20W50 operating on both type of fuel

Considering the same case for SAE10W30 engine oil for Acidity analysis the initial TAN measured was 1.57 mg KOH/g. Different samples were collected at 1345km, 2685km and 3590km which shows the TAN of 2.52 mg KOH/g, 3.15 mg KOH/g and 3.81 mg KOH/g respectively. Similarly, when the same engine oil was driven with CNG fuel different samples was collected at 1335km, 2690km and 3575km which shows the TAN of 2.63 mg KOH/g, 3.28 mg KOH/g and 4.11 mg KOH/g respectively. Table 4 shows the TAN of SAE10W30 engine oil using both type of fuel and Figure 4 shows the comparative analysis of TAN of SAE10W30 operating on both type of fuel.

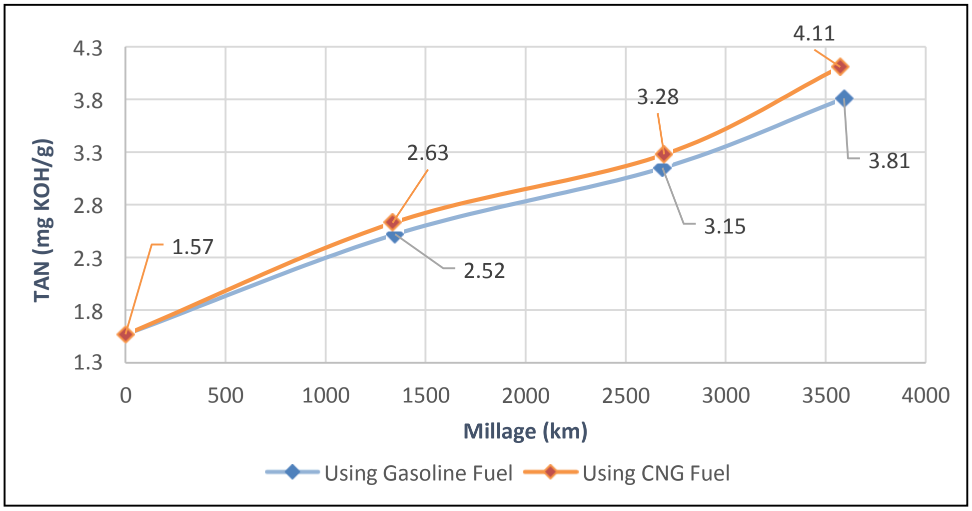

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Figure 4: Comparative analysis of TAN of SAE10W30 operating on both type of fuel

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The result shows that Gasoline fuel is better with respect to acidity because acidity is lower than CNG fuel operating. By analyzing both type of engine oil shows that the CNG acidity is greater as compared to Gasoline operating engine moreover, SAE10W30 engine oil degrades more swiftly than SAE20W50 engine oil because of less additives and more corrosive materials in SAE10W30 oil which increases the acidity level.

4. CONCLUSION

Two different oil grades of SAE20W50 and SAE10W30 were used to investigate the behavior of engine lubricating oil running in the same capacity of engine with Gasoline and CNG as fuel. Lower viscosity cannot lubricate engine parts properly so wear and tear were produce and effect engine performance. Viscosity result shows that using CNG as fuel can decreases more viscosity with respect to Gasoline fuel used for both type of engine oil used. High acidity in engine oil reduces engine life. TAN results reveal that engine oil used in Gasoline driven engine perform better than that of CNG driven engine and using CNG fuel has greater acidity and SAE10W30 engine oil has greater acidity as compared to SAE20W50. Moreover, SAE20W50 engine oil shows better performance than SAE10W30 engine oil in both viscosity and TAN tests. Based on these results we can conclude that using Gasoline fuel is more preferable engine oil because it less degrades the oil. Using CNG fuel can cause rapid degradation of engine and engine oil due to high acidity and high nitration rate.

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PARAMETERS IDENTIFICATION FOR PLACER GOLD DEPOSITS IN NORTHERN PARTS OF KHYBER PAKHTUNKHWA, PAKISTAN

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Abstract

North Pakistan represents a highly favourable area for gold and other base metals. Research studies have been conducted on the exploration, characterization and extraction of the placer deposits in northern Pakistan and Khyber Pakhtunkhwa (KP). Panning and direct stream sediments sampling techniques were mostly used. Panned samples showed relatively good results for gold than that of stream sediment sample. However, panning is generally used as a prospecting tool for placer and therefore could not be more effective for detail exploration and characterization of placers. Investigations for the presence of sulfide and carbonaceous materials is also missing which results in the consumption of reagents and the gold may also be lost due to adsorption on carbonaceous materials. Thus the values obtained from analysis may be low from actual values. Therefore, the sample materials with higher level of sulfide bearing minerals or organic matter must be pre-treated
i.e. roasted (oxidation of organic carbon and sulfide) before aqua regia-digestion. The economics investigation of the placer deposits of the northern areas is also missing in the literature. From the detail study of the published literature regarding the placer deposits of northern Pakistan, it is concluded that almost all the researchers in the study area have missed some key parameters like roasting (oxidation of sulfide and carbonaceous materials) of samples before aqua regia digestion, particle size distribution analysis, determination of gold in various size fractions, proposing of suitable mesh size for treating gold placers. It is recommended that placer gold deposits in the study area should be investigated in more details with a technical sampling from the most suitable gold placer deposits and effective laboratory investigation for the determination of chemical composition, bulk mineralogy, grain size and particle size distribution. It is further recommended that a suitable mesh size for treating placer gold of different deposits and a suitable location(s) for the installation of processing plant needs to be identified in order to start mining operation of placer gold and get revenue from it.

Key Words: Placer, gold, base metals, exploration, characterization.

1. Background:

The presence and occurrence of placer gold in district Chitral, Gilgit, and along the Indus River has been reported by the Austromineral in 1976 and 1978. The placer gold deposits has been identified and proved through drilling and panning [1, 2]. For the exploration and identification of placer deposits and recovery of valuable heavy minerals specially gold and silver, panning and washing activities has been practiced in northern areas of Pakistan from the last two decades [3]. Presently over 200 families are directly involved in the extraction of gold and other valuable placer minerals along the Indus river through panning and washing. These peoples use conventional techniques and primitive tools for gold extraction. Therefore, in-spit of hard working throughout the year their income is very minimum (few

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thousand rupees per year).They use panning and mercury for the extraction of course gold while the remaining gold particles including fine, ultrafine and invisible gold is discarded into the river along with other materials containing high amount of mercury and other

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valuable heavy metals. It is not only causing water pollution but also destroying the fish and other animals living in the river [4]. The very first technical activities in Pakistan for mineral exploration were conducted by a team of Australian geologist, Ivanac, Traves, and King in 1951 [5].

Pakistan and specifically Northern areas of Pakistan are geographically very interesting and beautiful by its area to area and region to region. Almighty Allah has gifted us with high mountain ranges through which different streams of water and rivers are coming out and flowing towards lower elevation areas of Pakistan. God has also gifted us with lot of mineral resources including gold, platinum, cassiterite, magnetite, chromite, ilmenite, rutile, native copper, zircon, monazite, various gemstones, etc in those areas. Mineral grains of gold and other heavy metals disintegrate from their source rock through weathering and then transported by the streams and rivers. As these mineral grains are heavy therefore they accumulate or concentrate in stream or beach and form workable ore deposits. There are so many such deposits along different rivers. Research studies have been conducted on the exploration, characterization and extraction of the placer deposits in northern Pakistan and Khyber Pakhtunkhwa. The results shows that gold in the form of colors (<0.3 mm), and specks (0.3-0.5 mm) have been identified in pan concentrates. Also gold and other base metals have been detected by atomic absorption spectrometry in stream sediments samples after aqua regia- digestion.

2. Purpose and Scope of this Study:

The present study is a compilation of published information relating to the placer gold deposits of Khyber Pakhtunkhwa (KPK) and northern Pakistan. The purpose of this study is to outline areas of placer deposits in Khyber Pakhtunkhwa and northern Pakistan and to serve as a guide to their location and source. This paper summarizes the published articles and information of placer gold in KPK and northern Pakistan. Their findings are described briefly and key things missed during these research works are summarized. Moreover, recommendations are given for filling the research gaps and conducting a more detail, technical and effective investigation.

3. Research Work Conducted on Gold Placers along the Indus River and its Tributaries:

3.1 Geochemical Studies of Stream Sediments, Panned Concentrates and Talus Deposits in District Tank, KP, for the Investigation of Gold, Silver and Base Metals:

Jalil, et. al., conducted a detailed geochemical studies of stream sediments, panned concentrates and talus deposits in district Tank, KP, for the investigation of gold, silver and base metals. During this study a total of 96 (54 stream sediments samples, 23 panned concentrates samples, and 19 talus samples) samples were collected. Mineralogical studies of panned concentrates were carried out under microscope. Gold grains were identified and classified as color (<0.3 mm), speck (0.3-0.5 mm) and

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piece (>0.5 mm). All the samples collected were treated by aqua regia-digestion and then analysed by atomic absorption spectrometry (AAS) for the determination of gold, silver and other based metals. The concentrations of gold ranges from 0.001 to 0.091 ppm in stream sediments samples, 0.002 to 5.863 ppm in panned concentrates, and 0.003 to 0.082 ppm in talus deposit samples. The data obtained from the geochemical analysis of all samples were then further processed on different software (IBM SPSS Statistics 21 and Arc GIS 10.1) to get geo-statistical and geo-spatial data. Mean, median and standard deviation for gold is 0.021, 0.009 and 0.023 in stream sediments, 0.652, 0.009, and 1.531 in panned concentrates, and 0.024, 0.009, and 0.023 in talus samples. Results of geochemical investigation shows that the concentration of gold and base metals are higher in panned concentrates as compare to stream sediments and talus deposits. However, the concentration of silver (Ag) and cadmium (Cd) are relatively high in stream sediments and talus deposits. Interpretation and analysis of geochemical, geo-statistical and geo-spatial data of stream sediments, panned concentrates and talus deposits shows that the area under investigation is of low economic potential for placer gold, while no economic potential for base metals [6].

Table 1: Summary of statistics for gold (Au) in ppm in various samples [6]

	Stream Sediments	**Panned Concentrates**	**Talus Deposits Samples**
Mean (ppm Au)	0.021	0.652	0.024
Median (ppm Au)	0.009	0.009	0.009
Std. Deviation	0.023	1.531	0.023
Minimum (ppm Au)	0.001	0.002	0.003
Maximum (ppm Au)	0.091	5.863	0.082

In this study both panning and direct stream sediments sampling is used for sample collection. Panned samples show relatively good results for gold than that of stream sediments and talus deposits. Panning is generally used as a prospecting tool for placer and therefore could not be more effective for detail exploration and characterization of placers. Apart from this they did not investigate the presence of sulfide and carbonaceous materials in the samples. Due to presence of sulfide or carbonaceous materials in sample the consumption of reagents used will be high and gold may be lost due to adsorption on carbonaceous materials. Thus the values obtained from analysis may be low from actual values. Therefore the sample materials with higher level of sulfide bearing minerals or organic matter must be pre-treated i.e, roasted (oxidation of organic carbon and sulfide) before aqua regia-digestion [7]. For roasting samples it should be transferred to porcelain dish (crucibles) placed in muffle furnace at 600 Co for 1 and 1/2 hours [8].

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3.2 Regional Geochemical Exploration for Precious Metals in the Southern Parts of Khyber Pakhtunkhwa, Pakistan:

Directorate General of Mines and Minerals, Mineral Development Department, Khyber Pakhtunkhwa, Pakistan in collaboration with National Centre of Excellence in Geology (NCEG), University of Peshawar investigated the regional geochemical exploration for precious metals in central and southern parts of Khyber Pakhtunkhwa. This project of geochemical exploration cover districts Peshawar, Charsada, Nowshehra, Sawabi, Mardan, Kohat, Hangu, Karak, Bannu, Lakki Marwat, D.I. Khan, & Tank. Prior to field work and detailed laboratory investigation compilation of base map was carried out by digitizing the survey of Pakistan topographic maps (1:250000) in term of topography (contours), drainage, locationof towns/villages, and political boundaries districts, and then the, ASTER/Landsat TM images (15-30 m resolution) and SRTM satellite was used to develop a digital elevation model (DEM). The base map was prepared in the Arc-GIS platform and was used to plan and design the mineral exploration survey in the central and southern parts of Khyber Pakhtunkhwa. Using the base map developed from the survey of Pakistan topographic maps and digital elevation model (DEM) based on satellite data, the region mainly comprising the indus river basin was classified into drainage sub basins (Kabul river basin, Kurram river sub basin, Tochi river sub basin, Gomal river sub basin etc.). Source of sediments input into the central and southern Khyber Pakhtunkhwa is primarily the western himalyas in the north and sufaid koh (Khyber-Kurram- Waziristan ranges) in the west. This sub-basin classification helped in differentiating the region based on source contribution, and thus greatly helps in planning and designing the mineral exploration survey. Geological maps of the study area were compiled from existing maps and geological mapping through satellite image processing. The base map and geological map were then used to compile a mineral database based on the existing published and unpublished data. The mineral database compiled is in GIS framework, where a mineral occurrence layer has been added to the system. A geochemical database was compiled for central and southern KP from the geochemistry of rocks from various parts listed in a number of reports and research papers. This database has greatly helped in planning and designing of geochemical survey. After the planning and designing of this survey, detailed field and laboratory investigation work was conducted. For this purpose pan concentrates, stream sediments, grab and channel samples were collected from all the areas under investigation. About 2142 samples were collected which include 330 pan concentrates, 1323 stream sediments, 318 talus/quaternary sediments, 16 bulk samples and 155 rock samples. The location of each sample was marked with hand held GPS and was then marked on geological map using Arc-GIS. All the samples collected were subjected to petrographic study, thin section analysis for rock samples, mineralogical analysis and chemical analysis. The geochemical data of the pan-concentrates is highly variable. Cu ranges from <0.020 to 349.770 ppm, Pb from <0.020 to 203.45 ppm, Zn from <0.020 to 131.300 ppm,

Ni from <0.020 to 699.350 ppm, Cr from <0.020 to 541.0 ppm, Co from <0.020 to 47.350 ppm, Cd

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from <0.020 to 6.350 ppm, Mn from <0.020 to 986.6 ppm, Ag from <0.05 to 20 ppm, and Au from <0.05 to 45.456 ppm. The threshold value of each element in pan-concentrates is found to be 80 ppm for Cu, 40 ppm for Pb, 65 ppm for Zn, 200 ppm for Ni, 160 ppm for Cr, 25 ppm for Co, 4.5 ppm for Cd, 450 ppm for Mn, 6.8 ppm for Ag and 2.5 ppm for Au. The geochemical data of the stream sediments clearly indicate that there is much variation in the data. Concentrations of Cu ranges from <0.02 to 133.5 ppm, Pb from <0.02 to 53.55 ppm, Zn from <0.02 to 59.55 ppm, Ni from <0.02 to 732.5 ppm, Cr from <0.02 to 201.85 ppm, Co from <0.02 to 38.15 ppm, Cd from <0.02 to 11.0 ppm, Mn from <0.02 to 780.4 ppm, Ag from <0.05 to 16.0 ppm and Au from <0.05 to 10.61 ppm. The threshold value of each element in stream sediments is found to be 45 ppm for Cu, 17 ppm for Pb, 46 ppm for Zn, 200 ppm for Ni, 75 ppm for Cr, 12 ppm for Co, 5 ppm for Cd, 400 ppm for Mn, 3.2 ppm for Ag and 1 ppm for Au. Greater variation was found in the geochemical data of Tallus samples. Cu is ranging from <0.02 to 100.5 ppm, Pb from <0.02 to 26.7 ppm, Zn from <0.02 to 77.5 ppm, Ni from <0.02 to 988 ppm, Cr from <0.02 to 157.45 ppm, Co from <0.02 to 82.55 ppm, Cd from <0.02 to 6.3 ppm, Mn from <0.02 to 766.5 ppm, Ag from <0.05 to 11.5 ppm and Au from <0.05 to 5.31 ppm. The threshold values of each element in taluss samples is found to be 30 ppm for Cu, 11 ppm for Pb, 40 ppm for Zn, 200 ppm for Ni, 60 ppm for Cr, 20 ppm for Co, 3 ppm for Cd, 375 ppm for Mn, 3 ppm for Ag and 1 ppm for Au. The geochemical data of the bulk samples did not show any major variation. Cu is ranging from 0.28 to 14.72 ppm, Pb from 0.138 to 4.789 ppm, Zn from 0.476 to 6.678 ppm, Ni from 0.036 to 4.993 ppm, Cr from 0.894 to 12.180 ppm, Co from 0.382 to 0.903 ppm, Cd from 0.020 to 0.202 ppm, Mn from 2.576 to 12.960 ppm, Ag from 0.029 to 0.260 ppm, and Au from 0.020 to 20.970 ppm. The threshold value of each element in bulk samples is found to be 11 ppm for Cu, 3.5 ppm for Pb, 5 ppm for Zn, 3.5 ppm for Ni, 9.5 ppm for Cr, 0.9 ppm for Co, 0.25 ppm for Cd, 12 ppm for Mn, 0.2 ppm for Ag and 2.5 ppm for Au. Furthermore, they suggest that follow up studies in the prospective areas for gold and other heavy minerals may lead to the discoveries of placer deposits of a marketable significance in the region [9].

This survey project is a very detail investigation for the prospecting and exploration of placers in central and southern KP. They use panning, stream sediments sampling, bulk sampling etc, for sample collection. Panned samples show relatively good results for gold than that of stream sediments and talus deposits. Panning is generally used as a prospecting tool for placer and therefore could not be more effective for detail exploration and characterization of placers. Apart from this they did not investigated the presence of sulfide and carbonaceous materials in the samples. Due to presence of sulfide or carbonaceous materials in sample the consumption of reagents used will be high and gold may be lost due to adsorption on carbonaceous materials. Thus the values obtained from analysis may be low from actual values. Therefore the sample materials with higher level of sulfide bearing minerals or organic matter must be pre-treated i.e, roasted (oxidation of organic carbon and sulfide) before aqua regia-digestion [7]. For roasting samples it should be transferred to porcelain dish

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(crucibles) placed in muffle furnace at 600 Co for 1 and 1/2 hours [8]. There is no sieve analysis and investigation of gold and other heavy metals in each size fraction. Such kind of investigation could be helpful in proposing a suitable mesh size for treating gold placers. Moreover, they have given more attention to the origin or source of the deposit. They have not given any information about the economic status of placer deposits in the study area.

3.3 Gold and Base Metal Exploration Studies Based on Mineralogical and Geochemical Characterization of Stream Sediments from north Pakistan:

A Ph.D. research study has been conducted by Liaqat Ali on "Gold and base metal exploration studies based on mineralogical and geochemical characterization of stream sediments from north Pakistan. This research project covers different areas of Gilgit (Bagrot, Teru, Ishkoman, Sher Killa, & Henzal) and district chitral (Shintari Gol, Asheriat Gol, Kaldam Gol, Awireth and Sewakht). Significant data has been from stream sediments sampling campaigns by local and international organization. A large dataset has been provided by the Pakistan Mineral Development Corporation (PMDC). Spatial catchment maps have been generated by incorporating all the data along with stream catchments, geological information, and detail of all known areas of mineralization into an Arc-GIS 9.2 database. On the basis of this spatial catchment map and multi-element geochemical associations various areas showing anomalous values for gold and other base metals, have been identified. A total of 134 (67 stream sediments samples and 67 panned concentrates), samples were collected with 6 to 8 samples from each location. Stream sediments samples were sieved into 4 fractions (1.68 mm-400 µm, 400- 180 µm, 180-75 µm, and <75 µm). All the samples and various size fractions were subjected to mineralogical and chemical analysis by GF-AAS for Au determination, X-ray fluorescence (XRF) spectrometry and inductively coupled plasma-mass spectrometry (ICP-MS) for the determination of low level of Au path finder elements. Morphological studies of gold grains under SEM were also conducted for the determination of grain size and shape. Mineralogical studies were also carried out by X-ray diffraction (XRD) analysis of stream sediments. Summary of statistics for gold (Au) in ppb in various size fractions of stream sediments samples is given in table 2.

The author further suggests that prospective studies of the areas identified in this study needs to be carried out in more detail. Further geochemical studies on soils and rocks from the identified areas should be carried out, possibly by carrying out a helicopter sampling campaign, to narrow down the likely zones of mineralization [5].

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Table 2: Summary of statistics for gold (Au) in ppb in various size fractions of stream sediments samples [7]

	Au (1.68 mm-400 µm)	Au (400-180 µm)	Au (180-75 µm)	Au (<75 µm)
No. of Samples	67	67	67	67
Mean (ppb Au)	73	51	69	108
Median (ppb Au)	11	9	17	15
Std. Deviation	252	143	200	423
Minimum (ppb Au)	0.15	0.15	0.15	0.15
Maximum (ppb Au)	1549	818	1326	3346

3.4 Exploration and Extraction of Placer Gold in the Terraces of Bagrot valley, Gilgit, northern Pakistan:

Shah, et. al., investigated the exploration and extraction of placer gold in the terraces of Bagrot valley, Gilgit, northern Pakistan. It is mentioned that in Pakistan due consideration has not been given to the mining of placer gold. Therefore the study of placer gold deposits of Bagrot valley has been carried out to determine the mineralogy of placer deposits, which could be helpful for the identification of source rock and also for designing of an extraction method for placer gold in a more economical way. For this purpose representative samples of sediments from both fluvial and glacio-fluvial sediments have been collected in Chirah, Farfooh and Bluchi villages of the area under investigation. During field work a total of 16 samples along the Bagrot river were collected and then processed through gravity separation and mercury amalgamation techniques. The samples were also subjected to mineralogical and chemical analysis. The mineralogical and chemical analysis shows that the sediments load of Bagrot valley generally contains rock fragments, magnetite, quartz, biotite, muscovite, chlorite and epidote as major constituents and garnet, tourmaline, amphibole, pyroxene, olivine, pyrite and chalcopyrite as minor constituents. Zircon and sphene occurs in terrace amount. Gold in the form of colors (<0.3 mm) is present in almost all samples while specks (0.3-0.5 mm) of gold have been identified in the sediments of few terraces. Moreover, no piece or nugget of gold has been found in the sediments of Bagrot valley. The chemical analysis of concentrates, tailings and middling shows that the gold and other heavy minerals are variably distributed among the three media. Magnetite, rock fragments, pyroxene, olivine, tourmaline, garnet, amphibole, pyrite and chalcopyrite are generally trapped in the concentrate while rest of the phases is washed into the middling and tail. Almost all the colors and specks of gold have been reported to the concentrates and non-gold particles are found in middling and tail. The results

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of fluvial and glacio-fluvial samples

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show that gold concentration is less in fluvial sediments as compare to glacio-fluvial sediments [10]. This research is also missing some key things like roasting (oxidation of sulfide and carbonaceous materials) of samples before aqua regia-digestion, particle size distribution analysis, determination of gold in each size fraction, proposing of suitable mesh size for treating gold placers.

Table 3: Concentration of Gold (in PPM) in the sediments samples of various terraces from the Bagrot Valley [10]

Sample No.	Wt. of sample in kg	Head	Concentrates	Middling	Tail
1	61.10	0.16	0.92	0.08	0.05
2	64.20	0.56	1.12	0.09	0.06
3	63.12	0.34	0.70	0.12	0.09
4	48.12	0.31	2.19	0.11	0.08
5	45.20	0.28	1.14	0.15	0.10
6	51.30	0.27	0.89	0.09	0.05
7	61.12	0.12	1.08	0.09	0.03
8	62.10	0.25	1.06	0.08	0.06
9	58.20	0.35	1.36	0.08	0.06
10	49.73	0.14	1.58	0.17	0.11
11	58.12	0.16	1.08	0.08	0.05
12	51.20	0.28	1.87	0.12	0.09
13	60.13	0.23	2.32	0.10	0.07
14	53.20	0.29	2.98	0.13	0.09
15	57.12	0.13	2.08	0.09	0.06
16	49.80	0.14	1.42	0.07	0.05

3.5 Gold Anomaly in the Quaternary Sediments of Peshawar Basin, Shaidu Area, District Nowshehra, NWFP, Pakistan:

Shah, et. al., investigated gold anomaly in the quaternary sediments of Peshawar basin, Shaidu area, District Nowshehra. During this study a total of 15 pan concentrates samples were collected from the study area. These samples were then subjected to mineralogical and chemical analysis. Pan concentrate samples were studied under stereoscope for mineralogical analysis. Gold grains were identified in the form of piece (> 0.5 mm), speck (0.3-0.5 mm) and colour (< 0.3 mm). Gold grains were also studied for other morphological features i.e, shape and colour. Shape of various grains were identified as rounded, sub-rounded, square, sub-angular, irregular, cylindrical, flaky, etc. Similarly

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colour of various grains was identified as light yellow, bright yellow, dark yellow, etc. For chemical analysis the pan concentrate samples were treated with aqua-regia and methyl isobutyl ketone (MIBK). The organic layer recovered was then studied in atomic absorption spectrometry (AAS) for the determination of gold. The results show that concentration of gold is highly variable and ranges from 1.6 mg/kg to 169.54 mg/kg. It is finally concluded that gold concentration in these sediments seemed to be economical. This research work also misses some key things as discussed in above sections [11].

Table 4: The concentration of gold in various pan concentrate samples of Peshawar Basin, Shaidu Area, District Nowshehra [11].

Sample No	Wt. of original sample in kg	Concentration of gold in mg / kg	Concentration of gold converted to g / kg	Wt. of gold in grams in original sample
1	18.9	3.15	0.0032	0.060
2	20.21	18.5	0.0185	0.374
3	19.78	2.25	0.0023	0.045
4	20.78	42.5	0.0425	0.883
5	22.75	2.15	0.0022	0.049
6	17.90	1.60	0.0016	0.029
7	19.67	63.00	0.0630	1.239
8	20.23	2.85	0.0029	0.058
9	20.65	39.00	0.0390	0.805
10	17.45	4.10	0.0041	0.072
11	18.54	43.50	0.0435	0.806
12	20.34	169.54	0.1695	3.448
13	17.56	3.80	0.0038	0.067
14	18.43	62.50	0.0625	1.152
15	18.67	3.45	0.0035	0.064

4. Conclusions and Recommendations:

All the published articles and information regarding the placer gold deposits of Khyber Pakhtunkhwa and northern Pakistan has been studied in detail and then the following points are concluded. Remedial measures are also given.

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- Almost all the researchers of the study area had used panning for sample collection but panning is generally used as a prospecting tool for placer and therefore could not be more effective for detail exploration and characterization of placers.
- There is no information regarding the presence of sulfide and carbonaceous materials in the samples which results in the consumption of reagents used will be high and gold may be lost due to adsorption on carbonaceous materials. Therefore the sample materials with higher level of sulfide bearing minerals or organic matter must be pre-treated i.e, roasted (oxidation of organic carbon and sulfide) before aqua regia-digestion.
- Most of them have not done any sieve analysis and investigation of gold and other heavy metals in each size fraction. Such kind of investigation could be helpful in proposing a suitable mesh size for treating gold placers.
- There is no information about the economic status of placer deposits in the study area.
- They have not given any suggestion for the installation of a gold concentration plant in the study area.

Finally it is recommended that a more technical and detail investigations studies of placer gold in the study area should be carried out with keeping all the above points in mind. Moreover, further study will identify potential deposits of placer gold and will provide sufficient data for the installation of a gold concentration plant(s) in the study area. Also a more acceptable and feasible location for the installation of concentration plant could be identified.

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CORRELATIONS OF ECONOMIC AND ENVIRONMENTAL KEY PERFORMANCE INDICATORS IN SUSTAINABLE CEMENT PRODUCTION

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Abstract

Cement is one of the important manufacturing sectors of Pakistan that might face various sustainability challenges in near future. Cement industry being extensive consumer of natural resources and fossil fuels as an energy input, produces large amount of air pollutants and emits greenhouse gases (GHG) as a waste. This trend is continually disturbing the eco system and needs to be controlled. This study identifies the economic and environmental sustainability Key performance Indicators (KPIs) that has an effect on sustainability and are correlated to understand the effects of one KPI on another. This study shows that the "total amount of energy used in Gj/T of Cement production" has a highest degree of correlation with the "Total electricity consumed from Non-Renewable sources (Kwh)" whereas "Amount of CO2 that is emitted into the Environment" has the lowest degree of correlation with "Amount of significant Air Emissions of NOX" keeping 0.70 correlation threshold among all KPIs.

Keywords: Economic sustainability, environmental sustainability, key performance indicators, cement, correlation.

1. INTRODUCTION

Cement industry in Pakistan is playing a critical role in the socio monetary improvement by exporting their product and by creating approximately 1.5 million jobs to skilled and unskilled workers throughout the country. It is a source of creating large business opportunities ranging from procurement of raw material to the purchase of fuel to the transportation of finished products to the markets. These activities for example; consumption of large amount of coal has a direct economic impact such as the cost of production and the environmental impact such as the emission of large amount of obnoxious gases into the environment[1]. To achieve the sustainable production there is a need of reducing the consumption non-inexhaustible assets.[2][3]

Sustainability is a complex idea. The most common definition is developed by the UN Bruntland commission: "sustainable improvement is improvement that meets the wishes of the existing without compromising the capability of future generations to satisfy their own wishes"[4]. Sustainable manufacturing is certainly one of the critical issues for the cement industry.[5] Cement is the main consumable for infrastructure projects which are the essential part of society's development in the world. [6]

In this study, the economic and environmental KPIs for cement manufacturing were identified through literature. One of the widely used repository of KPIs for sustainable manufacturing is developed by world business council for sustainable development (WBCSD) comprising of tons of cement manufactured per MJ of fossil fuel consumed, rates of non-renewable fuel consumption per ton of cement production, CO_2 produced per ton of cement[4][1][7][8]. The cement industry is utilizing various types of resources that has direct impact on the economic sustainability of the cement industry. While the use of alternative fuels and variation in raw materials significantly affect the environmental sustainability. The changes in the consumption of these resources impacts the eco system[6]. The economic and environmental aspects are inter dependent, and this study tries to understand the correlation among the KPIs in these aspects related to cement manufacturing [4] .

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2. METHODOLOGY

A comprehensive of literature was conducted to identify economic and environmental key performance indicators (KPIs) that might affect the sustainability of cement industry. The methodology adopted has six main steps as shown in Figure 1. Cronbach alpha test was conducted to check the internal reliability of the data. Regression analysis was then performed to identify correlation among the economic and environmental KPIs. The threshold value for the correlation was set at 0.50.

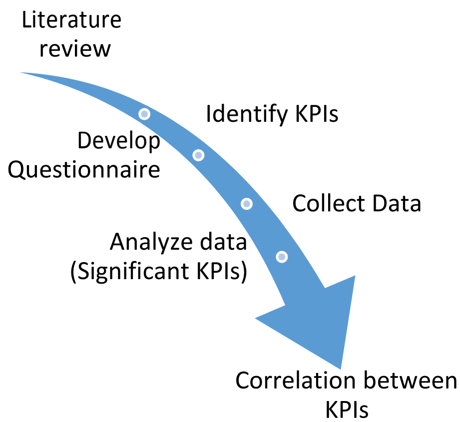

Figure 1: Methodology flow chart

According to United Nations Environment Program report “Basic construction materials serve an ever increasing demand for the building sector; this leads to annual growth rates of about 6% for cement. At the same time these industries caused about 6% of global anthropogenic greenhouse gas emissions” [13]. Generally the cement industry is regarded as the pollution emitters [14][15]. Initially a list of 20 KPIs for economy and 14 KPIs for environmental sustainability were identified [16]. Table 1 shows the list of KPIs for both the economic and environmental sustainability.

Table 1: Key performance Indicators (KPIs)

Aspect	S.No.	KPIs	Cronbach's Alpha
Economic Indicator	1	Revenue generated from sale of the product	0.7677
	2	Increase in Market share	0.7404
	3	Revenue generated from investments in other financial products	0.7666
	4	Revenue generated through any other sources	0.7794
	5	Exploring new markets such as exports etc.	0.7355
	6	Generating revenue through carbon credits.	0.7701
	7	Operating cost per ton of cement production	0.7377
	8	Cost of borrowing money	0.7436
	9	Cost of development and infrastructure investments	0.7458
	10	Implementing measures such as using alternative fuels.	0.7458
	11	Implementing measures such as heat capture etc.	0.7394

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12	Financial implications and other risks for the organization's activities such	0.7488

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		as physical, regulatory or other	
	13	Cost of Inventory	0.7306
	14	Cost of wages and other financial benefits to the employees	0.7677
	15	Cost of organization defined benefit plan obligations	0.745
	16	Cost of investments for enhancing skills and knowledge among the professional community.	0.7544
	17	Cost of investment in the community.	0.723
	18	Cost of taxes to the government	0.7328
	19	Value of tax credits and tax reliefs received from government	0.7366
Environmental Indicator	20	Value of investment grants, research and development grants received from government.	0.7494
	21	Total amount of energy used in Gj/T of Cement production	0.97
	22	Total Electricity consumption per ton of cement production.	0.9705
	23	Total electricity consumed from Renewable sources (Kwh)	0.9728
	24	Total electricity consumed from Non-Renewable sources (Kwh)	0.9701
	25	Total amount of coal fuel used per ton of cement production	0.9704
	26	Total amount of natural gas used per ton of cement production	0.9717
	27	Total amount of waste fuel used per ton of cement production	0.9705
	28	Amount of heat captured by ton of cement production	0.9705
	29	Total amount of Emissions in metric tons of CO2 equivalent per year	0.9709
	30	Amount of CO2 that is emitted into the Environment.	0.9713
	31	Amount of significant Air Emissions of SOX	0.97
	32	Amount of significant Air Emissions of NOX	0.9699
	33	Amount of significant Air Emissions of Hazardous Air Pollutants (HAP)	0.9717
	34	Amount of Air Emissions of Particulate Matter (PM).	0.9739

3.
4. QUESTIONNAIRE

Questionnaire consisting of the KPIs mentioned in Table 1 were distributed to 200 executives and engineers in cement manufacturing industries. 5 point Likert scale was used to get their opinion on each KPI. The valid received questionnaires were 39% of the total distributed questionnaires. Cronbach alpha was calculated to check the internal consistency of the data. Cronbach's alpha for the economic and environmental indicators are above the threshold value of 0.70.

5. CORRELATION

The final result of a correlation is referred to as correlation coefficient (or "r"). It value ranges from -1. 0 to +1. 0. If r is nearing zero, that would mean there is not a significant relation among the variables. If r gets nearer to +1.0 , that suggest that increasing one variable will also increase the other variable, while if r gets nearer to -1.0 then it would suggest that the increase in one variable would decrease the other variable, often known as "inverse" correlation. The R square, coefficientof determination is the square of correlation coefficient, shows the percentage variation in one variable which is explained by the other variable.

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Table 2: Correlations among economic and environmental KPIs.

	21	22	23	24	25	26	27	28	29	30	31	32	33	34
1	0.52			0.50					0.66		0.50		0.60	
2														
3														
4														
5														
6														
7					0.57									
8														
9					0.51						0.56	0.49		0.54
10				-0.51	-0.52									
11			0.62				0.55	0.60					0.56	
12			0.61											
13														
14														
15														
16												- 0.52		
17							0.54							0.56
18														
19														
20				-0.53					-0.60					

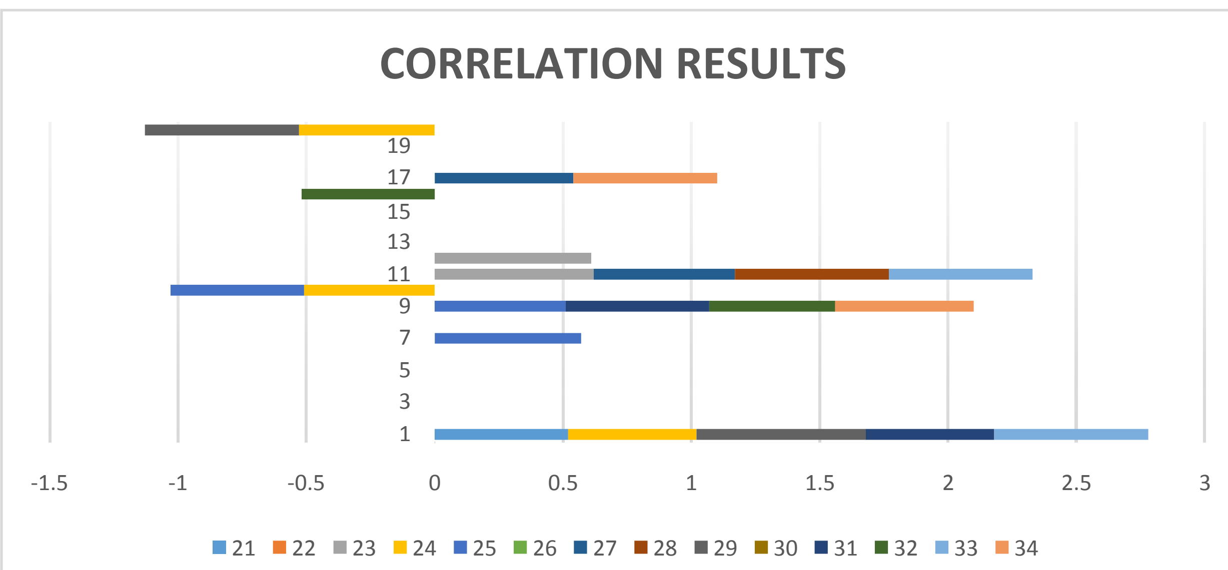

Figure 2. Correlation of economic and environmental KPIs

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6. RESULTS

Cement manufacturing is a complex process and consumes large quantities of raw materials, fossil fuels, energy, and is a major source of multiple pollutants. It is facing multiple challenges to implement sustainable manufacturing into their processes.

Table 2 and Figure 2 shows that there are positive and negative correlations among economic and environmental KPIs. The correlation among the economic KPI "Revenue generated from sale of product" has the highest positive correlation of 0.66 with the environmental KPI "Total amount of emissions in metric tons of CO_2 equivalent per year", whereas the economic KPI "Value of investment grants, research and development grants received from government" has the highest negative correlation of -0.60 with the environmental KPI "Total amount of Emissions in metric tons of CO_2 equivalent per year".

7. CONCLUSION

Cement is one of the largest manufacturing sector in Pakistan, achieving sustainable manufacturing is being accepted as a significant requirement due to diminishing non-renewable resources. This study has identified that there is a strong correlation both positive and negative among various KPIs of economic and environmental sustainability of cement manufacturing in Pakistan. This study can further be extended by considering the social aspect of sustainability to determine all aspects of sustainability. This study will help the decision makers in achieving sustainability.

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IMPATIENCE AMONG DRIVERS WITH VARYIGN DEMOGRAPHICS

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ABSTRACT

This study was conducted to uncover the impatience of drivers of different demographics in traffic. The data was collected from the students and teachers of MUET, Jamshoro, Sindh, Pakistan. The questionnaire as developed by Dr. Larson was used for the data collection. 145 questionnaire samples were collected. The data was analyzed in Statistical Package for Social Sciences (SPSS) version 22. At the very first, demographics were presented graphically. Then reliability of the data was checked by using cronbach alpha test which came out to be 0.787. 8 hypothesis were developed in order to reveal the difference in impatience among drivers with varying demographics. Descriptive statistics and normality i.e. skewness and kurtosis were calculated: Hypothesis testing was carried out by using T-test and ANOVA. Unpredictably, the impatient behavior of all the groups was found to be same except the impatience of male and female was found to be different when the car next to them slowed down in the traffic.

Index Items: Anger, driving, hypothesis.

1. INTRODUCTION

Driving impatience is commonly observed among the drivers. It has become stressful, demeaning and dangerous to drive. Drivers report for being stressed out and threatened by one another, exhibit bad moods, terrorize their passengers, and often fantasize violent acts against other motorists or bicyclists [1]. Driving aggressiveness as defined by Tasca "A driving behavior is aggressive, if it is deliberate, likely to increase the risk of collision and is motivated by impatience, annoyance, hostility, and/or an attempt to save time" [2]. Aggressiveness is caused by anger and

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impatience, moreover anger suggests offender to harm another driver/person [3][4][5][6]. An accident happened and 21 peoples were injured; police reported that driver`s actions were due to his impatience and anger [7].

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This study was conducted to investigate the driving impatience among student and teachers of Mehran university of Engineering Technology, Jamshoro across both genders.

2. RESEARCH METHODOLOGY

I. Hypothesis development

Following hypothesis were developed in this research

1. There is no significant difference between males and female drivers in getting impatient while waiting for passengers to get in.
2. There is no significant difference between males and female drivers in getting impatient while the car engine is warming up
3. There is no significant difference between males and female drivers in getting impatient at stoplights
4. There is no significant difference between males and female drivers in getting impatient while waiting in lines (car wash, bank, parking space)
5. There is no significant difference between male and female drivers in getting impatient with the drivers as a passenger.
6. There is no significant difference between male and female drivers in getting impatient, when car ahead slows down
7. There is no significant difference between male and female drivers in getting impatient while driving in far right slow lane
8. There is no significant difference between male and female drivers in getting impatient with pedestrians crossing street

II. Data Collection

Data was collected from the teachers and students of Mehran University of Mehran UET, Jamshoro. Questionnaire was used as the data collection instrument as developed by Dr. Larson. 145 samples were collected for the study. Impatience of drivers was measured by the help of 8 questions as given in table I below.

Data Analysis

Data was analyzed in the statistical package for social sciences (SPSS) version 22. At the very first, demographics were presented graphically. Then reliability of the data was checked by using cronbach alpha test which came out to be 0.787. Descriptive statistics and normality i.e. skewness and kurtosis were calculated (see table I); after it was revealed that the data was normal then hypothesis were tested by using T-test.

III. Calculation of skewness and kurtosis

It is the assumption of T-test that the data should normally distributed; so it was required to calculate the skewness and kurtosis in order to know the data was normal or not.

Table I (Skewness and Kurtosis for the various questions)

	Skewness		*Kurtosis*	
Questions	*Statistic*	*Std. Error*	*Statistic*	*Std. Error*
I get impatient waiting for passengers to get in	.425	.202	-.477	.401
I get so impatient, won't let car engine warm up	.332	.202	-.825	.401
I get impatient at stoplights	.234	.202	-.706	.401
I get impatient waiting in lines (car wash, bank, parking space)	.038	.202	-.181	.401
I as a passenger, impatient with driver	.173	.202	-.940	.401
I get impatient when car ahead slows down	.198	.202	-.858	.401

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I get impatient driving in far right, slow lane	.096	.202	-.821	.401
I get impatient with pedestrians crossing street	.366	.202	-.053	.401

The normal range of skewness and kurtosis is between +1 and -1; and the normal range of kurtosis is between +3 and -3. It can be seen in the figure that the values of skewness and kurtosis for all questions are in the normal ranges. Hence, it was revealed that the data was normal.

3. RESULTS

Result was split into two sections: firstly, the demographic characteristics of the respondents were presented in the below given heading; secondly, developed hypothesis were tested by applying the suitable tests.

Presentation of Demographic Characteristics

Frequency distribution of the data revealed that 26 (18.1%) respondents were females and 118 (81.9%) were males: 90 (62.5%) were students and teachers were 54 (37.5%). For the organization of data five age groups were formed: 80 (55.5%) respondents belonged to age group of (18-22), 35 (24.3%) were from (23-27), 17 (11.8%) fell into the (28-32) group, 4 (2.7%) respondents were from (33-37) group, rest of 8 (5.5) were from the age group of (38-42+). The average experience of the respondents was calculated to be 5.167$\pm$3.32 years.

IV. Hypothesis Testing

S#	*Hypothesis Description*	*Sig.*	*Decision*
1	There is no significant difference between males and female drivers in getting impatient while waiting for passengers to get in.	0.229	Failed to reject
2	There is no significant difference between males and female drivers in getting impatient while the car engine is warming up	0.218	Failed to reject
3	There is no significant difference between males and female drivers in getting impatient at stoplights	0.179	Failed to reject
4	There is no significant difference between males and female drivers in getting impatient while waiting in lines (car wash, bank, parking space)	0.956	Failed to reject
5	There is no significant difference between male and female drivers in getting impatient with the drivers as a passenger.	0.611	Failed to reject
6	There is no significant difference between male and female drivers in getting impatient, when car ahead slows down	0.006	Rejected
7	There is no significant difference between male and female drivers in getting impatient while driving in far right slow lane	0.514	Failed to reject
8	There is no significant difference between male and female drivers in getting impatient with pedestrians crossing street	0.514	Failed to reject

All the hypothesis were tested by using independent sample T-test. P-value for all hypothesis came out to be greater than 0.05 except hypothesis 6; hence, 7 hypothesis failed to reject.

P-value for seventh hypothesis came out to be $0.006<0.05$; this values was interpreted that there was significant difference between male and female drivers in getting impatient, when the car ahead slow down on the road.

4. CONCLUSION AND RECOMMENDATIONS

In this research, it was concluded that there was no significant difference in impatience of male and female drivers while driving. Significant difference was found only in getting impatient in the situation when car ahead slow down on the road.

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In this research, questionnaires were not filled by the respondents suddenly after driving. For further work, questionnaires can be got filled by the drivers while driving or suddenly after driving so that the real time conclusions can be drawn; which will be great contribution and in the literature and it would be societal contribution as well.

5. AKNOWLEDGEMENT

Eight questions from the questionnaire as provided by AAA foundation for Traffic and Safety and developed by Dr. Larson was utilized for the data collection: and especial thanks to the teachers and students of Mehran UET for cooperation during data collection process

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6-AXIS MEDIUM SIZE INDUSTRIAL ROBOTIC ARM FOR ADVANCE MANUFACTURING

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ABSTRACT

This paper discusses Pakistan's first indigenously designed industrial robotic arm. Pakistan needs to develop its robotics and automation industry. Pakistan's manufacturing companies have traditionally been slow to react to the advent of digital technologies like intelligent robots, sensor technology, artificial intelligence, nanotechnology, and 3D printing. To survive and thrive, manufacturers must focus on growth. 6-axis robotic arm is a step toward industry 4.0. With robotic arm complex manufacturing processes can be introduced into the industry such as ISF (incremental sheet forming), 3D printing, pick and place etc. ISF is developing manufacturing technique around the world. The robotic arm can also facilitate researchers in various scientific fields such as biological, chemical, medical etc. 6-axis robotic arms are currently available internationally in different size and configurations. 6-axis robotic arm is the most common example of industrial robots. The development of a design for a collaborative robot is a complex task. Design of frame, motors, gears, control system, integration of hardware and software are based on torques, speed and accuracy requirement.

Index Terms— Robotic arm; ISF (incremental sheet forming); Industry 4.0.

1. INTRODUCTION

Six-axis robots allow for greater flexibility and can perform a wider variety of applications than robots with fewer axes. As we know, in industry time is money and robots can significantly reduce production time and cost as well.(Schneider, Apfelbaum et al. 2005, Bergs 2006) Robots can perform duties that are dangerous or unsuitable for human workers. Since 2012 28%-35% increase in robot's demand in industry.(Lasi, Fettke et al. 2014) Industrial robotic arms have various axis configurations. The vast majority of articulated robots, however, feature six axes, also called six degrees of freedom. Articulated robots can have at least three joints. A robotic arm is a type of programmable mechanical arm, with similar functions to a human arm.(Ayres and Miller 1981) The working envelope of 6-axis robotic is almost spherical.

2. LITERATURE REVIEW

As technology increases, robots not only become self-sufficient through autonomous behaviour but actually manipulate the world around them.(Breazeal and Brooks 2005) Robots are capable of amazing feats of strength, speed, and seemingly intelligent decisions. Industrial robots are machine tools. More realistically, they are programmable manipulators which can move parts or tools through a specified sequence of motions.(Ayres and Miller 1981) Re-programmability means that the robot's actions can be modified by changing control settings, without changing the hardware. They combine some attributes of traditional machine tools as well as attributes of machine tool operators. Like a machine tool, the robot can repeat the same task for prolonged periods with great precision. Like an operator, it is flexible enough to be taught to do a new task, and it can use accessory tools to extend its range of physical capabilities.(Ayres and Miller 1981)

The emergence and evolution of the modern industrial robot can be summarized as occurring in four distinct stages.

Stage 1: *Emergence*. The historical origins of modern industrial robots from the da Vinci's robotic arm to KAIST's Hubo humanoid robot over a period between 1480 and 2015 on. During this period, several companies were involved in developing various industrial robot technologies. In 1954 the father of Robotics, George Devol's "Programmed Article Transfer" (Patent by George C. Devol Jr.). George Devol and Joe Eagleburger design the first programmable robot 'arm'. This later became the first industrial robot, completing dangerous and repetitive tasks on an assembly line at General Motors (1962).(Ayres and Miller 1982) In 1963 the "Rancho Arm" is developed at Rancho Los Amigos Hospital, California.(Moran 2007) Kawasaki bought the license to manufacture industrial robot arms from Unimation in 1966.(Moran 2007) Competition came quickly, the Cincinnati-based Milacron appeared, and by 1963 AMF Hermatool brought out their commercially available Versatran industrial robot which Japan imported in 1967 and in 1968 the Minsky-Bennet arm is developed which was biologically influenced by crayfish claws and nerves. Nachi Fujikoshi Corp. enters the robotics industry. Nachi robots mostly spot weld, arc weld, and handle parts (1969).(Wilson 2014) General Motors, with the help of industrial automation, was able to produce 110 cars per hour, which

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encouraged BMW, Volvo, Mercedes Benz, British Leyland, and Fiat to invest industrial robot.

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Stage 2: *Fundamentals*. In 1969 Victor Scheinman at Stanford University invented the Stanford arm, an all-electric, 6-axis articulated robot designed to permit an arm solution.(Hägele, Nilsson et al. 2008) In 1970, Shakey is first autonomous robot due to its AI, and mobility.(Chen, Chen et al. 2009) In 1973, Kuka Robotics, a German company, debuts with its first automated arm to have six electric motors and axes (Famulus).(Jalil 2009) Next year, Fanuc debuts its robot products which primarily deal with drilling, moulding, and wire cutting. With the arrival of the new decade (the 80s) the robotics industry gains investment and experiences a growth spurt containing much competition and rivalry between companies and their products. At the height of the robot boom in 1984, Unimation was acquired by Westinghouse Electric Corporation. Westinghouse sold Unimation to Stäubli Faverges SCA of France in 1988, which is still making articulated robots for general industrial and cleanroom applications and even bought the robotic division of Bosch in late 2004. At the end of the decade in 1989 the founding of Yaskawa Motoman, under Yaskawa Electric Corp.(Okabayashi and Sakanashi 1999) There are roughly 300,000 Yaskawa Motoman robots implemented globally, whose jobs vary widely due to the extent of the company.

Stage 3: *Computing power*. With the revolution in computers in the 90s, it transformed the robotics industry. In 1994 the Motoman MRC is released. It can synchronize motions between two robots and features an impressive ability to able to control 21 axes at once. In May 1997 IBM's robot Deep Blue beat the world chess champion Garry Kasparov in a match.(Moravec 1998) It had beaten Kasparov in a single game in 1996. And in 2000, ASIMO, Honda's Advanced Step in Innovative Mobility, is completed after over a decade of development. In 2014, NASA builds and implements a large yet extremely precise robot named ISAAC (Integrated Structured Assembly of Advanced Composites).

Stage 4**: **Industry 4.0. Industry 4.0 is a confluence of trends and technologies that could reshape the way things are made.(Lasi, Fettke et al. 2014, Roblek, Meško et al. 2016) Industry 4.0 involves the heavy use of automation and data exchange in manufacturing environments, encompassing areas such as cyber-physical systems, the Internet of Things (IoT) and cloud computing, among others.(Chen and Hu 2013) With Industry 4.0, manufacturers will be able to operate "smarter" factories, in which they can more easily tailor products for specific customers. It seems the trend is driven by improvements in transferring digital instructions to the physical world, such as advanced robotics and 3D printing. The Zero Down Time Solution (ZDT), General Motors (GM), like most of the automotive industry, is an innovator in automating production. Alongside FANUC and Cisco, they developed ZDT– a cloud-based software platform to analyse data collected from robots across GM's factories.(Low, Win et al. 2005) The growing concept of Industry 4.0 in the automotive, electrical, and electronics industries is key for the growth of the smart machine's market in the world.

3. NEED AND DEMAND FOR INDUSTRIAL ROBOT

Robots are valued in industry for the usual qualities of machines: untiring availability, predictability, reliability, precision and (relative) imperviousness to hostile environments.(Singh, Sellappan et al. 2013) State-of-the-art robots (mostly in research labs) do have crude senses of "sight" and "touch", and limited capability to coordinate their manipulators with sensory input.(Gelli 1993) Because of current limitations, today's robots are usefully employed in highly structured industrial environments where practically all of the variability and decision making can be engineered out of the workplace.(Wang, Zhang et al. 2017) Existing usage of industrial robots all involve repetitive pre-programmable tasks such as spot welding, spray painting, palletizing, and the loading and unloading of many types of metal forming and metal cutting machines. The next generation of sensor-based robots will be able to perform a broader range of tasks under less structured conditions, in addition to becoming cheaper and easier to use.(Kalash 2004) Expected uses of robots with vision and improved feedback control will include inspection, assembly, heat treatment, grinding and buffing, and electroplating.(Corke and SpringerLink (Online service)) Eventually, many of the "hands-on" tasks performed by production workers on the factory floor will be done by robots in computer-controlled manufacturing systems. Programmable automation is beginning to replace the current generation of manually controlled machines.

The rise of robots has been proven true with the sales of industrial robots, particularly in the US, South Korea, China, and Germany.(Ray, Atha et al. 2016) According to International Federation of Robotics, "In 2014, robot sales increased by 29 percent, to 229,261 units, by far the highest level ever recorded for one year. Sales of industrial robots to all industries increased compared to 2013."(Fortunati, Esposito et al. 2015) Their estimates show that sales will increase to 400,000 by 2018. The total stock of operational robotic units in the world reached the level of 1.5 million in 2014.

Robots are becoming ubiquitous even in Pakistan. A narrative in Pakistan is building for adapting robots in industry. This challenge is not unique to Pakistan. Indeed, it is being confronted by economies at different levels of development. Many manufacturing and outsourced jobs have started going back to developed economies due to the availability of customized robots. Pakistan has almost missed the opportunity of being part of this information technology and outsourcing value chain. Now is the time to stage a comeback and strengthen research in the field of robotics and at the same time, focus on education and a technical education system, to better equip our future generations. Notably, Pakistan is still struggling with massive

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labour migration from rural areas to urban centres in the wake of marginal mechanization in agriculture.(Hussain and Ishfaq 1998)

A majority of people were fearful of computers in the 1980s, due to potential job loss, but they have created convenience and opportunities around the world. The debate of whether robots will enter the labour force or not has now changed into a question of who stands to gain or lose in the robotic and automation revolution and how best can one develop appropriate technological, economic, social and multilateral responses. The same discourse needs to be adopted in Pakistan: how can Pakistan tech industry become part of this global value chain and what Pakistan needs to do to transform its education and labour market to embrace the challenge of robotics and digitalization.(Iftikhar 2016.)

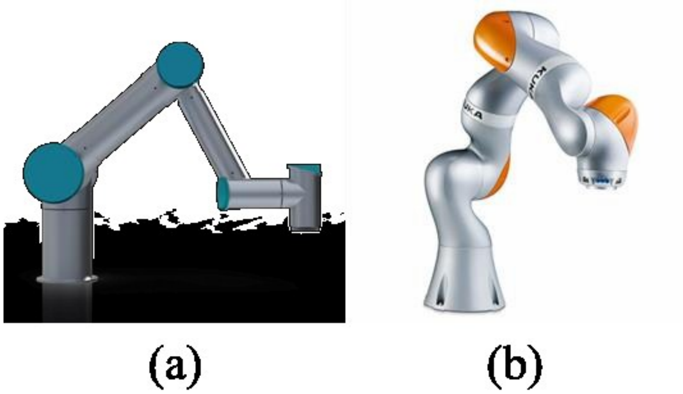

Figure 3-1: a) XTECH 10, b) KUKA LBR

3.1. COBOTS (COLLABORATIVE ROBOTS)

Despite the fact that international companies like KUKA Robotics, Universal Robots, Rethink Robotics, and etc. are developing state of the robotic technologies. The Universal Robots has three basic variants of robotic arm i.e. UR3, UR5, and UR10. The naming of Universal robots is on the basis of; how much payload it can lift. KUKA robotics have many SCARA configuration robotic arms but in competition, the KUKA robotics introduce a new variant KUKA LBR. The universal robots' UR10 has a maximum reach of more than 1 meter and it has 6 DOF (degree of freedom). It can lift up to 10 kg payload. The UR10 weigh about 30 kg. While KUKA LBR has a maximum reach of 0.82 meter and it has 7 DOF (degree of freedom). It can lift up to 14 kg payload.

Table 3.1-1: Comparison of collaborative robots

Manufacturer	Universal Robots	KUKA robotics
Model	UR 10	LBR 14 R820
Maximum reach (m)	1.3	0.82
Payload (kg)	10	14
DOF (degree of freedom)	6	7
Weight of IRA (kg)	29.8	30

These features come with high costs i.e. robotic arm, training, maintenance support etc. The UR10 variant of Universal Robots price is $45,000/- exclusive of all other costs. While KUKA LBR minimum price is $50,000/- exclusive of all other costs.

We usually budget around $75,000/- USD for a UR10 and KUKA LBR with a basic set of tools and accessories, which in most cases will be enough for your application. If you have a little advance application, you can go up to $100,000/-. All of the above information was about COBOT (collaborative robots).

3.2. INDUSTRIAL ROBOTIC ARM

In this category, there are BUNCH of different models, categories, and sub-categories. In fact, with large manufacturers like Fanuc, ABB, KUKA, Motoman and many others; the major (and almost entire) selection of robots on the market are included in this 'industrial robot' category. The other thing is that it is very hard to have a comparative price for an industrial robot because there are just too many options that are available for any single robot. However, to have an example for comparing to have an estimate of an equivalent robot to a UR10 and KUKA LBR. The robotic arms that are designed for pick and place applications with a payload of around 10 kg and a decent reach were evaluated. The winner was the KUKA KR 10 R1100 Sixx.

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The robot has a 6-axis (DOF) configuration, a 10-kg payload, and a 1101.00mm maximal reach. The basic price of the robot is around 25k USD.

At first glance, an industrial robot might seem to be less expensive than a collaborative robot ($45k VS $50k). However, there are a couple of things need to be considered. Integrating an industrial robot on your shop floor means safety fencing (5k+ USD), the introduction of safety PLC ($2k+), tooling ($7k+), integration time ($10k+), programming training or recruiting a robot programmer (kind of hard to evaluate). This increases the bill by at least $75,000/-. There is a rule of thumb that says: the budget should be at least 3x times the price of the robot for integrating it. Once again you can increase your bill to over 100k USD easily.

4. CAD MODEL OF XTECH 10

The design process is consisting of two iterations. The first model was bulky and designed for heavy-duty jobs. It was very slow. While the second model is lightweight and fast as compared to the previous model. It has 6 DOF and nice aesthetics.

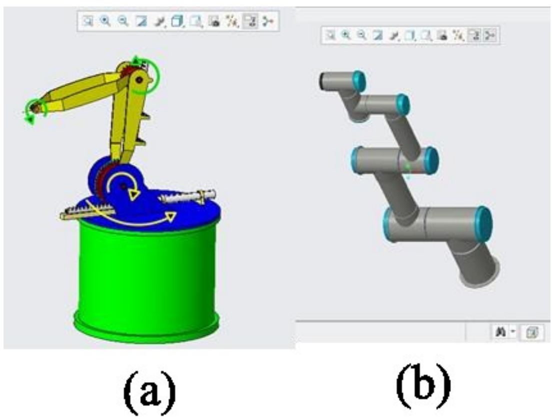

Figure 4-1: CAD model a) First iteration, b) Second iteration

5. DESIGN ANALYSIS - XTECH 10

The robotic arm has a maximum reach of approximately 1 meter. The robotic arms which are available in the market, also have approximately 1 meter e.g. KUKA LBR which is about 1 meter and Universal Robots UR 10 which is 1+ meter. The robotic arm is designed to handle a payload of 10 kg. The robotic arm has 6 DOF, with these number of DOF it can perform complex movements.

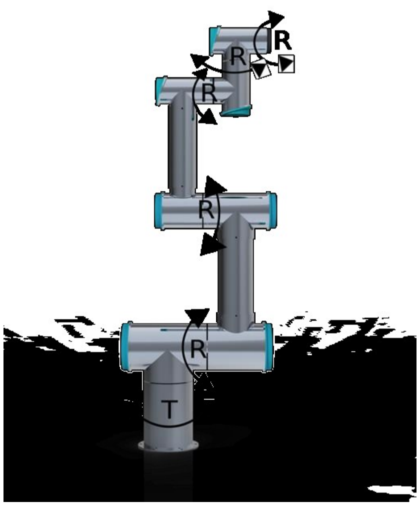

Figure 5-1: XTECH 10 rendered image with DOF representation

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5.1. DESIGN PARAMETERS

Under the above-mentioned specification, the robotic arm will experience the following torques at various joint. The maximum torque is experienced by the base joint which is 550 Nm.

Table 5.1-1: Torque table of XTECH10 joints

$$\text{Wrist} - \text{joint} - 1 = \text{Twrist1} = 11.6\ \text{N} - \text{m}$$
$$\text{Wrist} - \text{joint} - 2 = \text{Twrist2} = 28\ \text{N} - \text{m}$$
$$\text{Wrist} - \text{joint} - 3 = \text{Twrist3} = 54.6\ \text{N} - \text{m}$$
$$\text{Elbow joint} = \text{Telbow} = 227.2\ \text{N} - \text{m}$$
$$\text{Shoulder joint} = \text{Tshoulder} = 477.2\ \text{N} - \text{m}$$
$$\text{Elbow joint} = \text{Tbase} = 550\ \text{N} - \text{m}$$

No. Links	Length of link (cm)	Mass of link (kg)	Torque at joints (N-m)
1	9.22	5.2	11.6
2	9.22	5.2	28
3	11.57	5.2	54.6
4	57.16	9.2	227.2
5	61.27	12	477.2
6	18	9.4	550

5.2. MOTORS SELECTION

To counter such torques at various joints of the robotic arm, one hybrid servo motor is adapted for each joint or DOF. Hybrid servo motors are lightweight as compared to AC servo motor or DC servo motor. Incremental encoders are mounted on each hybrid servo motor. They are very economical as compared to any servo motor.

Table 5.2-1: Motors selected for IRA

Motor model	Step/angle	length	Holding torque	Current	Rotor inertia	Encoder	Lead wire	Weight
	°	mm	N-m	A	g.cm^2	PPR	No.	Kg
LC57H276	1.8	76+22	2	3	480	1000	4	1.2
LC86H2120	1.8	120+22	8.22	6	3600	1000	4	4
LC86H2160	1.8	156+22	12	7.5	5400	1000	4	5.4

The holding torque of the hybrid servo motor decreases as the speed of the motor increases. The holding torque is maximum when the speed is minimum.

Table 5.2-2: Comparison of applied torque Vs motors output torque

Joint	Applied Torque (Nm)	Motor Torque$_{rated}$ (Nm)	Gear ratio	Output Torque$_{max}$ (Nm)
Wrist joint 1	11.6	2	1:50	100
Wrist joint 2	28	2	1:50	100
Wrist joint 3	54.6	2	1:50	100
Elbow joint	227.2	8.2	1:60	492
Shoulder joint	477.2	12	1:60	720
Base joint	550	12	1:60	720

As the torque of hybrid servo motors decreases while speed increases, the output maximum torque also decreases. The gear ratio are selected on the basis of rated torque reduction due to speed.

5.3. MATERIAL SELECTION – ROBOT STRUCTURE

The maximum torque is experienced by the base joint is which is 550 Nm. The material selected for the robot structure is 6061-

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T6 - 6000 Series Aluminium Alloy. Following are the properties of the aluminium alloy.

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Table 5.3-1: Mechanical properties of Aluminium Alloy 6061-T6

Mechanical Properties of Aluminium Alloy 6061-T6	
Hardness, Brinell	95
Hardness, Knoop	120
Hardness, Rockwell A	40
Hardness, Rockwell B	60
Hardness, Vickers	107
Ultimate Tensile Strength	310 MPa
Tensile Yield Strength	276 MPa
Elongation at Break	12 %
Elongation at Break	17 %
Modulus of Elasticity	68.9 GPa

5.4. FEA RESULTS

The FEA analysis was conducted technically as any mistake can lead to serious precision and accuracy loses. The deformation caused due to payload and the total mass of the link is inversely proportional to accuracy, precision, and repeatability.

(a) maximum deformation = 0.031095 mm **(b) maximum principal stress = 2.93 MPa**

Figure 5-2: FEA results by CREO simulate of base joint

The FEA results were satisfactory for the base joint with the maximum deformation of 0.03mm. The FEA analysis was conducted on CREO simulate. The heat diagram in (Figure 5-2) shows the deformation of the base joint. The loading was applied to the maximum scenario. The Aluminium alloy 6061-T6 can withstand such loadings. The material is locally available in the market.

6. DESIGN ANALYSIS – ISF (INCREMENTAL SHEET FORMING) INSERT

The ISF (incremental Sheet forming) insert is designed to transmit 5kN of force through 16.5mm diameter tip. It will create 333 MPa of pressure which is enough to deform titanium sheet.(Petek, Kuzman et al. 2009) The tip of the ISF insert will be rotating while performing ISF process. The thrust bearing is installed to ease the relative rotation the tip. The factor of safety of the ISF insert is 2.1.

The ISF (incremental sheet forming) insert consists of three basic components i.e. tip, the supporting shaft, and thrust bearing.

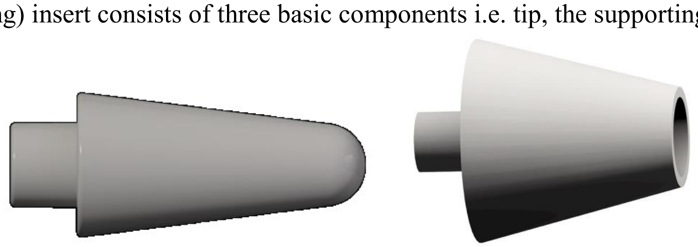

Figure 6-1: a) Tool tip, b) Supporting Shaft

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The length of the tooltip is 73.84mm. The minor diameter is 15mm major diameter is 30mm. The length of the supporting shaft is 151.6mm. The minor diameter is 50mm and major diameter is 101.6mm of the supporting shaft.

Figure 6-2: Thrust bearing LM11749

The thrust bearing is off the shelf standard bearing LM11749. The thrust bearing has dynamic radial rating of 29400N and Static radial rating of 23400N.

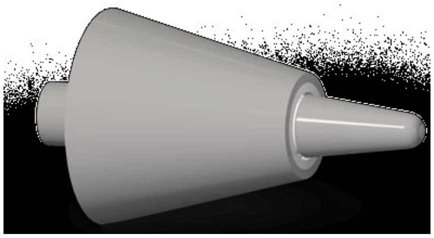

Figure 6-3: ISF (incremental sheet forming) insert

6.1. MATERIAL SELECTION – ISF INSERT

To withstand such huge, load the material selected for the ISF insert is stainless steel SS 201 with following properties.

Table 6.1-1: Mechanical properties stainless steel SS 201

Mechanical Properties of Stainless steel SS 206	
Tensile strength (transverse)	685 MPa
Tensile strength (longitudinal)	1696 MPa
Yield strength (transverse)	292 MPa
Yield strength (longitudinal)	301 MPa
Compressive yield strength	365 MPa
Elastic Modulus	197 MPa
Poisson’s ratio	0.27-0.30
Elongation at Break	56 %
Hardness, Rockwell B (trans.)	85
Hardness, Rockwell B (longi.)	85

6.2. FEA RESULT OF ISF INSERT

A study of force developed during the ISF of a steel DC05 sheet by Petek et al.[33] reported that the maximum force was just under 2kN. A force of 5kN can deform titanium sheet. If the force is transmitted through 16.5mm diameter tooltip, it can create a pressure of 333MPa.

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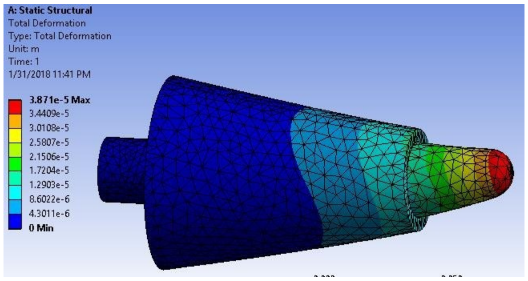

Figure 6-4: FEA results ISF insert

The FEA results were satisfactory for the ISF insert with the maximum deformation of 0.00038mm. The FEA analysis was conducted on ANSYS workbench. The heat diagram in (Figure 6-4) shows the deformation of ISF insert. The maximum force of 5kN was applied for the maximum scenario. The stainless-steel SS 201 can withstand such force. The material is locally available in the market.

7. EXPECTED OUTCOMES

Following are the expected outcomes of the project.

- Initialization of robotic industry in Pakistan.
- Robotic arm capable of the ISF (Incremental sheet forming).
- Robot Arm with GUI – Real-time Control System.
- Creation of the new jobs in robot sector.
- Training of the individuals and transferring required skills to operate the robotic arm.
- Complete documentation along with user as well as developer's guide.
- Research publications in an internationally reputed conference, magazines, and journals.

8. KEY BENEFITS AND BENEFICIARIES

Following are the Key Benefits of the project:

- Low cost and cost-effective system for the end consumer.
- Improved manufacturing flexibility by reprogramming robots for different projects, or having multiple robot programs for short production runs.
- Increase production, reduced cycle times and increased repeatability that can't be matched by manual applications.
- Reduced work-in-process inventory by combining operations.
- Floor space savings with flexible robot mounting configurations.

9. CONCLUSIONS

This industrial robotic arm will be Pakistan's first robotic arm, which is designed by Pakistani engineers. This robotic arm will be industrial viable product and cost-effective. It will perform the industrial task like welding, palletizing, pick-and-place, ISF, etc. The robotic arm is designed to compete with the international robotic arm with low cost. Robotic arm structure is locally manufactured while motors, drives, controllers, etc. are imported.

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ANALYSIS OF MECHANICAL PROPERTIES OF CNT'S AND GLASS FIBER REINFORCED POLYMER COMPOSITES

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ABSTRACT

In the stream work, the change in mechanical properties of polymer composite with different cast of deoxyephedrine fibre and also effect of CNTs on the mechanical properties of epoxy resin matrix field glass fiber reinforced composite were studied. Modification of polymer glass fiber reinforced composites by Single Walled Carbon Nanotubes (SWCNTs) had the purpose to improve interfacial bond strength and inter laminar shear strength which is responsible for good mechanical properties in plane and out of plane/through thickness respectively. Chopped and continuous glass fibers were used to fabricate epoxy matrix glass fiber nano composites. Three points flexure trial run test, shoring insensibility test and scanning electron microscopy (SEM) was done to investigate the changes in mechanical properties of epoxy based glass fiber composites by CNTs and fracture surface respectively. By adding the CNTs, flexural strength has improved about 47.36%, flexural modules 28.57%, shear strength 36.36%, hardness by 14.84% in chopped PMC. Similarly, in continuous fiber PMC, the flexural strength, flexural modulus, shear strength and hardness increases by 24.28%, 10.8%, 21.87% and 15.55%, respectively.

***Index Terms*—** Composites, CNTs, Light weight

1. INTRODUCTION

Fiber reinforced composites are of great importance as the US fiber reinforced polymer composites industry has grown its average growth rate upto 6.5% since 1960, due to their unique mechanical properties, fabrication, flexibility and design capabilities the US economy growth rate of PMC's is twice than that of metals, aluminum and steel (Agarwal et al, 2017).

The PMCs were the first manufactured composite materials during World War II (Gojny et al, 2005). During the energy crises in 1970s, the demand for PMCs further increased due to their relatively lower cost. During this period, the properties of PMCs, the design methodologies, and manufacturing capabilities were further modified (Abdalla et al, 2008). Polymer matrix composites (PMCs) are comprised of a variety of short or continuous fibers bound together by an organic polymer matrix. The reinforcement in a PMC provides high strength and stiffness. The PMC is designed so that the mechanical loads to which the structure is subjected in service are supported by the reinforcement. The function of the matrix is to bond the fibers together and to transfer loads between them (Sumfleth, et al, 2008).

PMC are often divided into two categories: 'reinforced plastics' and 'advanced composites'. The distinction is based on the level of mechanical properties (usually strength and stiffness), however, there is no unambiguous line separating the two. Reinforced plastics, which are relatively inexpensive, typically consist of polyester resins reinforced with low-stiffness glass fibers. Advanced composites, which have been in use for only about 15 years primarily in the aerospace industry have superior strength and stiffness, and are relatively expensive (Shakoor et al, 2013).

Chief among the advantages of PMCs is their light to weight coupled with high stiffness and strength along the direction of the reinforcement. This combination is the basis of their usefulness in aircraft, automobiles, and other moving structures. Other desirable properties include superior corrosion and fatigue resistance compared to metals. Because the matrix decomposes at high temperatures, however current PMCs are limited to service temperatures below about 600 °F (316° C). Experience over the past 15 years with advanced composite structures in military aircraft indicates that reliable PMC structures can be fabricated with significant reduction in weight to strength ratio. However, their high cost remains a major barrier to more widespread use in commercial applications (Sumfleth, et al, 2008).

The first manufactured PMCs used glass fibers as reinforcement while the most commonly used polymer matrix is epoxy (Gojny et al, 2006). The glass-fiber reinforced epoxy has found many applications in defense, aerospace, marine, electrical appliances, and pressure vessels etc. These widespread applications of glass fibers are because of easy availability, handle ability, high strength, ease of processing and cost effectiveness. The fibers as reinforcement can be aligned in one particular

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direction, in two directions, or randomly oriented (Santos et al, 2011). In the current study, randomly oriented chopped and continuous fiber was used in the PMC to study its mechanical properties.

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Fiber reinforced laminated composites are increasingly being used in structural applications because of their mechanical performance and potential for significant weight reduction relative to metals. The in-plane properties of laminated composites are fiber dominated and they are sufficient for many structural applications. The out of plane through thickness properties, such as inter laminar shear strength (ILSS), are matrix dominated and are the limiting factor in many structural applications. ILSS has been improved by various methods such as Z pinning, stitching and matrix modifications. However, Z pinning and stitching fibers in the thickness direction lead to significant additional manufacturing complexity and cost. Matrix modifications include the addition of nano fillers such as nano clay, nano fibers and nano tubes (Choi et al, 2001).
This work is on the modification of glass fiber reinforced epoxy resin with single wall carbon nano tubes (SWCNTs) using hand layup process to improve the inter laminar shear strength (ILSS) and investigate the change in the mechanical properties of composite by introducing SWCNTs in glass fiber reinforced polymer composite. The nano tubes poor distribution can cause cracks in the composite rather giving then reinforcement, the pack of nano tubes in stress loading can slip pass each other, splitting off layers from the host and hence result the composite to weaken (Ajayan et al, 2007).

2. MATERIAL AND METHOD

MWCNT's were used for the analysis .The as-received CNTs had average diameter in the range 20-30 nm and were 95% pure. The remaining mainly contained carbonaceous impurities like graphite amorphous carbon, fragments, polyhedral carbon, and metal catalyst particles. Electrical glass or E-glass fibers were used in this work. E-glass is made from borosilicate glass. Three different form of fibers (continues, woven mat and chopped) were used in this work. In continuous fibers, fibers are aligned in on direction. In woven mat, fibers are aligned in two direction perpendicular to each other and in chopped, fibers are aligned in random direction. These fibers had a density of 2.5 g/cm^3.
The epoxy resin used was DGEBA based epoxy. DGEBA based epoxy was purchased from Honlu Technology Co. Ltd, curable at ambient temperature (25 °C, 24 h) was used to strengthen the nano composites. DGEBA based epoxy has density 1.2 g/cm3. It has the ability to impart high strength to composites. First of all glass fibers epoxy composites were fabricated by mixture of epoxy and dicyandiamide hardener in ratio of (1:2) in a beaker and using glass fiber sheets through hand layup process. The purpose of fabrication of these samples was to have some standard samples to compare properties of polymer nano composites with them and also to study the effect of different forms of fibers on the mechanical properties of polymer composites. Table 1 represent some of the features of the fiber used in PMC. Seven layers composites were fabricated with CNTs and without CNTs by using hand layup process. Then these samples were cured at 25^{o}C for 48 hours and then at 100 ^{o}C for 3 hours as shown in Figure 1.
The first and most important part of nano composites was the deagglomeration and dispersion of CNTs in epoxy. Different methods are used in literature for the stated purpose. In the current work, magnetic stirring was used for the said purpose. Magnetic stirring and manually stirring were used to deagglomerate and disperse CNTs into epoxy. Magnetic stirring of CNTs was done in acetone for 30 minutes; following this was the mixing of epoxy in acetone containing CNTs for 30 minutes. After this, manual stirring was done for complete and uniform mixing of CNTs in epoxy. Then the epoxy was kept in oven at 70 c to evaporate acetone. After the dispersion of CNTs in epoxy, epoxy containing CNTs and hardener were mixed in the ratio 1:2 in beaker and by using hand layup process polymer nano composites were fabricated. Following flow chart is explaining the fabrication process in details. We have fabricated about 50 samples using different forms of glass fibers to get consistent values of different mechanical properties.

Table 1: Weight % and Volume %, Volume and Density of Polymer Nano Composites

Sr No.	Composite type	%Weight of fibers	% Volume of fibers	Volume of composites(cm^3)	Density of composites(g/cm^3)
1	Continuous Fiber Nano Composites	47-50	51-62	22-25	2.60-3.26
2	Chopped Fiber Nano Composites	51-55	51-58	19-22	3.00-3.26

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(a) (b)

Figure 1: Composites without CNT's (a), Composite with CNT's (b)

3. EXPERIMENTAL PROCEDURE

3.1. Three Point Bend Test

The three point bend test of polymer nano composites was conducted to study the variation in the flexural strength and flexural modulus of nano composites with the presence of CNTs and without CNTs of the produced PMCs. A minimum of three specimens were tested for each composition and the average values calculated are given in table 2 and table 3. The displacement rate was kept constant at 0.5 mm/min. The test was conducted on 100 KN Instron universal testing machine (Model 8501). These specimens were of rectangular geometry.

Rectangular specimens were prepared according to ASTM standard D790. The dimensions had width 14 mm with different thickness vary from 5 mm to 7 mm and span length was adjusted according to formula '16×thickness' for all specimens. To calculate Flexural stress, Flexural Modulus, Shear Strength following formulas were used

$$\sigma f = 3PL/2bd^2 \tag{1}$$

Where:

σf = Stress in outer fibers at mid-point,(N/m^2); P = Load at a given point on the load deflection curve, N; L = Support span, m; b = Width of test beam, m and d = Depth of test beam, m.

$$Ef = L^3m/4bd^3 \tag{2}$$

Where:

Ef = Flexural modulus

$$\tau = 3Pmax/4bd \tag{3}$$

Where

τmax = Shear strength, N/m^2

$$\in f = 6Dd/L^2 \tag{4}$$

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Where

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Єf = Flexural Strain, m/m

D = Maximum deflection of the center of the beam, m

The flexural strain is defined as the change in length per unit original length of the outer fiber in the specimen.

3.2. Shore Hardness Test

Shore hardness test is used to measure hardness of the nano composites. Shore hardness number was measured on D scale according to ASTM standard D2240. The shore hardness is basically hardness in terms of material elasticity. A diamond-tipped hammer is fallen through a graduated glass tube from a certain height on the specimen. The hammer rebounds at the impact and the height it gains is a measure of material's hardness. The harder the specimen, the higher is the rebound.

3.3. Scanning Electron Microscopy

Scanning electron microscopy was carried out on the fractured surfaces of three-point bend test samples to study fracture modes in the polymer nano composites. The fractured surfaces area was cut from the three-point bend test sample and fixed vertically on aluminum stubs by using silver paste to view the top surface. A thin coating of copper was applied on fractured surfaces by using Edwards sputter coater (Model S150B) to provide electrically conductive surface to the incident electron beam.

4. RESULTS AND DISCUSSIONS

The obtained results from the bending tests are plotted in Figure 2. A significant improvement in the strength of PMC with the addition of CNTs was achieved. From above table 2, it is observed that the flexural stress increases as CNT's are added to the composite i-e from 30 MPa to 57 MPa for continuous glass fibers and 30 MPa to 57 MPa for Chopped glass fibers. It's because of the remarkable mechanical properties of carbon nanotubes, such as high elastic modulus and tensile strength, make them the most ideal and promising reinforcements in substantially enhancing the mechanical properties of resulting polymer composites. Similarly from table 3, experimental results showed that the composite without CNT's gave the strain result of 0.0331 and 0.055 for continuous and chopped glass fibers respectively. Whereas the composite having the composition of 0.1% CNT's gave the result of 0.0213 and 0.035. The decrease in the strain calculation is because of the CNT's alignment over the layers of fibers causing them to produce pullouts in the fibers hence resulting in the increase in the overall results.

Table 2: Flexural Stress of polymer nano composites

Fiber Type	0%CNT's	0.1%CNT's
Continuous	106MPa	140MPa
Chopped	30MPa	57MPa

Table 3: Flexural Strain of polymer nano composites

Fiber Type	0%CNT's	0.1%CNT's
Continuous	0.0331 mm/mm	0.0213 mm/mm
Chopped	0.055 mm/mm	0.035 mm/mm

The obtained results from the bending tests are plotted in Figure 2. The flexural strength of the chopped fibers based composites increased from 30 to 57 MPs when the amount of CNT increased from 0 to 0.1 % bringing a significant improvement of 47 % in the flexural strength. Flexural strain increased by 36.36% for 0%CNT's the value was 0.055mm/mm and for 0.1% 0.035mm/mm . The value of shear strength increased by 36.36%. Also the flexural modulus increased by 28.57%. Additionally from figure 3, for the continuous fiber composite the measured flexural strength for 0% CNT's was reported as 106 MPa and for that of 0.1% CNT's, an additional increase of 34 MPa was noted. A significant increase in the flexural modulus (from 27 GPa to 31 GPa) was reported with doping of CNTs in to the continuous fiber PMC. Similarly, the shear strength also increased upto 21.87 %.

From the theoretical concept of doping CNT's in a matrix results in strengthening the overall material properties (Ajayan et al, 2007), the experimental results seems to collide with it as the flexural stress increased and decrease in the flexural strain(table 2 and table 3) is noticed as CNT's are introduced.

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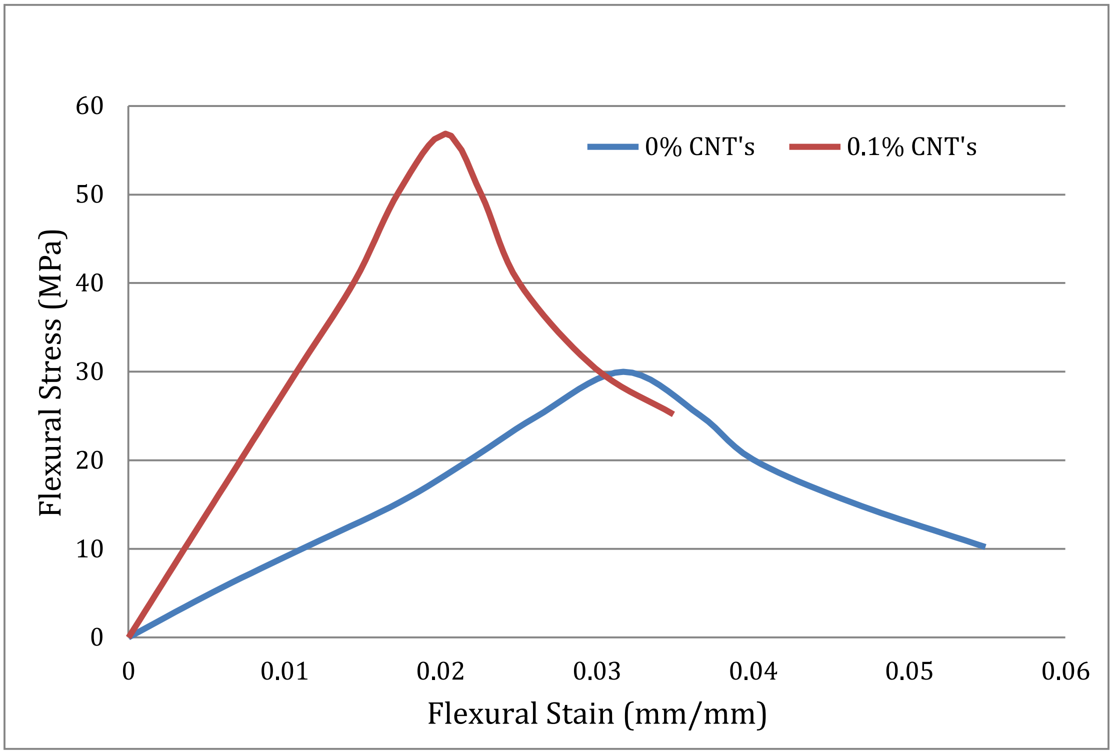

Figure 2: The flexural stress-strain response of chopped fiber composites

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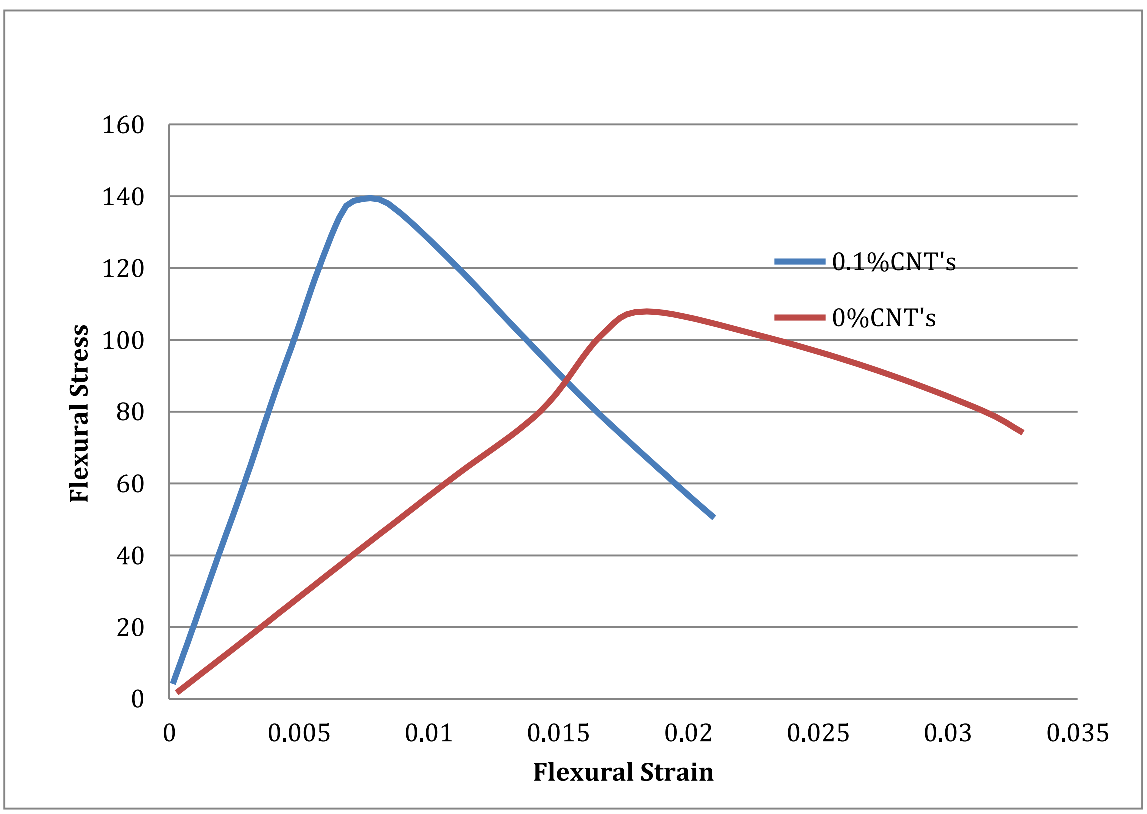

Figure 3: The Flexural Stress-Strain response of Continuous Fiber composites

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4.1. Shore Hardness Test

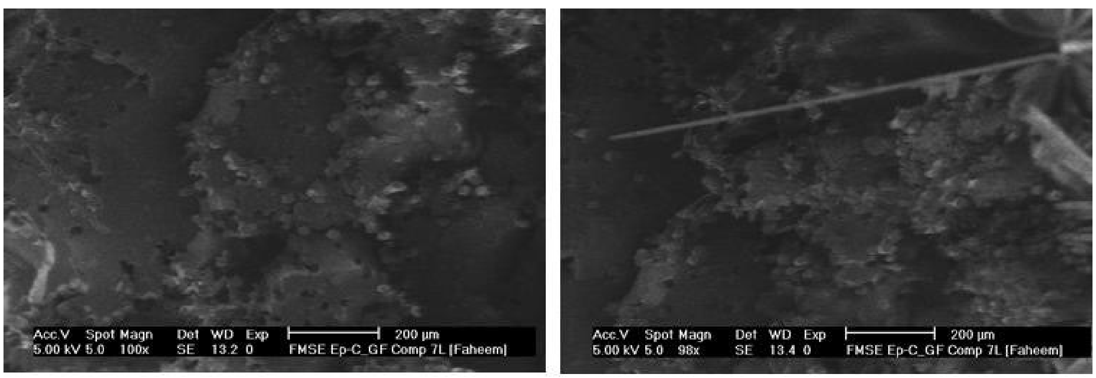
From table 4 it's clear that the Hardness values increased almost same for fibers epoxy composites which was measured about 15.55% for continuous and 14.84% for chopped. That is because shore hardness test was giving the value of hardness of outer epoxy layer containing the CNTs, so as CNTs increased in the epoxy, outer layer got harder and that is why hardness values increased with the increase in CNTs.

Table 4: Shore Hardness Test Results

Fiber Type	0%CNT's	0.1%CNT's
Continuous	38HS	45HS
Chopped	40HS	47HS

4.2. Scanning electron Microscopy

Scanning electron microscopy was carried out of the fractured surfaces of three point bend test samples to study the possible fracture modes in the nano composites. The fractured surface were cut from the specimens and fixed on aluminum stubs by using silver tape to view the top surface. A thin coating of copper was applied on fractured surface by using sputter coater to provide electrically conductive surface to the incident electron beam. Following are the SEM images of different forms of glass fibers reinforced nano composites.



(a) (b)

Figure 4(a) (b): SEM image of the continuous GF nano composite fracture

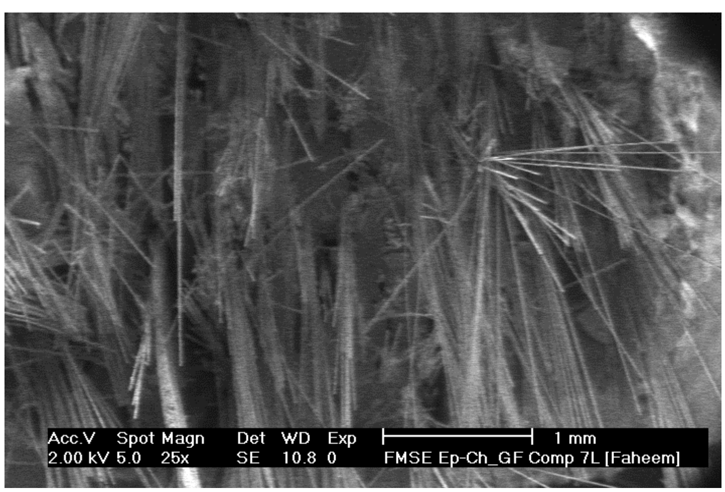


Figure 5: SEM image of the chopped GF nano composites fracture surface at 25X

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Comparing the SEM image of continuous glass fibers epoxy nano composites figure 4 with image of continuous glass fiber epoxy composite without CNTs figure 4, specimen with CNTs has shown a small number of pullout fibers compared to without CNTs. So it means CNTs have improved the interfacial bonding between glass fibers and epoxy matrix. That is why with increase in CNTs, mechanical properties of specimens have increased. Some pullout of fibers has been also occurred which is good as energy is dissipated during friction thereby delaying the time to fracture.

5. CONCLUSIONS

Three Point Bend Test of samples having CNT's improved the mechanical properties up to 0.3% as compared to samples without CNT's. Increase in CNT's above 0.3% to 0.5% caused the decrease in mechanical properties, it may be because of formation of CNT agglomerates on the interface between glass fibers and epoxy and in this way decreasing the interfacial bonding between matrixes and reinforced.

When CNTs were increased from 0 to 0.1%, Hardness values increased almost same for fibers epoxy composites. That is because shore hardness test was giving the value of hardness of outer epoxy layer containing the CNTs, so as CNTs increased in the epoxy, outer layer got harder and that is why hardness values increased with the increase in CNTs.

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APPLICATION OF INDUSTRIAL INTERNET OF THINGS IN THE MANUFACTURING SECTOR

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ABSTRACT

The future of manufacturing is tended towards the Industry 4.0 and the Industrial Internet of Things (IIoT). The IIoT is the main component of industry 4.0, as it increases the interconnectivity of the smart factories of industry 4.0. Advancements in Industrial Internet of Things (IIoT) technology are rapidly making Industry 4.0 a reality, and the resulting change shift will have a profound impact on every aspect of the manufacturing sector, from machine tools to measurement. Conventionally in manufacturing industries, the quality control procedures are performed when the product completes its manufacturing process phase. Quality control (QC) check becomes inadequate when the manufactured workpiece does not meet the base required dimensions. This leads likelihoods of producing low-quality products and increase the overall cost of the manufacturing process. Using vision technology the quality control and the manufacturing process can be integrated into the same segment i.e. quality control check is performed during the manufacturing process stage. This research project aims to implement in-process measurement for developing a real-time inspection system that can give the quality control check of the product when the product is in the manufacturing phase. Real-time measurement operations are performed with adequate image processing techniques during the manufacturing process. As a result, this will not only increases the productivity but also provides a high quality and more cost-effective products.

Keywords— *Industrial Internet of things, Industry 4.0, Measurement, Manufacturing process, Quality control*

1. INTRODUCTION

Industry 4.0 is a new globally emerging concept for industries. The new future-oriented concept is surrounded by many different technologies e.g. cybersecurity system, Industrial internet of things, simulation, big data analysis, autonomous robots, augmented reality, additive manufacturing, the cloud, horizontal and vertical system integration as shown in figure 1.

Among all these technologies this paper focusing on its contribution to the internet of things and more specifically to the Industrial internet of things (IIOT) technology. The industrial internet

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of things is the part of the internet things that focus on the objects and devices used in business settings. The IIOT can control machine data and transform the systems and process of the new evolving manufacturing environment. Real-time operational efficiencies in manufacturing are determined by changes in manufacturing process, robotic plants, supply chain, embedded systems and connected devices. IIOT create the connected environment enabling various enterprises to

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optimize manufacturing process by integrating their applications, machines, clouds and other technologies efficiently, thereby offers manufacturing systems to provide better control on the manufacturing process (Rüßmann, 2015). This integration of technologies help the manufacturing sector enterprises to manage and exchange the data in a digital environment and improve safety, productivity and quality in the industry. The IIOT has a great potential for the economic growth. Interconnected devices in IIOT will revolutionize business by increasing productivity, process efficiency, and cost. Cisco analysts estimate that IIOT can produce a profit of $1.95 trillion for manufacturing through Industry 4.0 (Thierer, 2015).

The applications of IIOT are different from one manufacturing sector to another e.g. automotive industry uses IIOT to increase the car production, whereas turbine manufacturing leverage IIOT to enhance the performance of wind turbine.

Some of the important factors, which can be ensured in Industry 4.0 with IIOT (Lanza, 2017)

(a) Influencing quality assurance and measurement
(b) Quality control improvement
(c) Real time measurement operation.

(a) Influencing quality assurance and measurement

With the use of sensor technology, the large amount of data can be collected, measured and therefore improve detection of causal connections that give Industry 4.0 to influence both quality assurance and measurement.

(b) Quality control improvement

Different manufacturing process techniques can implement to get the Intelligent, adaptive quality control, which will improve the quality of the product.

(c) Real time measurement operation.

Real time measurement operations can perform such as finding the dimensions of the work piece in the given set of tolerance range. Measurements are no longer taken in a separate measuring room, but directly in the production process. Among the aforementioned factor, the focus of research is to enhance the real-time measurement operation in an industry by applying the application of IIOT in the manufacturing process.

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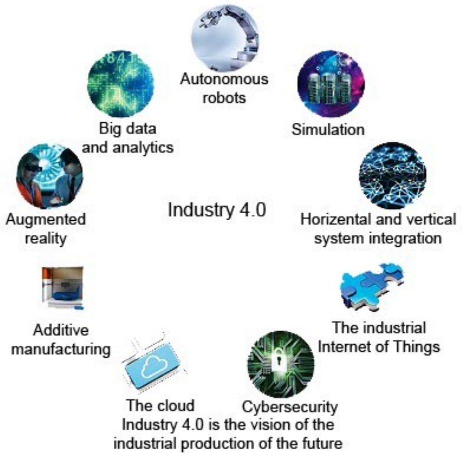

Figure 1 Nine technology transforming Industrial production (Rüßmann, 2015)

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2. MANUFACTURING PROCESS

The advancement in the technology provides different alternatives methods in the various manufacturing sector to update their method of working in order to produce high quality and low-cost products. This benefits to the manufacturing sector, and also meet the requirements for end user. In Industries such as automotive, aerospace etc., the main focus for manufacturers is to produces produce high quality production order to satisfy the customer's needs. Measurement processes are most important and critical for such industries, as the products must follow strict rules and customer requirements (Abollado, 2017). This become essential for most machined parts, as they required more precise geometric and dimension control. Once a machined part is produced, an inspection process carried out to check whether the part is within specified tolerances. The main purpose of the inspection process is to ensure that the manufactured part meet the desire tolerance range (Bell, 1999).In producing high quality and low-cost product in industries such as aerospace etc., manufacturing companies need to establish measurement process regularly. But the formation of measurement process is complicated, as it requires a good relationship between the acquired expertise and the measurement data, in order to decide what is necessary to be measured (Zhao Y. K., 2011) With the rapid growth of product variation, complexity and demand of reducing product development cycle, industries are in search of more efficient, reliable and automated inspection methods for measurement operations and efficient decision support tools. In manufacturing processes, the development procedures and planning process has the significant effect on the resulting product, with the addition of production cost and time. Selecting in appropriate manufacturing procedures, methods and sequences during the manufacturing process are more prone to inconsistencies and errors results because of the large number of setups and not selecting the proper choice of datum and reference. Integrating manufacturing process planning with the inspection process decisions can be done on real time, will improve the manufacturing process procedures in future and also enhance the quality of the product. This will lead to safe cost i.e., reduce the ratio of expensive rejected parts and time (Shah, 2013). Applying the application of IIoT at manufacturing sector can minimized these complexities.

3. CURRENT STATE OF THE ART

Conventionally quality control (QC) operation performed on the workpiece after the completion of the manufacturing process. The workpiece has to remove from the machine for performing the measurement operation in order to measure it with measurement instrument situated near to the machine tool. These procedures make the overall process slow. Moreover, parts are recommended to be inspected under controlled environment e.g., specific temperature, humidity, and pressure for precise measurement. The workpiece is taken to a properly equipped inspection room inspected by using contact and non-contact measurement techniques. A coordinate measuring machine (CMM) is an example of a contact 3D scanner (Heier, 1993) . The High-value components require very tight tolerances and accuracy in parts manufacturing. CMMs machines have been most widely achieving signal point accuracy but CMMs are not portable and costly as well. It can modify or damage the

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workpiece while scanning the workpiece. In contrast, non-contact measurement systems are capable of capturing 3D data from complex geometries. Non-contact measurement systems are further divided into two types; 1) Non-optical inspection system 2) optical inspection systems. Non-contact optical measurement techniques are more cost effective and fast as compared to conventional Non-optical inspection techniques. There are various non-contact inspection techniques which can be considered for on-machine measurement presented in figure 3. Yet very few measurement

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applications such as a robot and machine tool industry have already been carried out by utilizing non-contact optical inspection techniques. Inspection process for CMM has been focus for more than twenty-five year (Zhao Y. , 2009). Measurement requirements depend on the complexity level of components. Measurement requirements for different geometries (parts) are shown in fig.2. (OMM) to evaluate the geometry of piece-part during or after the manufacturing process. With increased accuracy and stability of CNC machine tool, and more precise measuring devices, on- machine measurement (OMM) has become broadly accepted in the industry. However, for on- machine measurement operations the inspection process planning require more research work The main goal of performing measurement in a manufacturing process system is to get close control on the manufacturing process based on tolerance requirements and to correct the process errors as they occur. The key issue is to connect tolerance requirements with manufacturing procedures. When to measure and what to measure is another critical issue.

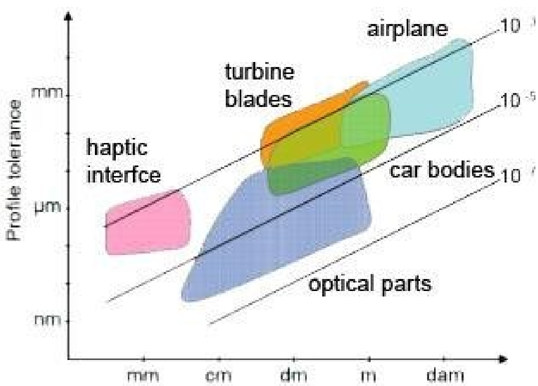

Figure 2 values of tolerance vs dimensions for most common free form shaped part

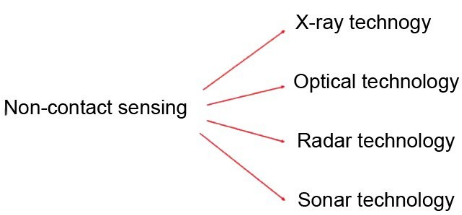

Figure 3 Non-contact optical inspection techniques

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4. FURTURE OF MANUFACTURING

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With the evolution of industry 4.0, the applications of IIOT increase rapidly. As it connects different machine equipment within the industry and with the other industry through a network and forms a real-time inspection system. By digitization of machine equipment's and the products, will ensure the manufactures to perform real-time inspection operation in manufacturing processes. The physical equipment's in the industry digitize with different technologies e.g., embedded systems, network technologies etc., are components of IIOT in the industry, which produces a cyber-physical system within the industry. With the digitization of physical component in the industry, IIOT which is the integral part cyber-physical system for industry, provide a real-time inspection of different processes.

In the industry, reduces the overall cost in the manufacturing sector. The manufacturing process can be improved, accurate and reliable due to the digitization of different physical manufacturing components. With IIOT, the products and machines will be able to communicate with each other for exchange of information. Moreover, because of the digitization of the physical apparatuses, the human involvement minimizes in the manufacturing process and inspection system. This will reduce the cost of the manufacturing process and save time. Staff can be equipped with different other skills and can be deployed in more durable operations within the industry. Furthermore, the important benefit of IIOT is that it reduces the chances of any incidents that may happen, which severely affects both workers and assets of the industry. As real-time inspection will be performed through IIOT, this will give a better understanding of overall manufacturing process in the industry. Eventually helps the industry to plan for future. As real-time inspection will be performed through IIOT, this will give a better understanding of overall manufacturing process in the industry. Eventually helps the industry to plan for future Due to the digitization of the physical product and machine, the manufacturing process can inspect in real time and modified. Real-time data can be provided to the manufactures, makes the manufacturers and the industry to be updated with their product condition and quality. This data eventually helps the industry and manufactures in making the decision in their foregoing products. Therefore, the errors and the quality control of the manufacturing process improves with the real-time information provided to the manufacturer. Within the industry, this information /data will automatically provide to the machines through the IIOT, complexity will be reduced, and quality of the manufacturing process improves provided to the manufacturer. Within the industry, this information /data will automatically provide to the machines through the IIOT, complexity will be reduced, and quality of the manufacturing process improves. For example, cyber-physical system of the car contains the different sensor, which communicates with each other through different sensors makes a cyber-physical system of a car. The system constantly inspects the different parts condition of the car in real time. Any problem occurs in any part of the car the sensor exchanges the information and applies different operation based on the required information. The information is sent through a network to the manufacturing sector. Informing manufacturing operators and the designers about the cause in real time.

Real-time quality control through IIOT produces a digitized environment helps to produce a quality product. Introducing vision technology in the IIOT can further get the inside of the quality control of the product. In the manufacturing sector, this can be helpful for doing real-time operation.

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Operational intelligence can be inducted into quality control in the manufacturing sector with technologies e.g. vision, image process through IIOT. The real-time measurement operation can perform and the quality of the product can be improved. This will not only save time but also minimize the cost of the manufacturing sector. The applications of IIOT can be applied in the manufacturing sector in industries. Different measurement techniques in different steps of the manufacturing process can be applied and inspected through IIOT. Real-time inspection of different

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measurement techniques in different phases of the manufacturing process can be performed. The acquired information will help to get the inside of the manufacturing process. This will improve the quality of the final product and increases the productivity. The applications of IIOT can be applied in the manufacturing sector in industries. Different measurement techniques in different steps of the manufacturing process can be applied and inspected through IIOT. Real-time inspection of different measurement techniques in different phases of the manufacturing process can be performed. The acquired information will help to get the inside of the manufacturing process. This will improve the quality of the final product and increases the productivity control procedures are performed when the part is manufactured shown in figure 4 (Groover Mikell P, 1987). The quality of the product is described by the Quality control (QC) check once the product completed its manufacturing phase. If the product dimensions do not lay in the given tolerance range the product gets discard and becomes the part of the waste material.

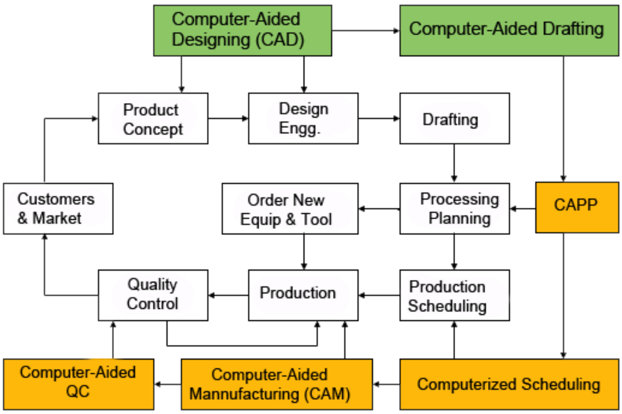

Figure 4 PDC with CAD/CAM overlaid (Groover Mikell P, 1987)

This factor not only affects the cost of the manufacturing process but also the waste generated through industries influence the environment badly, as this wastage material get expose to the environment and makes the environment polluted. Today, only some of machines and manufacturer's sensors are arranged and make utilization of embedded computing. They are typically composed of a vertical automation pyramid in which sensors and field devices with less intelligence and automation controllers encourage an overall manufacturing process control system. However, with the Industrial Internet of Things (IIOT), more devices sometimes including even unfinished products will enhance with embedded computing and connected using standard technologies. This permits field devices to convey and associate both with each other and with more centralized controllers (Jeschke, 2017).

The focus of the research is to highlight the integration of manufacturing process, machines

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and quality control inspection system by applying IIOT applications, in order to make the processes and system intelligent enough so that real time computations can be done. This way the efficiency of the overall process and product quality increases. The emerging concept of IoT inducts the intelligence in the physical product by using different technologies e.g., networking, machine vision, wireless sensor networks, embedded system etc. The physical product gets intelligent enough to

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communicate with each other. Implementing IoT at industry sector develops into IIOT for the smart industry. Implementing the applications of IIOT in industry, real time systems at smart factory can be achieve using the technologies such as machine vision, networking, embedded system. The intelligences in the manufacturing process, machines and quality control etc., can be merged and more intelligence can be install to get the efficient real time inspection systems. The paper suggested that by considering adequate measurement techniques, sensor technology in the manufacturing process during the inspection phase, quality control factor can be optimized with the use of appropriate image processing methods so that the real-time measurement solutions can be performed to get the high quality and cost-effective products through IIOT. This way operational intelligence during a manufacturing process for quality control can be achieved. This can become a useful application for IIOT and industry 4.0 in the manufacturing sector.

5. CONCLUSION

In the revolutionary digitization industrial era, Industrial Internet of things (IIOT) and industry 4.0 provides a high potential for increasing productivity in the manufacturing sector. Using real-time process measurement technique, the dimension of the work piece can be inspect in real time. This provide higher quality and cost-effective products and thus increases the productivity. Appropriate measurement techniques can provide both real-time data acquiring and quality control functions in the same phase i.e. Measurement operations performed during the manufacturing process to insure the quality control. The scope of this research is relevant to the industries manufacturing high quality, low tolerance products e.g. aerospace, automotive, electronic industries through IIOT. This research highlights some facts, so that manufacturing sectors can improve manufacturing process procedures to get the high-quality products. By doing further research in the findings i.e. Measurement operations performed during the manufacturing process to insure the quality control. The scope of this research is relevant to the industries manufacturing high quality, low tolerance products e.g. aerospace, automotive, electronic industries through IIOT. This research highlights some facts, so that manufacturing sectors can improve manufacturing process procedures to get the high-quality products. By doing further research in the findings.

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OPTIMIZED MATERIAL SELECTION FOR IGNITION COILS INSULATION APPLICATION WITH CES EDUPACK

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ABSTRACT

Ignition coils (IG) are designed with an impregnated electrical insulator resin separating primary coil, secondary coil and magnetic core respectively. The ignition coils are exposed to have possible failures because of electric discharge. To protect ignition coil from possible failures due to electric discharges or corona occurrence, high dielectric strength (DS) materials are used as insulators. The insulation material need to fulfill the specific properties required for insulation. It should provide resistance against unnecessary discharges, have high dielectric strength vs less dielectric constant (DC). In addition insulation material must be able to transfer heat to environment and protect coil from dust particles, greases and lubricating oils. Bubbles and cracks are the prominent defects that significantly affect the insulation quality. Cracks are generally formed in epoxy based insulators. In this research a systematic procedure for selection of insulating materials for the ignition coil is used with the application of CES software and heuristic approach with optimized parameters of the insulating media.

Index Terms— IG, DS, DC, CES.

1. INTRODUCTION

Working principle of automobile, generators and boilers constitute of a major part called Ignition coil (IG). Ignition system of a vehicle includes combination of ignition switch, capacitor discharge unit (CDI), magneto/ battery, ignition coil, and spark plug. IG mainly acts as a transformer for converting low voltage of battery, to higher voltage which results in spark generation. IG works on the principle of electromagnetic induction and it stockpiles the magnetic energy produced as a result of change in primary current and releases this energy for spark production once high voltage had been achieved. (Berk, 2003) (Ganghua Ruan, 2013).

Ignition coils in terms of performance face severe chemical and electrical demands. Also the operating temperature of the device can vary from -40^{o}C to 150^{o}C. In addition, it should bear dynamic vibration loading, resistive to materials associated with vehicles that is gasoline, greases, brake oils, humidity and a secondary voltage in the range of 15 to 35 kV. (Reif, 2015).

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Distinctive failure in high voltages is electric discharges or corona occurrence and high dielectric materials are used to insulate IGs in order to protect it from possible failures. Dielectric material used as insulation should fulfil three main purposes i.e. it should provide proper electric resistance against unnecessary discharges, transfer heat to environment and protect IG from any foreign charged particle (Nawaz, 2013). Preliminary insulating material used in 19 century for insulation

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was craft paper (Paulapuro, 2000). However pores in kraft paper made it ineffective for high voltages. Impregnating oils substituted the prior technique but faced the issue of oil leakage from enclosed surface due to dynamic vibration of vehicle (Ahmad Nawaz, 2012). Oil based insulation is still used in Pakistan for high voltage transformers but its use in ignition coils can lead towards complex corona effects due to spilling or leaking of oil and air filling in generated gaps. Sodium silicate was used to overcome the prior subjects however failed due to less dielectric strength (Young, 2008). In 1960 polyester based impregnation (both solvent based and solvent less) was first used by Germans (Young, 2008). However, insulations having the necessary properties still fail due to two prominent defects i.e. bubbles formation and electrical treeing or cracks (Arbab, 2013). Cracks phenomena is usually observed in epoxy based insulations (Berk, 2003) (Sanchez., 1991). However Polyester is usually observed with the issue of bubble formation based upon its Impregnation technique. Polymer materials are used generally for insulation but are not suitable in high voltage insulations. Contamination occurs in polymers due to atmospheric conditions that includes moisture or fog, salts, dust particles and ionic pollution. Such contaminations results in insulation failure due to flow of leakage currents across the surface of insulation. Electrical stress and discharge or spark takes place due to such leakage currents generated under high voltages. The spark temperature is extremely high, 2000° C. or higher, and the heat produced is sufficient to cause degradation of the insulation (Penneck, 1980). Heger in his insulating materials study found that polymer insulator materials when tested at a test voltage of 4.0 kV (rms) exhibited less erosion however the IG voltages are higher than 4kV (Heger, 2009). Polluted epoxy resin insulators when compared to Polluted porcelain insulators were less susceptible to high relative humidity (Waluyo Waluyo, 2008). Moreover, there is a difference in coefficient of thermal expansion of copper winding and cured epoxy or polypropylene capsule which results in cracking of epoxy insulation (Ahmad Nawaz, 2012). This research is conducted to follow a systematic procedure for shortlisting of insulation materials for IG using the application of CES software and the selected materials will be ranked using heuristic approach with optimized parameters of the insulating media. The CES software is implemented to take into account all the key parameters that had to be considered for designing of IG dependent upon constraints of the environment and objectives that had to be met.

2. METHODOLOGY

ASTM standards for insulating material are based upon following electric properties:

- Dielectric breakdown voltage,
- Dielectric strength,
- Permittivity (dielectric constant),
- Resistance and conductance.

The initial step for selecting a specific application material is to establish link between materials and required application function. Function generation leads towards specified constraints that had to be met. Hence constraints screen out the materials which cannot meet the design requirements.

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For our electrical insulation purpose basic distinct constraints are defined in table 1. Those constraints were applied in CES using limit stage . To conclude our material selections,

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objective is designated for optimization. List of all the objectives that can enhance electrical insulation are shown as follows:

Table 1. Material selection chart

Function	**Ignition Coil insulation**
Constraints	Minimum Service Temperature = -25° C Glass temperature = 120° C Minimum thermal conductivity = 0.2 W/m.° C Insulating material with high electrical resistivity (minimum)=2.5 x 10^{18} µ.ohm/cm
	Maximize dielectric strength. (to overcome breakdown at higher voltage) Minimize Dielectric Constant. (to decrease charge storing capacity) Maximize thermal conductivity. (to release heat generated due to high voltage) Maximize thermal expansion coefficient. (to avoid insulation breakdown due to internal temperature rise)
Free Variables	Dimensions of coil

2.1. Dielectric Strength and Dielectric Constant

Dielectric breakdown is key property which defines high voltage insulation. It states the insulation breakdown in terms of flow of current through insulator when the applied voltage across insulator exceeds the breakdown voltage. As a result the insulator becomes electrical conductor to some extent. Our objective here was to maximize the dielectric strength while keeping the dielectric constant minimum.

***2.1.1** Material index calculation:*

Dielectric strength is defined as follows,

$$E_{max} = \frac{V_b}{d} \tag{1}$$

where

V_b is breakdown potential.
d is thickness of the dielectric material.

Similarly relative permittivity εr in formulation form can be stated as:

$$C = \frac{\varepsilon_o \varepsilon_r A}{d} \tag{2}$$

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Where $\varepsilon_o = 8.85\times10^{-12}$ F/m
A is area of dielectric,
d is Thickness of the dielectric material.
Equating both results in

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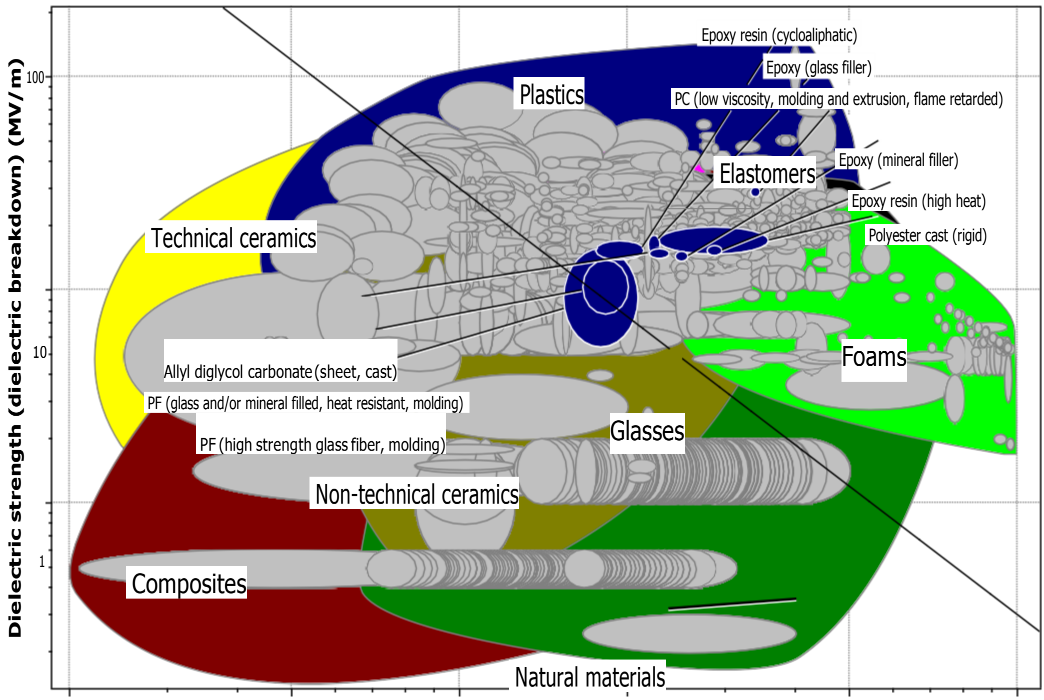
$$\frac{V_b}{E_{max}} = \frac{\varepsilon_o \varepsilon_r A}{C} \qquad (3)$$

$$E_{max} = \frac{1}{\varepsilon_r}\left(\frac{V_b C}{\varepsilon_o A}\right) \qquad (4)$$

Here V_b is representing f(F), while A, ε_o and $C$are representing f(G). Hence the f(M) is defined as:

$$M_1 = \frac{\boldsymbol{E_{max}}}{\left(\frac{\mathbf{1}}{\boldsymbol{\varepsilon_r}}\right)} \qquad (5)$$

Hence the CES plot of equation is shown in the figure 1. The materials with maximized dielectric strength with reference to minimized dielectric constant are selected using slope line.



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0.02 0.05 0.1 0.2 0.5 1

1/Dielectric constant (relative permittivity)

Figure 1. DS vs DC graph.

2.2. Thermal Conductivity of Insulation

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Insulation selection in high voltages is based upon the concept that insulator material should conduct heat hence avoiding circuitry failure due to high temperatures which may leads towards melting and deterioration of insulating material. Thermal conductivity "k" is expressed in equation as:

$$\frac{Q}{t} = -kA\,\frac{(T_1 - T_2)}{d} \tag{6}$$

Where Q/t is the rate of heat transfer per second, measured in Joules per second, or Watts.
k is the thermal conductivity of the material.
T1 is the temperature of inner core, and T2 is the temperature of the insulator.
And d is the thickness of the insulating material.

2.2.1 Material index calculation:

In section 2.1 we considered the main property of high voltage ($Dielectric\ strength$) in conjunction with dielectric constant. However it is correlated in this section with thermal conductivity.

$$\frac{Q}{t} = -kA\,\frac{(T_1 - T_2)}{\left(\frac{V_b}{E_{max}}\right)} \tag{7}$$

$$k = \frac{\frac{Q}{t}\left(\frac{V_b}{E_{\max}}\right)}{A.\,\Delta T} \tag{8}$$

$$k = \left(\frac{1}{E_{\max}}\right)\left(\frac{\Delta T}{A}\,\frac{Q\ V_b}{t}\right) \tag{9}$$

$$V_b = \left(\frac{kE_{\max}A\,t}{\Delta T Q}\right) \tag{10}$$

Where $V_b\ and\ Q$ are representing f(F), while A, ΔT and t are representing f(G). Hence the f(M) is defined as:

$$M_3 = \left(\frac{k}{1}\right. \qquad (E_{\max})$$

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(11)

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Hence for achieving better insulation for a specific breakdown potential of insulator, we have to maximize E_{max} and maximize k. Both properties were plotted and selected candidates were picked based upon the box selection function of CES, we plotted the properties and shortlisted the potential candidates with higher thermal conductivity and dielectric strength.

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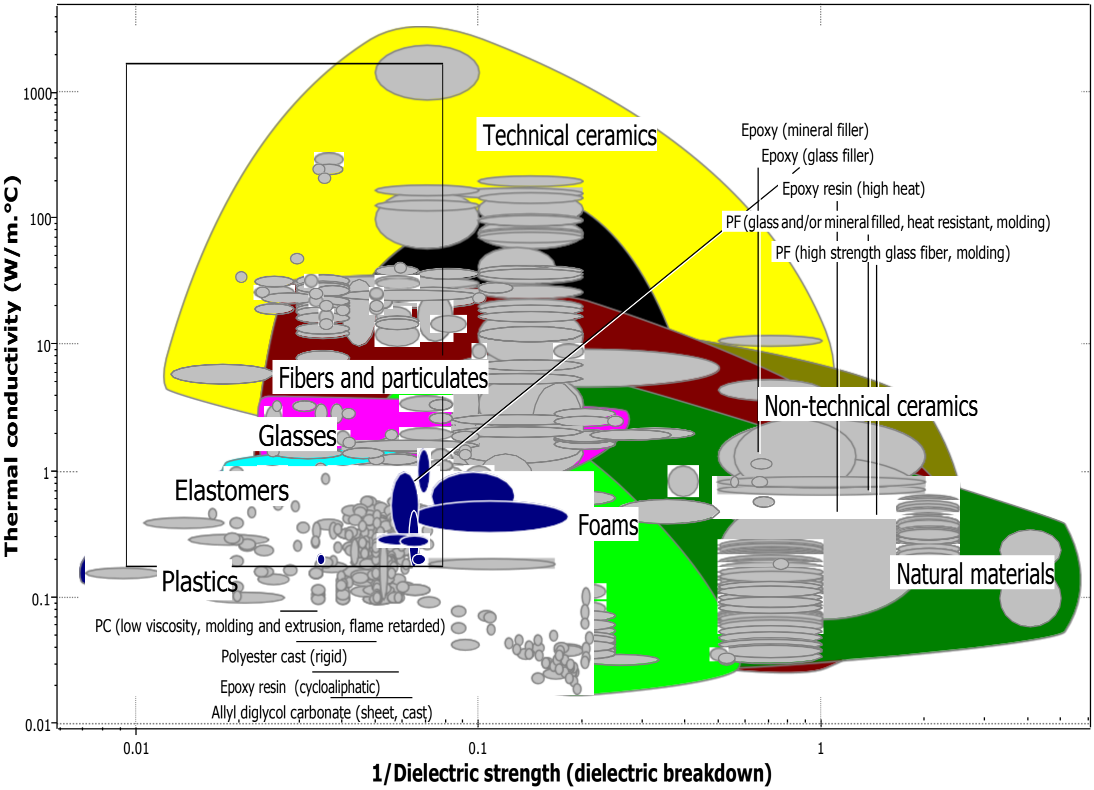

Figure 2. DS vs thermal conductivity graph.

Likewise established upon objectives and constraints the insulation material selection was subjected to 2 more graphs of Thermal Expansion vs Service Temperature and Maximum Service Temperature vs Dielectric Strength. Standards procedure of material selection lead toward selection of few materials among a kingdom of 3905 materials.

Material	DS (MV/m)	Thermal conductivity (W/m.C)	Electrical Resistivity (μohm.cm)	Glass Transition Temperature	Material cost (GBP/kg)
Allyl diglycol carbonate (sheet, cast)	15.6	0.209	1.2E+21	160	5.99
Epoxy (glass filler)	18	1	1E+21	167	3.04
Epoxy (mineral filler)	15	1.5	1E+21	167	2.34

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Epoxy resin (cycloaliphatic)	16.9	0.294	5E+20	167	2.29

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Epoxy resin (high heat)	16	0.5	3E+21	167	2.29
PC (low viscosity, molding and extrusion, flame retarded)	29.6	0.218	1E+21	158	3.29
PF (glass and/or mineral filled, heat resistant, molding)	13.8	1	3E+18	270	1.75
PF (high strength glass fiber, molding)	15.7	0.586	3E+19	270	2.22
Polyester cast (rigid)	19.7	0.298	3E+19	210	1.59

Table 2. CES based selected material chart

3. RESULTS

CES software shortlisted 9 potential candidates among a kingdom of 3905 materials. It can be seen that the selected candidates fulfil all the attributes of optimized high voltage electrical insulators in the ASTM standards.

The concluding stage after achieving the shortlisted candidates is ultimate selection of single material for suitable application. We achieved nine materials in screening and ranking through constraints and objectives. However selecting a single candidate among the optimized ones requires deep analysis. To choose the best option among shortlisted candidate which is neither costly nor it should face any industrial limitations is a challenging task. Statistical calculation methods are used at this stage to choose the ultimate potential option. Generally if all the final selections are fulfilling the basic criteria of insulation our general rough estimate of concluding material can be done by the cost of the material. However heuristic optimization is preferable over rough estimating. Table 3 and 4 are showing the procedures of rough estimation and heuristics approach.

Table 3. Final Material selection based upon rough estimation

Material	***Comments and discussion***
Allyl diglycol carbonate (sheet, cast)	Very costly
Epoxy (glass filler)	costly
Epoxy (mineral filler)	costly
Epoxy resin (cycloaliphatic)	Comparatively Less thermal conductivity
Epoxy resin (high heat)	reasonable
PC (low viscosity, molding and extrusion, flame retarded)	Costly
PF (glass and/or mineral filled, heat resistant, molding)	Less dielectric strength
PF (high strength glass fiber, molding)	Reasonable
Polyester cast (rigid)	Reasonable

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Based on the chart below, epoxy has the highest rating number. However the next potential candidate is polyester and both can be studied in CES shapes and processes checks and experimental level with multiple enhancement process and production techniques.

Table 4. Rating index chart heuristics

Material	***Go-No-Go***	***Relative rating number (R) = property weightage x material property no***				$\sum R$	$\sum r$ ***(total weightage)***	$\sum R/\sum r$
	Electrical Resistivity (uohm.cm	***DS (MV/m)***	***Thermal conductivity (W/m.°C)***	***Glass Transition Temperature***	***Material cost (GBP/kg)***			
Allyl diglycol carbonate (sheet, cast)	S	2 2x5=10	2 2x5=10	4 4x4=16	1 1x3=3	51	21	2.43
Epoxy (glass filler)	S	4 4x5=20	4 4x5=20	4 4x4=16	2 4x3=12	71	21	3.38
Epoxy (mineral filler)	S	2 2x5=10	5 5x5=25	4 4x4=16	3 3x3=9	60	21	2.85
Epoxy resin (cycloaliphatic)	S	3 3x5=15	2 2x5=10	4 4x4=16	3 3x3=9	50	21	2.38
Epoxy resin (high heat)	S	3 3x5=15	3 3x5=15	4 4x4=16	3 3x3=9	55	21	2.61
PC (low viscosity, molding and extrusion, flame retarded)	S	5 5x5=25	2 2x5=10	3 3x4=12	2 4x3=12	59	21	2.81
PF (glass and/or mineral filled, heat resistant, molding)	U	1 1x5=5	4 4x5=20	5 5x4=20	4 2x3=6	51	21	2.43
Polyester cast (rigid)	S	4x5=20	2x5=10	5x4=20	5x3=15	65	21	3.09

4. CONCLUSION

The ignition coils are failed mostly because of electric discharges. Hence IGs are protected from such possible failures due to electric discharges or corona occurrence by selecting an insulating

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material that have high dielectric strength (DS) in addition to the defined insulator property of high resistivity. CES shortlisted nine potential preferences that fulfilled optimistically high voltage

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insulation criteria. The concluding stage after achieving the shortlisted options were followed by heuristics approach which resulted in ultimate selection of single material class for suitable application. Bubbles and cracks are the prominent defects that significantly affect the insulation quality in indicated selections. Cracks are generally formed in epoxy based insulations. In the further extension of this research systematic procedure of testing will be followed on both the selections. Also the research will be extended to study the shapes and process constraints that can limit the insulation selection.

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SELECTION OF MATERIAL FOR NEUTRAL SAFETY SWITCH USED IN AGRICULTURE TRACTORS

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Abstract

Neutral safety switch is used in agriculture tractors to indicate the operation of neutral gear. Neutral safety switch is composed of main cover body, plunger, spring and cap with copper terminal. However, polyethylene (PE) is used in manufacturing of this cap. Issue with PE cap is that it fracture and cracks due to unknown reasons. Some caps are also received in burnt and fractured form. The market claim is more than 10% per month which is significantly higher failure rate. Therefore, proper material is required to replace PE material in this application. This research proposes alternative material in comparison to polyethylene (PE) cap of neutral safety switch in Massey Ferguson tractors using multiple constraints concepts. Computer based Materials Selection tool (CES) is used for shortlisting of the available materials followed by heuristical approach to select an alternative material based on optimized parameters.

Keywords: Safety switch, Polyethylene (PE), CES, Heuristic, manufacturing process

1. INTRODUCTION

Selection of appropriate material in various automobile components is an essential need (Leung and Lee, 1992; De Los Santos et al., 2002). These vehicles include two wheeled motorbikes, three wheeled (Rickshaws) and four wheeled cars, trucks and tractors. Different kinds of switches play a very important in automotive vehicles (Yerdon et al., 2008). These switches turn on or off the indicators to ensure the safety. Common examples are light switch (Rosso, 1998), door locking switch, hand brake indicator switch, neutral gear indication switch, mirror indicator switches (Tonar, 2015)etc. etc. These electrical switches are having simple mechanisms which show the working of a component installed in vehicle. Likewise, other automobiles (i.e., cars, motorbikes, trucks, rickshaws and pickups) auto switches are also installed in agricultural tractors.

In agricultural tractors a neutral safety switch is fitted to identify the neutral gear. If the tractor is in neutral gear, the switch is turned on. Therefore, neutral safety switch indicates that neutral gear is in working condition. This switch is composed of brass machined outer casing, copper based plunger,

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spring, cap composed of polyethylene in which copper terminals are installed. The market claims of agricultural tractors suggest that polyethylene cap is in appropriate for neutral safety switch. These caps were found to be cracked, broken and burnt in some cases. Possible reasons seem to be cracking during transportation, possible phase transformations and lower service temperature. Heat generated between metal and plastic interface increases if proper material interface is not formed. This ultimately affects joule heat generation (Leung and Wang, 1996).

This work analyzed the several materials using material index procedure(Ashby and Cebon, 1993;Kampe,2001)and material index chart. The properties which can possibly affect to resolve this problem are mass, impact strength and service temperature. Aforementioned properties were plotted on CES software after evaluating their indices. Afterwards, one material was selected by heuristic method. Finally, suitable replacement of polyethylene and manufacturing process are selected in this study.

2. METHODOLOGY

Initially, properties and constraints are determined based on the survey. Results of survey reveals that cap should be lighter; strong enough to resist cracking and heat resistance capability (see Table 1).Afterwards, material indices of these associated are determined. The respective material indices are maximized or minimized based on the requirement. Furthermore, thermoplastic material is used to manufacture this cap which is hollow from inside.

Table 1: showing constraints and objectives for neutral safety switch cap.

Function	**Cap of neutral switch**
Constraints	• Relatively higher impact strength • High fracture toughness i.e., ≥ 1 $MPa.m^{0.5}$ • Working temperature ≥ 70°C.
Objectives	• The cap should be lighter. • Strong enough to resist cracking. • Insulative material
Free variables	• Thermoplastic material
Part to be manufactured	• Cylindrical and hollow 3-D

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3. ANALYSIS & RESULTS

2.1 Minimizing mass

Initially mass is minimized by considering the basic equation of mass given as follows (Ashby, 2011):

$$m = A \times l \times q$$

Where m, *A*, *l* and *P* are mass, area, length and force respectively. Additionally, the cap should be strong enough to resist the cracking. Therefore, relation for fracture toughness can be given as:

$$K = co\sqrt{na} \text{ Where } K \leq K_{ic}$$

$$K = c(F/A)\sqrt{na}$$

$$A = c(F/K)\sqrt{na}$$

Finally putting the value of '*A*' into '*m*' the relation can be rewritten as:

$$m \geq CF\sqrt{na} \times (\frac{q}{K_{ic}})$$

But we have to minimize the mass therefore, the material index can be written as:

$$M_1 = (\frac{K_{ic}}{q})$$

2.2 Maximizing impact strength

Caps of the switch were found cracked due to possible impact faced by them during the transportation. Therefore, the impact strength of the material can be written in the relation as:

$$(\frac{K_{ic}}{o_y})^2 = 5[\frac{CVN}{o_y} \quad 0.05]$$

$$CVN = \frac{1}{5}(\frac{K_{ic}}{o_y})^2 \times o_y + 0.05$$

$$M_2 = (\frac{K_{ic}}{o})^2$$

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2.3 Heat transfer

Neutral safety switch is exposed to environment therefore; it should transfer less heat to the environment. The relation for heat can be given as:

$$Q = cm\ \ T$$

$$M_3 = c\ \ T$$

Material index in this case is $c\ \ T$. In this case both the quantities are in multiplication.

2.4 Material selection charts

To select the material selection charts are drawn based on available material indices. Initially, a figure is drawn between fracture toughness (K_{ic}) and density (q) between polymeric material (see Fig. 1). This figure depicts all the available thermoplastic material in blue color (see Fig.1). Afterwards, the slope is plotted between (K_{ic}) and (q) which screens out 205 materials (see Fig .2). Furthermore, Fig. 2 depicts the screened thermoplastic materials.

In order to maximize the impact strength another index is found and the slope of this index is between fracture toughness and yield strength(σ_y). This index further screens out only 28 materials including PEI (poly ether ether ketone), PEK (Poly etherimide), PES (poly ether sulfone), PET (Polyethylene tere phthalate) PI (Polyimide), PPA (Poly phthalamide), (PSU) Polysulfone, PVDF (Polyvinylidene Fluoride) and Poly amide (PA) (See Fig. 3). These materials are either in pristine form or having some filler. Finally, adiabatic condition is required for the cap to block the environmental temperature affect the electric load. Final Figure (Fig.4) depicts the slope between material index $c\ T$. Finally, seven materials are screened out which includes PA pristine, PA having different fillers composition, PET, polyarylamide and PVDF.

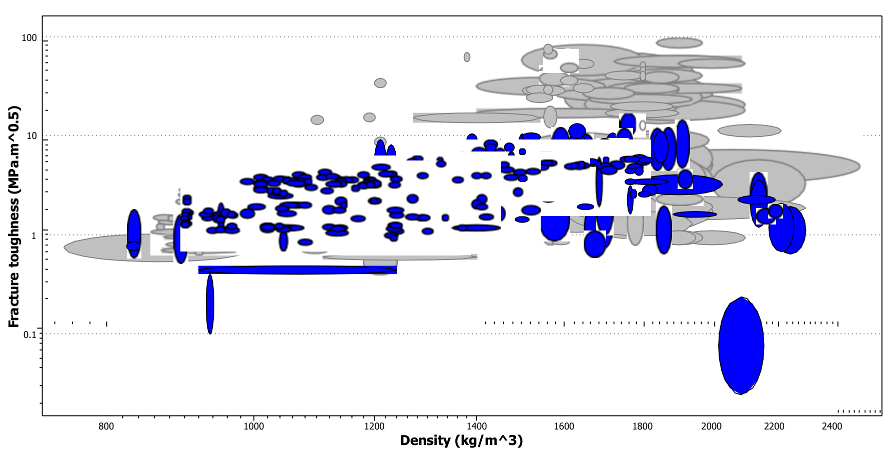

Fig. 1.Material chart between K_{ic} and q without material index slope.

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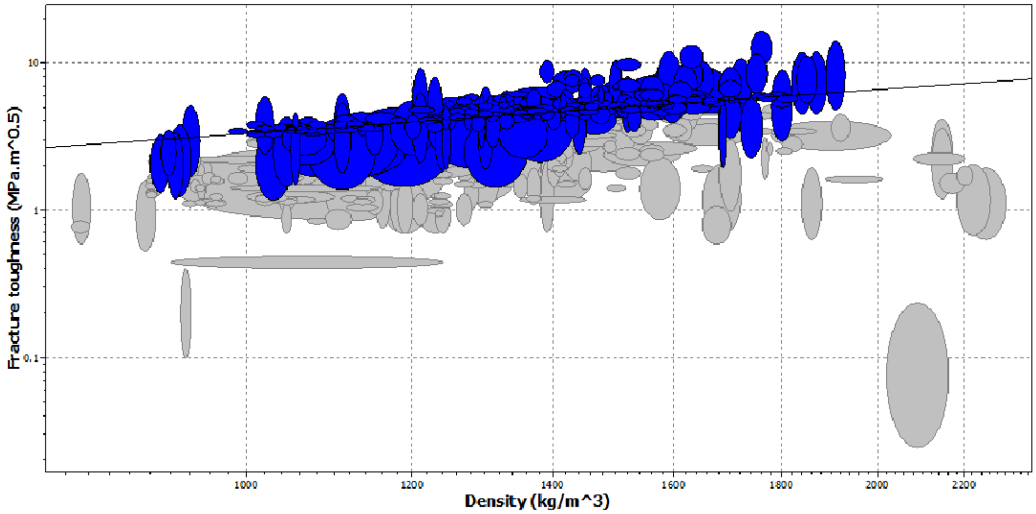

Fig. 2. Material chart between K_{ic} and q

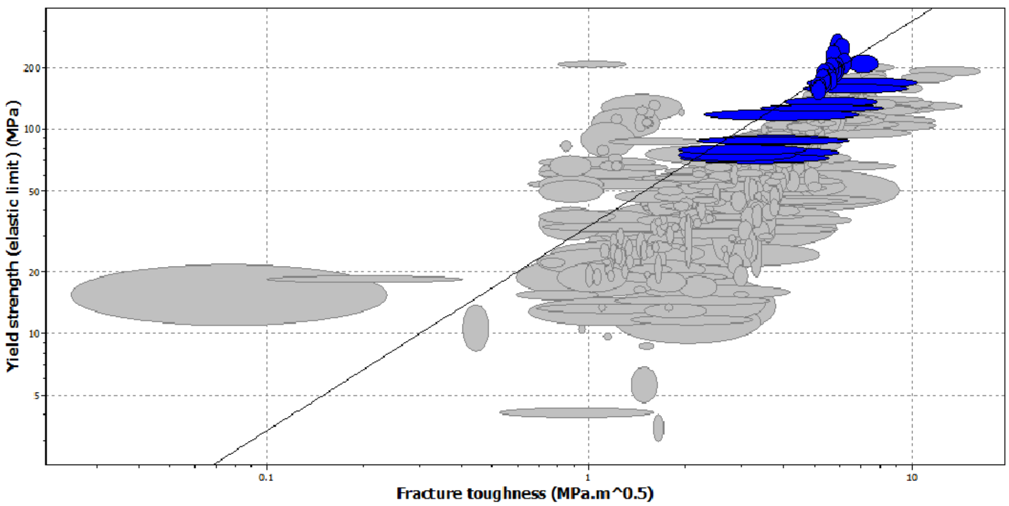

Fig. 3. Material chart depicts the K_{ic} plotted against σ_y.

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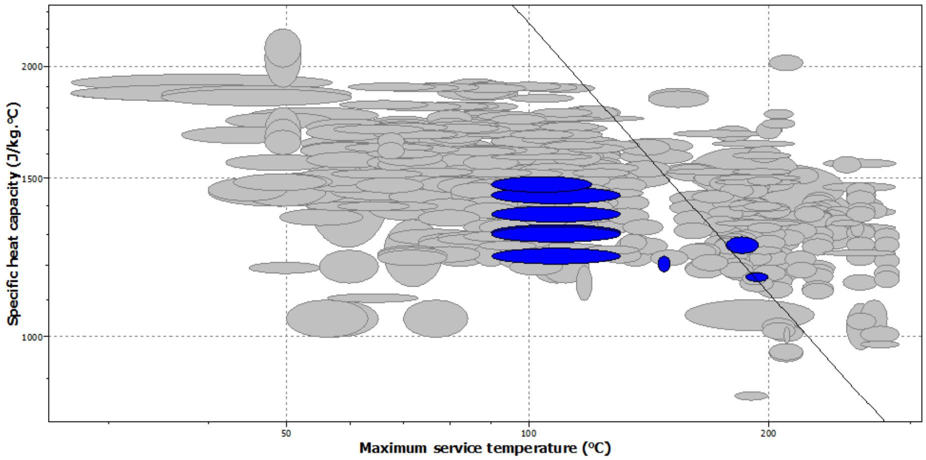

Fig. 4. Material chart depicts the T_{ser} and heat capacity c.

2.5 Screening of material by Heuristics

Heuristics are employed to further narrow down the selection process. Heuristic is basically a simplified mathematical approach to find a suitable candidate when more than one candidate is involved in the analysis. In this report, normalization of values are performed.

Case # 1

For converting properties with a normalized maximum value.

$$\alpha_{jÆ} = \frac{P_{Æ}}{P_{mas}}$$

Case # 2

For converting properties with a normalized value relative to minimum value.

$$\alpha_{jÆ} = \frac{P_{min}}{P_{Æ}}$$

By considering the equal weights for each property which can be written as:

$$W_E = \frac{1}{N}$$

For material selection the heuristic relation is given as follows:

$$MS_i = \sum_{Æ=1}^{r} \alpha_{1Æ} W_{Æ} + \alpha_{2Æ} W_{Æ+1} + \ldots\ldots + W_r \alpha_{nÆ}$$

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Table 2. Depicting results of heuristics

Materials	Fracture toughness	Density	Impact strength	MSA
PA type 6	2.82	1040	95	0.81
PA type 612	3.63	1000	13.2	0.73
PA type 66	3.52	1020	29.3	0.77
PET (30 % glass fibre)	4.6	1550	41.1	0.74
Polyarylamide	5.55	1750	41	0.69
PVDF	2.3	1720	7.5	0.71

2.6 Process selection approach

- Out of these processes only two processes are possible in our case for thermoplastic material on basis of cost effective production (Consult figure. 3).
  1. Injection molding
  2. Reaction injection molding

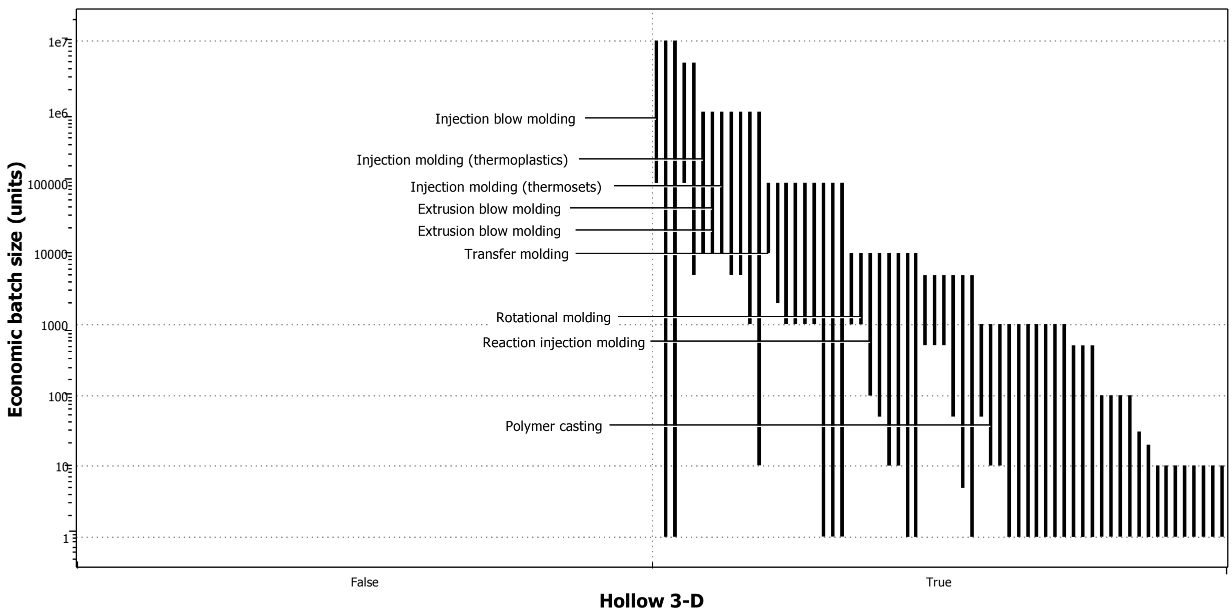

Figure. 3. Economic batch size versus hollow 3D object.

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3. Conclusion

Polyamide (PA) is selected for cap of neutral safety switch cap based on material indexes and heuristical approach. Furthermore, process was also selected using CES software. On the basis of CES analysis Injection molding and Reaction injection moldings are suitable processes for production of neutral safety switch cap. Economics of batch size suggests these two processes in comparison to other seven processes

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REDUCING THE REFLECTION LOSSES OF SOLAR CELL BY USING PDMS SCATTERING LAYER

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ABSTRACT

Flat surfaces in solar cell like tandem cells with silicon as bottom cell, perovskite cell, thin film cell and epitaxial grown cell are becoming more common with advancement in Photovoltaic (PV) technology. These surfaces present problem of Fresnel reflection and poor light trapping within cell compared to textured surfaces. In recent years light management through textured polymer surfaces is showing its advantages over multilayer Anti-Reflective Coatings (ARCs) in solar cells with flat surfaces to decrease its optical losses. This contribution demonstrates that replicas of commercially used texture when formed on polymer named polydimethylsiloxane (PDMS) can efficiently reduce the Fresnel reflection loss as well as it improves light trapping within cell for flat silicon based model. PDMS layers with random pyramid, isotexture and inverted pyramids when applied to the front surface of the silicon wafers decrease the weighted average reflectance in Visible–Near Infra-Red region. Random pyramid results decrease in reflectance of silicon wafer by 18.8% (absolute). Whereas replicas of Inverted pyramid and isotexture shows a decrease in reflectance by 15.72% and 14.42% respectively. Simulation results are in conformance with experimental measurements.

Index Terms--- Materials Engineering, Green and Sustainable Technologies, Renewable Energy.

1. INTRODUCTION

PV systems is emerging to be the most promising renewable energy technology due to its environment friendly nature, noiseless operation, flexible scaling, durability and low maintenance (Cengiz & Mamis, 2015). Efficiency of PV systems need enhancement in order to compete with fossil fuel on economy of scale. The efficiency of these systems is limited by their associated losses. Open Circuit Voltage (V_{oc}) has practically reached its theoretical limit due to improved device structures and passivating contacts; Hence short circuit current density (J_{sc}) is the limiting factor which has a lot of room for improvement.(Holman & Boccard, 2017)

Optical losses; such as front surface reflection, parasitic absorption, poor absorption in Infra-Red (IR) region; are the main obstacles in achieving higher J_{sc} by limiting the number of photons absorbed in the absorber material. Conventionally, this problem is dealt by using antireflection coatings and texturing the surface of wafers (Chen & Wang, 2011).

Monocrystalline silicon solar cell are textured in alkaline solution, hence forming random upright pyramids/periodic inverted pyramid of height between 1um to 10um with base angle of approximately 50^0 which decrease front surface reflection and enhances path length of light passing through cell; hence decreasing reflection losses of silicon from 35 % to approximately 15 % (Han et al., 2013; Manzoor et al., 2016). Multicrystalline silicon are acidic etched to form isotexture structure similar to honey comb structure. However, it is inconvenient to texture the absorber layer in next generation solar cells. Perovskite solar cells formed by spin coating requires a planar substrate, similarly to enhance the film quality, CdTe and CIGS needs planar substrate. Any effort to texture these layer will result in degradation of the material.(Dudem et al., 2016) The same problem is also observed in epitaxial solar cells, such as III-V cells that are grown on polished lattice-matched substrates. (Leem & Yu, 2015) Another challenge is that the practical limit of conversion efficiency, i.e. Shockley–Queisser limit, for silicon solar cells has nearly reached; thus leaving very little room for further improvement. To push efficiency beyond Shockley–Queisser limit, tandem solar cell like perovskite/silicon and perovskite/perovskite are developed which have flat surface in bottom sub cell, which induces huge reflection losses (Werner, Niesen & Ballif, 2017)

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Besides texturing absorber material, single and multilayer ARCs are applied which act as refractive index grading of layers at interfaces. Single layer ARCs are optimized for reducing Fresnel reflection losses at only a particular wavelength. These contribute very little for wavelengths of a vast range. In comparison multi-layer ARCs are used for a range of wavelengths. However the disadvantage of multilayer ARCs is thermal mismatch and material diffusion in harsh environments. Controlling the thickness of the layer is of critical importance in ARCs which is a difficult and expensive process to control (Chen & Wang, 2011).

ARCs are a good solution for decreasing the front surface reflection but their contribution for path light enhancement in a solar cell is little to none. A more suitable method for decreasing the optical losses in flat surfaces is to introduce a scattering layer on top of the device surface. This method of introducing an additional layer for light management is a better option for path length enhancement and reducing front surface reflectance. PDMS layer was used by Kuo et al. (2014) on CIGS cell decreasing its average reflectance from 9 to 6 percent without texture and up to 3 percent with textured PDMS. Similar approaches have been used on Perovskite Solar cell by applying light management foil with refractive index of 1.59 decreasing the reflection losses and enhancing J_{sc} from 20.7 mA/cm^2 to 21.7 mA/cm^2 (Jost et al., 2017). Similar results are reported by Leema and Yu (2015) for GaAs cell and Dudem et al. (2016) for Perovskite cell.

However this approach needs to be investigated in detail in order to evaluate the limits of the solution. In this contribution we have replicated different types of industrially available textures like random pyramid, inverted pyramid and isotexture on polymer PDMS and tested each of them on a silicon based model for assessment of optical properties. PDMS is used in this contribution, because in comparison with other malleable polymers the refractive index of PDMS is very close to glass which makes it suitable for use in the modules. The fabrication process of PDMS is also comparatively cheaper and convenient and well understood due to its use in other optical devices (Felix et al., 2014). A model based on silicon absorber material is chosen mainly due to reflectance problem for use of silicon as bottom cell in tandem cell, ease of comparison due to availability of data regarding solar cells with the same textures in absorber layer, silicon wafer is commercially easily available and degradation is not an issue for air/moisture contact of silicon wafer.

2. MATERIALS AND METHODS

PDMS scattering layers with random upright pyramids, inverted pyramids and isotextures were fabricated for experimentation. In order to replicate these textures on PDMS layers, silicon wafers with identical textures were required. Silicon master with textured random upright pyramids, of 2-5 µm in size, was fabricated in a potassium hydroxide (KOH) solution containing additive from GP Solar. Mono-crystalline silicon and multi-crystalline silicon, with inverted pyramids and isotextures respectively, were commercially purchased for the replication purpose. PDMS scattering layers were made with Slygard 184 from Dow Corning. The base and curing agent were mixed in a 10:1 ratio. The mixture was further diluted in a 10:1 weighted ratio with toluene. A vacuum desiccator was then used to remove the entrapped air bubbles from the mixture to attain a uniform refractive index throughout the layer. The mixture was then poured on three textured silicon masters, with different texturing. The mixture was uniformly placed on each master and volumetric computations were performed to maintain uniform thickness of the deposited fluid. The silicon wafer with deposited layer was baked at 46^{0}C for approximately 12 h. After cooling the wafer for a few minutes the PDMS scattering layer, with negative of the respective texture, was carefully removed from the silicon master. The details of the process and devices are already reported elsewhere (Manzoor et al, 2017)

2.2. Morphological Characterization

The morphological properties of the prepared PDMS scattering layers were examined with the help of a XL-30 Environmental Scanning Electron Microscope (ESEM). As PDMS is an insulating material, therefore a 10 nm thick gold layer was deposited on the PDMS scattering layer using argon sputtering to prepare the sample for testing. Normally an adhesive coating is also required in sample preparation for SEM but the adhesive nature of the PDMS layer mitigates this requirement

2.2. Optical Characterization

The Reflectance Absorbance and Transmittance (RAT) analysis is one of the major optical characterization tools for scattering layers. PerkinElmer Lambda 950 spectrophotometer was used to measure reflectance and transmittance of the PDMS scattering layers. Absorbance of the layer was calculated from relation $R + A + T = 1$. To observe the effect of scattering layer and calculate the reduction in reflection losses of polished silicon by applying PDMS scattering layer. Scattering layer was attached to the polished silicon wafer with the help of refractive-index matching fluid to avoid entrapment of air between the layer and wafer surface. Reflectance measurements were recorded on the silicon wafer before and after applying the PDMS

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scattering layers over the range of 400 – 1000 nm. PerkinElmer Lambda 950 spectrophotometer equipped with an integrating sphere was used for reflectance measurements over the entire wavelength range.

2.2.1. Simulations

Complementary reflectance simulations were performed using SunSolve™ (previously Module Ray Tracer) from PV Lighthouse which is widely used for solving the reflection, transmission and absorption in each material of a PV cell or module (Hohn, Tucher & Blasi, 2018; Yang et al, 2017). SunSolve™ combines Monte Carlo ray-tracing with thin film optics. This electrical solver helps quantify different losses and gains for each individual component. SunSolve™ allows texturing of any defined surface with arbitrary base angle. PDMS material was manually added to the ray tracing engine, by categorically defining its properties. Random and inverted pyramid texturing, with arbitrary angles and pyramid heights, are available in SunSolve™, whereas spherical caps, as reported in literature, were used as isotextures in the simulation environment (Sabater et al, 2017). Total reflectance simulations were performed on the silicon wafer with and without applying the textured PDMS scattering layers.

3. RESULTS AND DISCUSSIONS

The ideal scattering layer must transmit the maximum light/photons to the absorber material without absorbing/reflecting the light by the scattering layer and have minimum reflectance for the solar cell in this model case silicon.

3.1. Morphology of Scattering Layers

Morphology of scattering layers was studied by taking SEM images of replica. The morphological structures of the scattering layers as observed from the SEM are given in figure 1 and figure 2

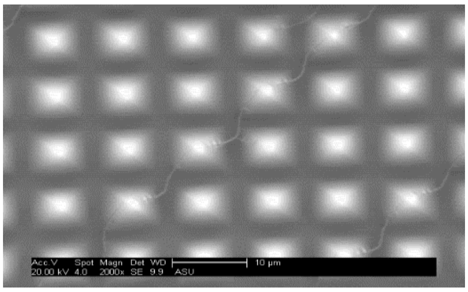

Figure 1. SEM image of inverted pyramid PDMS

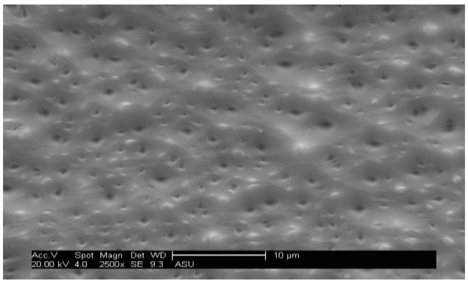

Figure 2. SEM image of random pyramid PDMS

It is evident from figure 1 and 2 that the PDMS layers were replicated successfully. However inverted pyramids (Figure 1) when replicated on PDMS show some flat surfaces between the periodically arranged pyramids, which will result in additional reflectance and/or absorbance by the PDMS layer. Hence it would be prudent to minimize or avoid the flatness for better results by the scattering layer for the inverted pyramid structure. Figure 2 shows replica of random pyramids on the surface of silicon with variable sizes. Randompyramids are well replicated and there are no flat surfaces on entire layer

3.2. Optical Characterization

RAT analysis was performed for all the layers which shows that the absorbance of all the three layers is negligibly small and transmittance in range of 92-96 % for the scattering layers.

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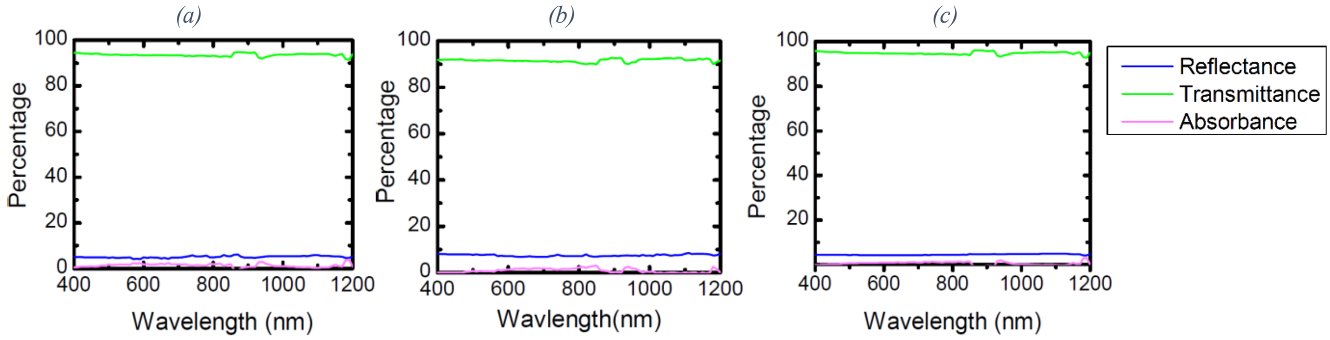

Figure 3. RAT Analysis of PDMS Scattering Layers with (a) Inverted Pyramids (b) Isotexture (c) Random Pyramids

Both theoretical and experimental approaches were used and comparison was done for directly texturing the surface with similar random pyramids. PDMS scattering layer was put on polished silicon as well as the same was simulated by SunSolve^{TM}. Figure 4 shows both the simulated and experimentally observed results of the comparison of reflectance before and after placing the PDMS scattering layers on polished silicon. Figure 4 shows that reflectance is significantly reduced by applying the PDMS layer. We can note from figures that there is slight difference between the reflectance values of polished silicon got from simulations and experimentation. The reason for deviation may be attributed to roughness of commercially available silicon which may lead to lesser reflectivity than if it was polished with zero or negligible roughness as in simulated results.

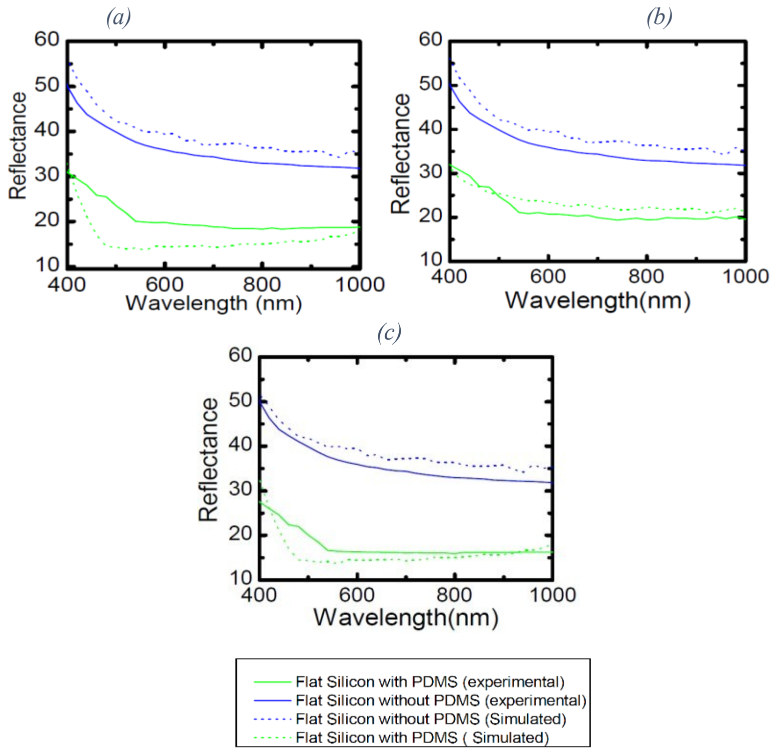

Figure 4. Reflectance of Polished Silicon before and after applying PDMS scattering layers with (a) Inverted Pyramids (b) Isotexture (c) Random Pyramids

Scattering layer with inverted pyramids in figure 4 (a) shows vast disparity in the results obtained through simulations and experimental data. Simulations predicted that the inverted pyramids will be nearly as good as random pyramids, but experimentally results are not in conformance to the simulated results. The difference in the results by simulation and experiment can be attributed to the formation of flat surfaces as seen in figure 1 that are formed in between the periodically arranged pyramids which does not deviate the light from its original path. So the inverted pyramids is behaving like partially textured and partially flat when it is applied to the surface of polished silicon wafer. Experimental results show that the

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reflectance of flat silicon can be decreased by using inverted pyramids scattering layer down to 18-19 % from 34-35 %. While the simulations shows a decrease from 37-38% to almost 13%.

Figure 4 (b) shows the results when the isotextured PDMS layer was put on the wafer. Silicon with isotextured PDMS layer also shows slight deviations in simulated and experimental results, which is due to the reason that the hemispherical model is only a supposition and this minor deviation may be caused by the approximation adopted in the simulated results. The total reflectance was decreased from average 33-34% to almost 20-21% for the visible and NIR range.

Figure 4 (c) shows the results when the random pyramid PDMS layer was put on the wafer. Scattering layers with random pyramids shows excellent results as the random pyramids were well replicated and there is very minute deviation in simulated and experimental results. The simulated results show that the total reflectance is decreased up to 14-15 % for Visible-NIR range of wavelength. The experimental results are also in agreement with the simulated results. The results show a decrease of up to 15-16% total reflectance which is also very near to the results for texturing the Silicon surface directly as reported in literature as well as results obtained via simulation for direct texturing the surface of Silicon absorber material.

	Polished Silicon	**Silicon Textured with Random Pyramids**	**Silicon with PDMS layer having Random Pyramids**
Simulation	39.6 %	15.90 %	14.44 %
Experimentation	35.9 %	14.90 % (Han et al, 2013)	16.32 %

Table 1. Reflectance of silicon wafer at 600nm wavelength

4. CONCLUSION

Solar cells with planar surfaces and their tandems suffer from large optical losses due to high front-surface reflectance and, in some cases, poor trapping of weakly absorbed long-wavelength light. This contribution has demonstrated that PDMS scattering layers with random pyramid, inverted pyramid and isotexture reduces the optical losses of solar cell with flat surfaces by a good proportion. Periodically arranged inverted pyramid and random pyramids were predicted to decrease this reflection more efficiently by simulations. However due to good quality of replication achieved by random pyramids, the scattering layers with random pyramids are much more effective for reducing these reflection losses.

5. ACKNOWLEDGEMENT

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https://www.pvlighthouse.com.au/sunsolve For simulation purpose

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PREPARATION AND TESTING OF HIGHLY EFFICIENT AND STABLE NON-PGM ELECTRO-CATALYST OF MNO_2 ON MWCNT FOR OXYGEN REDUCTION REACTION

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ABSTRACT

Highly active electro-catalyst of Manganese dioxide (MnO_2) on multi-walled carbon nanotube (MWCNT) was synthesized using a transition metal based precursor. Manganese on high surface area carbonaceous frame work of MWCNT was prepared by hydrothermal technique followed by pyrolyzing at 700^{o}C under inert nitrogen atmosphere. The enhanced catalytic activity of MnO_2/MWCNT towards the ORR was observed in a base medium (0.1 M KOH). The Linear Sweep Voltammetry (LSV) depicts a currents density of 6.5 mA /cm^2 Vs. Saturated Calomel Electrode (SCE), which was much higher than the commercial platinum catalyst. The RDE results were obtained at 400, 800, 1200 and 1600 rpm while the reference electrode was SCE. The promising results demonstrate that the Manganese based MWCNT could be a potential catalyst for PEM fuel cell electrodes.

1. INTRODUCTION

The practical applicability of the fuel cell is highly dependent on the choice of catalyst. According to the US department of energy (Wikipedia, 2013) the cost of fuel cell per kilowatt is $67 per kilowatt which is quiet expensive as compared to the conventional fossil. The better part of the cost of the fuel cell (about 70%) is only due to expensive platinum catalyst. (Alberto & Alberto, 2016)

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In the face of the rapid depletion of the fossil fuel, fuel cell offer better prospects and promising future. In comparison to the Internal combustion engine (efficiency is 35%) fuel cell"s efficiency is almost 60% (Wikipedia, 2014)which is quiet high as compared to IC engine. The major hindrance in the face of commercialization of the fuel cell is the sluggish kinetics of the

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Oxygen Reduction Reaction (ORR) occurring at the cathode side of the fuel cell and much of the todays research is focused to address this very issue, by fine tuning the catalyst and also finding out new cheap materials possessing good properties towards ORR. Recently Platinum based catalysts are deployed in modern day‟s practical purposes fuel cells. Platinum is used due to its excellent ORR properties and stability in both acidic and basic media. (Yu, 2012) Platinum is used as a nanoparticle, which are spread over high surface materials like Activated carbon, Carbon nanotubes and Metal organic frameworks (MOFS). (Luo, 2015) Platinum apart from being expensive is also very rare in the earth crust. Alloying is also one of the techniques to decrease the platinum loading and to impart excellent properties. Pt_3Y alloy is reported recently being the most efficient and stable alloy for ORR in the corrosive environment of the fuel cell. (Johansson, 2014) Yet Pt_5Gd also showed some remarkable features of ORR and stability in acidic medium. (Yoon, 2014) This implies that Platinum based rare earth noble elements could be a suitable candidate for fuel cell, but till now no researcher has reported the preparation of platinum based rare earth element via chemical route except for Pt_xY.

Transition metals alloys have also been tremendously studied for their excellent ORR properties. Noble metals based transition metals like Cobalt, Iron, Nickel, Manganese have also been researched. (Yang, 2017) (Todoroki, 2015) (Nishikawa, 2010) (Zhao, 2016) Carbon-nanotubes (CNT) are a class of interesting and advanced materials with good mechanical, thermal and electrical properties. (Souier, 2012) (DU, 2003) (Du, 2004)

In this work Manganese Dioxide based Multi-walled Carbon Nanotubes (MnO_2-MWNCT) was synthesized via hydrothermal technique and result were collected on the Rotating Disc Electrode (RDE). The Linear Sweep Voltammetry (LSV) was carried out under 0.1 Molar Potassium Hydroxide (KOH). For baseline for our experiment and for the sack of comparison same experiment was performed for commercial platinum catalyst under the same 0.1 M KOH.

Some properties of the MWCNT used in this experiment are; Surface area of MWCNT used is 20 m2/gm, electrical conductivity > 100 S/cm, and true density is 2.1 gm/cm^3

2. EXPERIMENTAL PROCEDURE

2.1. Synthesis of MnO_2-MWCNT

Reduction Pathway was used to impregnate MWCNT with MnO_2. (Saleha, 2016). MWCNT is firstly oxidized in a 3:1 conc. Sulphuric acid to conc. Nitric acid. (Li, 2014). The solution is

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sonicated for 60 minutes after which it is placed on the magnetic stirrer at 80_0C for 6 hours. After

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which it is collected by washing with De-Ionized (DI) water. Approximately 75ml nitric acid and 25 ml sulphuric acid is used for each gram of pristine MWCNT.

Once oxidized MWCNT are prepared it is dispersed in DI water and the solution is kept in sonicator for 3 hours and a constant drop wise addition of Potassium per mangante ($KMnO_4$) is fluxed at a constant rate of 2ml/4min was maintained. The solution is then subjected to rigorous stirring at ambient temperature. The drop wise addition of $KMnO_4$ progresses the reaction in the forward direction and marks the impregnation of MnO_4^- onto the surface of oxidized MWCNT by interacting with the active sites. Upon heating the mixture above room temperature triggers the formation of brown color which is indicator of MnO_2.

100 ml of DI water was used for each gram of oxidized MWCNT and 100 ml is used for 0.5 M of $KMnO_4$. The solution is then placed on the magnetic stirrer at 130^0C and it is increased at a ramp rate of 1^0C/min. the solution is then cooled down to room temperature after stirring for 8 hours. After which the solution is passed through a filter and subsequently washed with DI water. This whole procedure is illustrated in the figure 1 below.

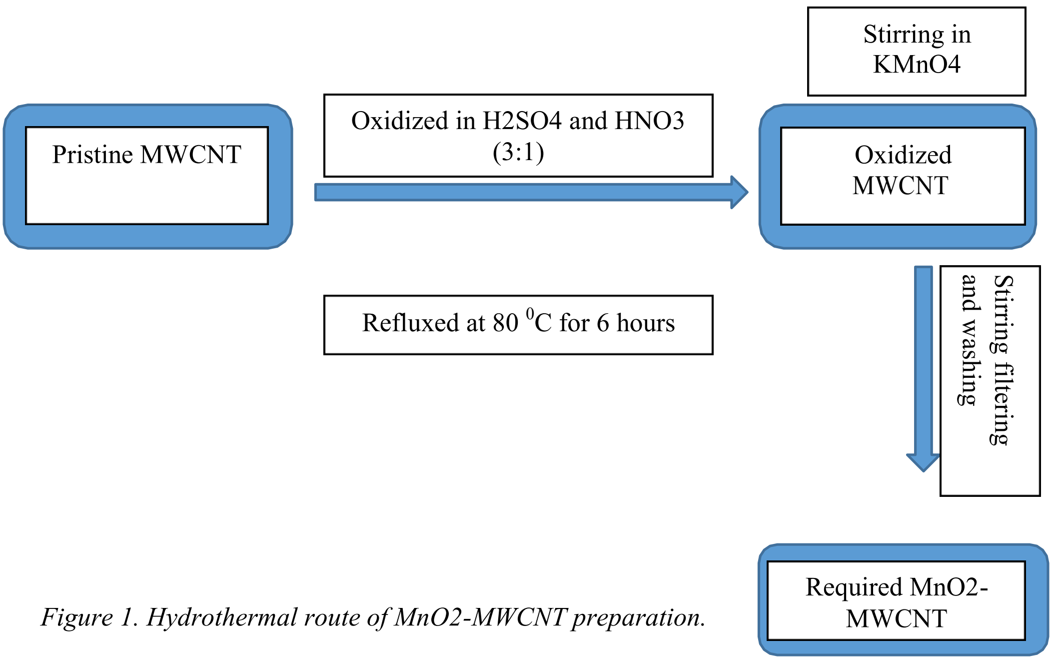

Figure 1. Hydrothermal route of MnO2-MWCNT preparation.

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2.2. Electrochemical evaluation of thin film RDE

Catalyst ink was made by taking 7.5 mg of MnO_2-MWCNT and dispersing it in 7.5 ml DI water, also Isopropyl alcohol and anionic Nafion was added into the solution as 2.4 ml and 40 micro litre respectively. The obtained solution was sonicated for 25 minutes (Li, 2014). The procedure is shown in figure 2 below.

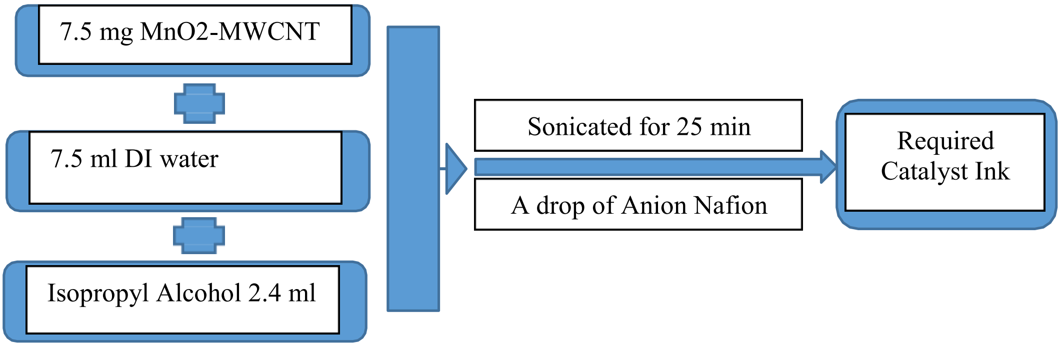

Figure 2. Catalyst Ink Formation

A small drop of the obtained ink is applied onto the surface of glassy carbon (4mm diameter) or the RDE, the RDE is rotated at 400 rpm with heater and fan on for forced convection. It takes about 15 minutes for the ink to become dry. Multiple layers of the ink are applied to the tip of glassy carbon of the RDE using micropipette, to obtain a catalyst loading of 270 microgram/cm^2.

The layers were dried for about 30 minutes to adhere well to the surface of glassy carbon. A solution of 0.1 M KOH is formed and used as an electrolytic solution to study the half cell. MnO2-MWCNT, catalyst layer is used as working electrode; platinum wire is used as counter electrode while saturated calomel electrode is used as reference electrode. The solution of electrolyte is purged for one hour with oxygen prior to testing and experimentation. A PAR Bistat Potentiometer was deployed for this setup (Shinozaki, 2014).

The same exact procedure was replicated for commercial Platinum carbon catalyst and LSV results were drawn for the sake of comparison.

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3. RESULTS AND DISCUSSIONS

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The LSV electrochemical measurements were taken using a PAR Bistat Potentiostat. The results were drawn at a scan rate of 20 mV/s and the polarization curves for ORR were recorded from 400 rpm. These experiments were repeated for 800, 1200 and 1600 rpm. The onset potential in case of MnO2-MMCNT is -0.4 which is not as good as in case of Platinum. But the current density in case of MnO2-MWCNT is 6.5mA/cm^2, which is far more superior as observed in case of Pt/C catalyst at 1600 rpm. The details are presented in the given figure 3.

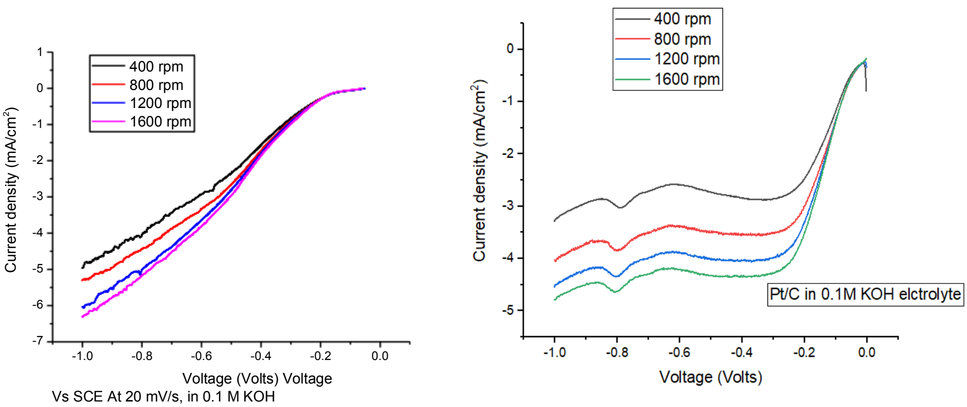

Figure 3.a. LSV of MnO2-multiwalled CNT at 20 mV/s b. LSV Pt/C catalyst Vs. SCE at 20 mV/s and 0.1 M KOH

3.1. Kinetics of ORR

To have an insight of the electron transfer on the surface of MnO2-MWCNT catalyst layer, the study of rotating disc voltammetry is presented with the help of Koutchkey-Levitch K-L Equation. An increase in the current density is observed as we progress from 400-1600 rpm (Faulkner, 2000)

The complete understanding of ORR is still mystery due to the level of high complexity and

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many pathways involved in the reaction. The complete reduction pathway of a single oxygen

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molecule follows four electron, four proton transfer (CPETs). There are different pathways in which the oxygen molecule can be reduced.

i. A four electron reduction to form water.
ii. A two electron reduction pathway to form hydrogen peroxide.
iii. Combination of 1 and 2 in series
iv. Combination of 1 and 2 in parallel
v. Direct addition of electron and proton to adsorbed oxygen molecule
vi. Splitting or dissociation mechanism in which O-O splits and attacks hydrogen of OH to form water (Nie, 2015)

To find out which reduction route the reaction follows we refer to the K-L equation and calculate for „n" which is the number of electrons transferred to each oxygen molecule. The K-L is a plot between inverse of current density on the vertical axis and inverse square root of rpm on the horizontal axis. The K-L equation is

--------1

Where J is the measure current density, JL is the limiting current density, JK which is the Y-intercept on the figure.4 K-L plot, is kinetic current density, n is the electrons transferred per oxygen molecule, F is equal to 96485 C/Mol, is the Faraday constant, D_0 is the diffusion coefficient, C_0 is the concentration of oxygen while v is the kinematic viscosity of the electrolyte.

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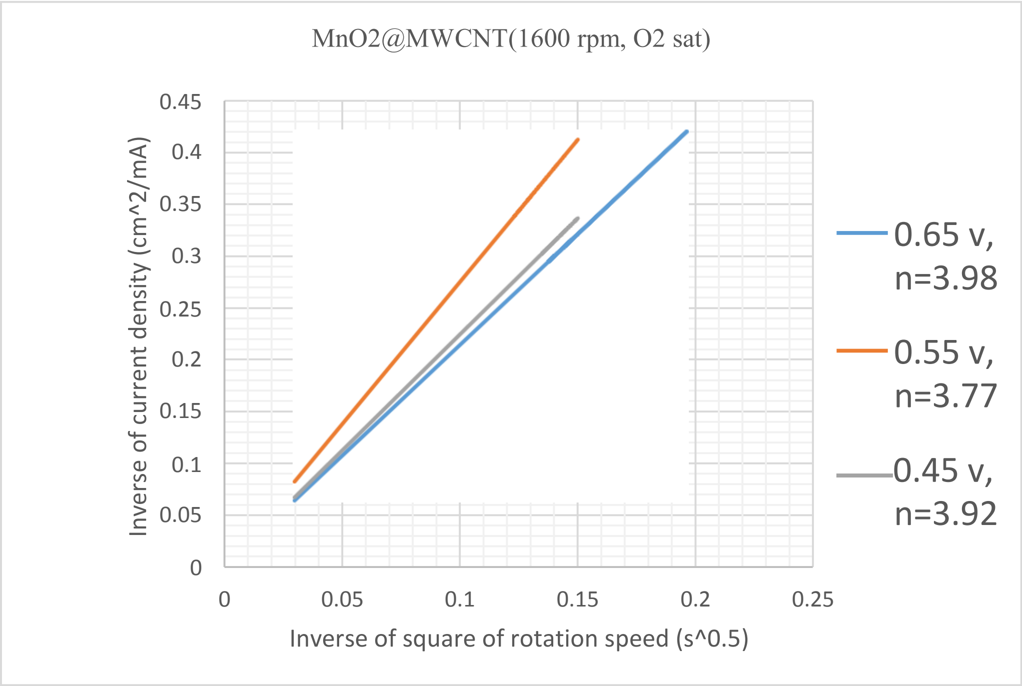

Figure 4. K-L for various potential values.

In 0.1 M KOH solution the values of the above constants are.

Table 1. Values of various constants at 0.1M KOH

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s.no	Constants	Values
1	C_0	1.2*10-6 mol/cm^3
2	D_0	1.9*10-6 cm^2/s
3	V	0.01 cm^2/s
4	F	96485 C/mol

While B is the slope of the line in K-L plot (fig.4) [18]

These values are plugged into the equation 3 to calculate “n”. The slope B is determined at various potential values using Excel to calculate the electron transfer number “n” which comes out to be very close to 4.0 the small deviation might be due to error in calculation.

This implies that complete oxidation pathway is used by Oxygen ORR to reduce to water. The various steps that happens during the ORR are presented

O_2 sol ---------------------->O_2 ads

O_2 ads -----------------> e^- + [O_2 ads]

[O_2 ads]$^-$ + H_2O --------> HO_2+ OH^-

HO_2 ads + e^- ------------>HO_2^-

HO^- ---------------------->HO_2^-

3.2. Conclusion

MnO2-MWCNT owing to its high current density, Onset potential, lower over-potential, cheap and ease of preparation could be a suitable alternative to the conventional Pt/C catalyst. MnO2 nano-particles were supported successfully onto the surface of MWCNT. MnO2-MWCNT shows excellent ORR properties in basic media. The comparison is drawn with commercial Pt/C catalyst.

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HIGH FREQUENCY H-BRIDGE TOPOLOGY FOR WIRELESS CHARGING OF MULTIPLE ELECTRONIC SMART PHONES BASED ON INDUCTIVE POWER TRANSFER TECHNOLOGY

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ABSTRACT

Wireless power transfer technology is a challenging, and interdisciplinary research area. It can make astonishing change in the field of electrical engineering. It can be used for charging batteries of single device as well as multiple electronic devices wirelessly, which cannot be connected physically. Based on the concept of high frequency H-bridge inverter topology, the prototype is developed in a wireless charging smart table for charging smart phones. The proposed prototype is implemented by using high frequency 0.1-0.4MHz H-Bridge topology to mitigate the transmitting coil size up to 15cm & receiving coil size up to 3cm. It can charge 4 electronic smart phones simultaneously with ameliorate efficiency of 89.34%. Numerical results are matched with simulation results which have been carried out in MATLAB/Simulink environment. This paper entrust out the numerical, simulation and hardware results for multiple wireless charging with maximum efficiency, their advantages and applications.

Index Terms— Wireless power transfer; contactless energy transfer; inductive power transfer, multiple wireless charging devices.

1. INTRODUCTION

The wireless power transfer technology is the transmission of electrical energy from a power source to a load without using wires/cables. It is a wide and interdisciplinary research area. This innovative technology is capable to charge mobile devices wirelessly and is becoming a popular research field due to the rising interest in charging electronic devices wirelessly such as Laptops, Tablets and Smart Phones. Elimination of cables and connectors increase reliability and maintenance-free operation of such as critical system as in biomedical and multi sensor. The wireless power transfer can be entrust out by means of acoustic techniques, capacitive, microwave, light/laser, inductive power transfer and wireless power transfer strong coupled magnetically resonance. From the above technologies it can be concluded [1], that acoustic techniques has very short distance. Similarly, Capacitive techniques has low efficiency as well as short distance up to 1mm and Microwave, light techniques has reduced efficiency up to 25%. The latest usable inductive contactless energy transfer and wireless power transfer strong coupled magnetically resonance have importance to focus on these because of high efficiency. By looking to the low maintenance cost, higher efficiency and maximum output power (MW), the inductive contactless energy transfer is a universal solution for wireless power transfer. [1]- [3].

Inductive coupling is an old and well-understood method of wireless power transfer. The source drives a primary coil, producing a sinusoidal varying magnetic field, which induces a voltage across the terminals of a secondary coil, and thus transfers power to a load. This mechanism is liable for power transfer in a transformer, where the magnetic field is typically confined to a high permeability core, also functions when the region between the primary and secondary coils is simply air. Inductive coupling without high permeability cores is used.

The latest research on inductive power transfer system for electronic devices is to enhance its efficiency, distance and frequency. The latest work done on inductive power transfer system for mobile phones are as follows, an inductive power transfer system with an air gap of 3.8cm and coil length 30cm were designed with frequency 8.3 MHz with low efficiency under 10% [2]. For maximum power transfer, impedance matching technique is used. Another inductive power transfer system was designed with 113cm transmission coil size and 30cm receiver coil size with 6.5MHZ frequency. For the same inductive power transfer system efficiency was obtained 80%, but coils size are very large in presence of high frequency [14]. For frequency 0.14MHz, another inductive power transfer system was designed with 35cm transmitting coil size and 30cm receiving coil size. The efficiency obtained was 57%, which lower as compare to other wireless systems [13]. For an efficient system reducing the coil size is essential. Reduction of coil size can be achieved by using higher frequency.

The proposed inductive power transfer research project work is tested for high frequency 0.1-0.4MHz to reduce Transmitting coil size up to 15cm and receiving coil size up to 3cm. Also the enhanced efficiency obtained is 85-89.34% to charge four smart phones simultaneously. The proposed inductive power transfer smart table can be extended to charge multiple devices

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wirelessly of different power requirements for example, Laptops, iPads, Mobile phones biomedical sensitive equipment and multi sensors. The configuration and analysis are presented in Section 2 along with simulation results which are carried out using MATLAB/Simulink environment while section 3 elaborates measurements results. Section 4 describe a brief conclusion about results obtained.

2. PROPOSED MULTI DEVICE IPT SYSTEM

2.1. Inductive Power Transfer Theory

In inductive power transfer, it does not certainly guarantee that maximum power transferred when maximum efficiency occurs. Also maximum power transferred only when resonance occur between transmitting and receiving coil. A magnetically-coupled series-resonant circuit with a deriving source of frequency is shown in Fig. 1. The resonance frequency is represented of Tx by ω_{tx} and for Rx coil by $\omega_{rx.}$

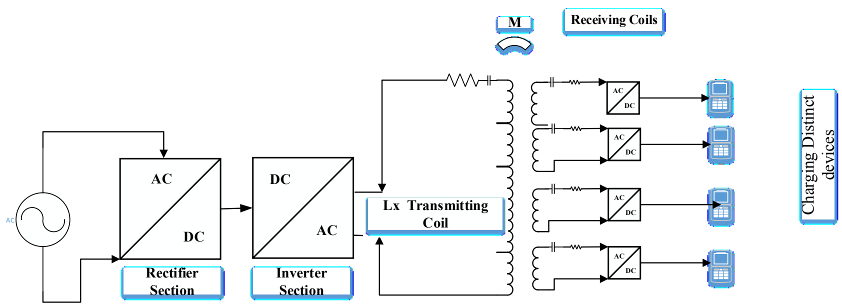

Fig.1 proposed multiple wirelesses charging inductive power transfer.

$$frx = \frac{1}{2\pi\sqrt{LrxC2}} \tag{1}$$

$$\mathrm{ftx} = \frac{1}{2\pi\sqrt{\mathrm{LtxC1}}} \tag{2}$$

$$P_{out=}V_1 I_1 K^2 Q_2 \tag{3}$$

Fig. 1 shows the configuration of the proposed inductive power transfer system for multiple devices/receivers. It consists of one transmitting and four devices. The transmitting coil is powered by a voltage source, and each receiver includes an Rx coil. The proposed IPT system can transfer power to multiple devices by using one Tx coil.

$$\eta = \frac{R_L\left|{}^{I_2}/_{I_1}\right|^2}{(Rs+Rsp)+(R_L+Rrp)\left|I_{2/I_1}\right|^2} \tag{4}$$

Where, I_1 is the Coil 1 phasor RMS Current, I_2 is the Coil 2 phasor RMS Current $R_L|I2^2|$ is the Power consumed in Load, $R_s|I1^2|$ is the power consumed in transmitting resistance, Rsp is the Parasitic resistance of Tx coil & Rrp is the Parasitic resistance of Rx coil. From equation (3), we can conclude that maximum efficiency will occur when ration of current is maximum. It is aimed to find the frequency conditions that maximize power transfer efficiency and capability under the given resistance or parasitic values. Using Kirchhoff's voltage law (KVL), to find$|I_2/I_1$.

$$\left(\frac{R_{TX}}{jwL_{TX}} + 1 - w_{TX}^2\right)I_1 + kI_2\sqrt{\frac{L_{RX}}{L_{TX}}} = \frac{V_S}{jwL_{TX}} \tag{5}$$

$$KI_1\sqrt{\frac{L_{TX}}{L_{RX}}} + \left(\frac{R_{RX}}{JWL_{RX}} + 1 - \frac{w_{RX}^2}{w^2}\right)I_{2=0} \tag{6}$$

Vs represent the phasor rms voltage of ac source. The mutual inductance is shown by M. Also $R_{TX} = R_S + Rsp$, and $R_{RX} = R_L + Rrp$. The ratio of I2/I1 can be found [6]. By using coupled resonators of high Q's, the energies which are not coupled to R_{Xs} are stored in the T_{Xs} without dissipation. Therefore, even with a very low coupling between TX and RX, highly efficient transmission is possible. Condition (4) is equivalent to maximizing the real part and canceling the imaginary part of reflected impedance. It can be seen by examining the total output impedance seen by the ac source. Also we can find maximum efficiency in terms of combined quality factor of inductors [1].

$$\eta = k^2Q^2/(1+\sqrt{1+k^2Q^2}\,)^2 \tag{7}$$

Q represents the combined quality factor of transmitting and receiving inductors. In case of two inductors, it can be defined as

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$$Q = \sqrt{(Q_1 Q_2)} \tag{8}$$

The proposed Tx coil consists of a conventional multi loop coil that has an N turn with the maximum radius and having radii of r1, r2, r3, r4 and so on.

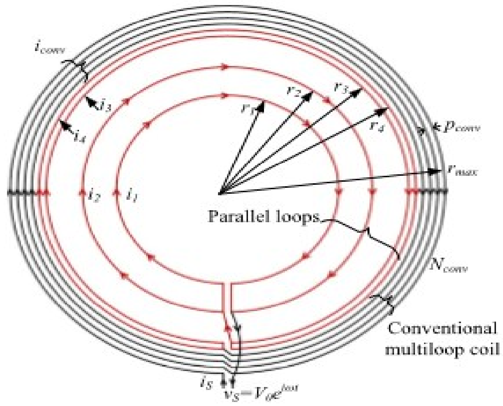

Fig 2 Spiral transmitting coil using multi turns

2.2. Simulation Results with One Transmitting Coil and Multiple Receiving Coils

The simulation of the proposed prototype is carried out through MATLAB/Simulink environment. A bridge rectifier has been used as a first part of transmitting section to rectify the AC voltage. The same output rectified signal is feed into a high frequency signal to change frequency up to MHz limit. MOSFTES are used for creating high frequency switching in inversion section. The inverted high frequency signal is passed through a coil to create a magnetic field. This magnetic field is linked with a secondary coil through mutual induction. Power is transferred wirelessly by means of mutual induction. Ability of power transferring is inversely related with air gap between primary and secondary coils. Efficient is mostly depending on quality factor of coils. Different software's have been used to verify the design before actual testing of transmitting circuit. Original specifications from our design proposal are described as power supply is taking from the AC supply at 220V and 50Hz. The simulation results in tabular form along with output power and efficiency are shown below in Table I.

Table .I Simulation results

k	L1(uH)	L2(uH)	F(MHz)	R1	R2	Q1	Q2	Q	M	$P_{out\ (W)}$	ŋ
0.1	100	100	0.128	2.1	2	38.278	20.096	27.735	7.1E-06	0.23	49.34
0.2	200	200	0.128	2.1	2	38.278	20.096	27.735	1.4E-05	0.94	69.86
0.3	300	300	0.128	2.1	2	38.278	20.096	27.735	2.1E-05	2.12	78.67
0.4	400	400	0.128	2.1	2	38.278	20.096	27.735	2.8E-05	3.77	83.52
0.5	500	500	0.128	2.1	2	38.278	20.096	27.735	3.5E-05	5.80	86.58
0.1	100	100	0.212	2.1	2	63.398	33.284	45.936	7.1E-06	0.39	64.92
0.2	200	200	0.212	2.1	2	63.398	33.284	45.936	1.4E-05	1.56	80.47
0.3	300	300	0.212	2.1	2	63.398	33.284	45.936	2.1E-05	3.51	86.50
0.4	400	400	0.212	2.1	2	63.398	33.284	45.936	2.8E-05	6.24	89.69

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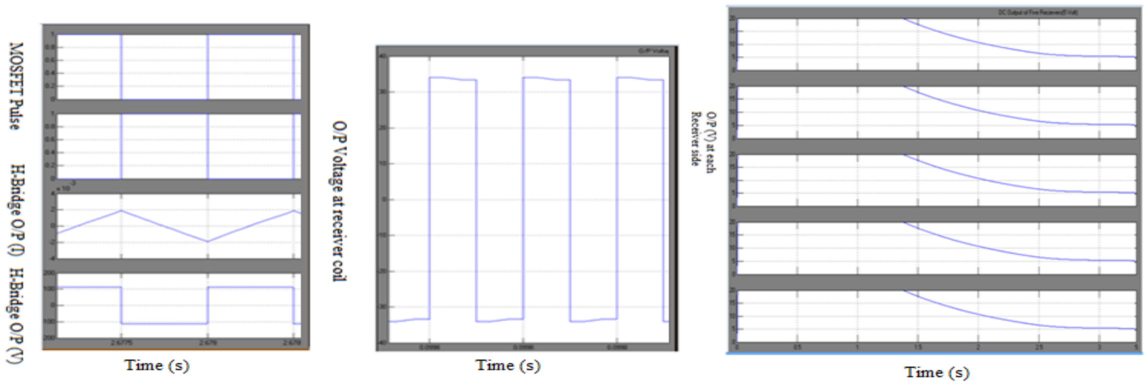

Fig. 3 Output Voltage at each receiver coil. Rectified output voltage (5V) at each receiver

3. MEASUREMENTS SET UP

Hardware setup is shown below. The transmitting circuit is placed under the table under as shown in below figure 4. The magnetic field is generated in transmitting coil, the flux lines is coming out of table. When receiver coil are placed table under the flux lines. An emf is generated in it and a current is start to flowing in it. This generated emf is further rectified and used for charging of electronics devices. Maximum distance between Tx and Rx coil is achieved up to 3.5cm.

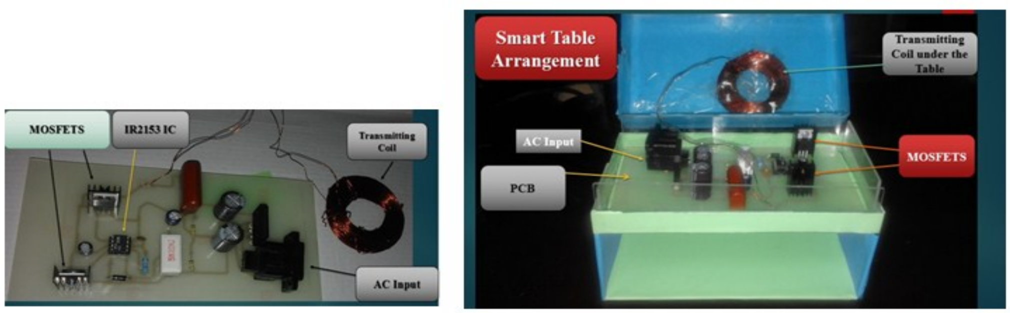

Fig 4 Hardware impelementation of transmitting circuit with Smart Table arrangements.

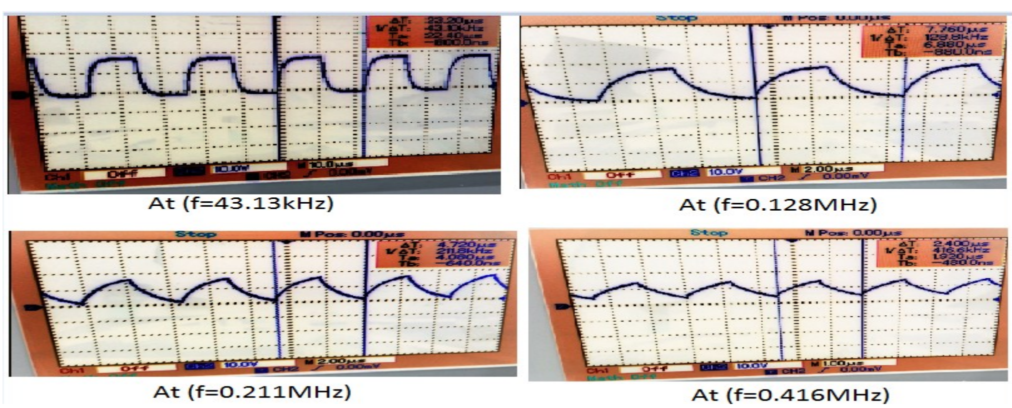

Fig 5 Output voltage at transmitting coil at different frequencies

4. CONCLUSION

The proposed wireless power transmission through inductive coupling worked on the principal of mutual inductance. The system was analyzed theoretical for higher efficiency 92.12% and smaller coil size. The same theoretically model was implemented in MATLAB/Simulink environment. In simulation model efficiency was obtained 89.34% which is nearly equal to the theoretical results. For hardware implementation, the Simulink model was implemented in Proteus for printed circuit

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board design. Hardware results obtained from PCB design are efficiency 88.7% transmitting coil size is reduced to 15 cm and receiver coil size is reduced to 3.1 cm.

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DESIGN AND FABRICATION OF SUPER-HYDROPHILIC, ANTIFOGGING AND ANTIREFLECTIVE NANOPARTICLES COATINGS FOR SOLAR PV APPLICATION

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ABSTRACT

Highly transparent, antifogging, super-hydrophilic and antireflective double layer coating of porous silica nanoparticles were fabricated using an aerosol spray deposition system introducing silane and air as precursors. By introducing additional amounts of helium, the pressure difference between the plasma chamber and the substrate was tuned, resulting in good control over layer thicknesses and refractive indices. Due to the porous nature and graded index of these films, transmittance of a glass substrate was increased from 91% to 99.2% when coated on both sides. Surface topology of these films were studied through AFM and it was indicated that excellent antifogging and super-hydrophilic nature are due to the roughness and nano-porosity in the film. Moreover, the super-hydrophilic nature endows these coatings with self-cleaning properties, which can increase the efficiency of solar modules

Keywords: Super-hydrophilic, Nano-porous, Silica nanoparticles, Thin films, Antireflective coatings, Aerosol deposition

1. INTRODUCTION

Photovoltaic power is slated to surpass fossil fuels in new energy deployment in the year 2020. The overwhelming popularity of photovoltaic power can be aggregated to the continuous improvement in efficiency, making it more and more feasible. One major challenge in photovoltaics is the reflection losses ranging 8-9% from the front glass surface of solar module caused by the disparity in the refractive index between air and glass, 1.0 and 1.52 respectively (Zhang, 2012). The application of antireflection coatings (ARC) to the front glass surface has been an effective measure in the mitigation of these losses, leading to improved efficiency of solar cells (Faustini, 2010). With such a margin for improvement in optical properties, research on ARC has drawn a lot of interest focused mainly on minimizing losses in sunlight entrapment. The underlying principle involves the destructive interference of light rays from the succeeding thin film interfaces at air-thin film and thin film-substrate junction (Chen, 2011), governed by the following two conditions;

Firstly, the thin film should follow the Fresnel equation (Macleod, 2011), $n_c = (n_a n_s)^{1/2}$ where n_c, n_a, and n_s represent the thin film, air and substrate refractive indices respectively. For glass (n=1.5) the equation dictates a thin film refractive index of 1.23 which is not possible with the conventional materials, the closest being magnesium fluoride (n=1.38) in the visible spectrum range (Vincent, 2007). To overcome this problem, porous materials, for instance, silica, with air molecules entrapped can be used. The low cost of silica and its ability to withstand severe environment along with the allowance of refractive index tuning to 1.23 makes it a viable candidate for thin films in PV applications (Martinu, 2000). Secondly the thin film coatings should have a thickness of $\pi/4$, π being the wavelength of light incident on the film (Budunoglu, 2012).

In addition to the optical properties of thin films, recent research has also been focused on diversification of the functionalities of the ARCs, branching their functions out for self-cleaning and antifogging purposes. These functions of thin films find vast applications in optical and optoelectronic materials aimed at enhancing the transmittance of light in solar cells, lenses, and periscopes (Zhang, 2010). To achieve antifogging and self-cleaning features the surface is made super-hydrophilic which turns the incident water droplets into thin layer, thus mitigating the light scattering from big droplets (Dou, 2011). The

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surfaces can be made super hydrophilic in two ways; by use of photocatalytic materials (e-g TiO2), and texturing the surface. The use of photocatalytic materials creates photo-induct effect which turns the material super hydrophilic upon subjection to light but this property is lost in dark conditions (Eshaghi, 2013). In the texturing approach, the material surface is made rough, r patterned or porous (Cebeci, 200). The TiO2 deposition method effectiveness is limited by the volume percentage, which should be kept on the lower side for antireflection property, while for the self-cleaning capability of the film are hindered by such a low volume percentage (Zhang, 2006). Several efforts have been made to strike an optimum balance between the antifogging and antireflective properties of thin films. In one such attempt multifunctional coatings using high index photocatalytic layers were shown to provide good self-cleaning properties but the optical transmittance was lowered (Prado, 2010). Texturing of borofloat glass with various deposition and etching processes showed the highest transmission for nanostructure of 200 nm depth at 94% while all other iterations gave transmittance below 93% (Verma, 2011). The most promising of these efforts showed silica nanoparticles deposition utilizing the sol-gel process achieving transmittance of 96.3% with good self-cleaning properties (Lu, 2011). Silica nanoparticles have also been used in conjunction with TiO2 nanoparticles, controlling the TiO2 particle size by TEOS/TIPT molar ratio. The SiO2-TiO2 nanoparticles were in raspberry like shape, fabricated using one-pot method and showed good self-cleaning and antireflective properties (Li, 2012). Mesoporous silica nanoparticles with binder addition has been found to give a refractive index of 1.28 at 112 nm thickness. These nanoparticles increased the transmittance to 99.5% at 540 nm thickness but due to high density the surface could not be textured and self-cleaning effect was minimal (Moghal, 2012). Dip coating colloid solution of silica nanoparticles using layer-by-layer (LBL) method, with addition of polyelectrolyte for adhesion enhancement, increases the anti-reflectivity of glass by 3.2% (Min, 2008).

Thus far, the research efforts to enhance the antireflective properties of thin films in conjunction with achieving antifogging and self-cleaning characteristics have not been fruitful. In this study, we report the use of aerosol deposition system for design and fabrication of multifunctional porous silica nanoparticles coatings. This is a custom-built tool (Fig. 1) whose use of a roughing pump and a simple plasma geometry could lead to low-cost nanoparticle depositions. A double layer coating was designed through Module ray tracer software and then fabricated using silane, helium and oxygen gas as gaseous precursors on a glass substrate. These coatings were super-hydrophilic, antifogging and highly transparent. Water contact angle of these coatings was found to be less than 5^{o}. The use of gaseous precursors made the process less time consuming as well as parameters like thickness and refractive index of the materials were controlled very easily compared to sol-gel methods, dip coating or spin coating.

2. MATERIALS AND METHODS

2.1 Fabrication

The double layer antireflective coatings were deposited on silicon substrates as well as borosilicate glass slides using an aerosol impaction deposition assembly (AIDA) (Boccard, 2016) as shown in Fig. 1. Silicon substrates and glass slides were cleaned with an ethanol solution, rinsed with deionized water several time and finally dried with nitrogen gas. The cleaned substrates were placed in the deposition chamber run at rough vacuum. Particles were synthesized by igniting a plasma between two parallel, rectangular electrodes and then accelerated through a slit-shaped nozzle. This was done using a 13.56 MHz RF power supply with a power density of 0.98W/cm^2 and slit width of 1 mm. Precursors of SiH_4 and O_2 were introduced using a 5% SiH_4

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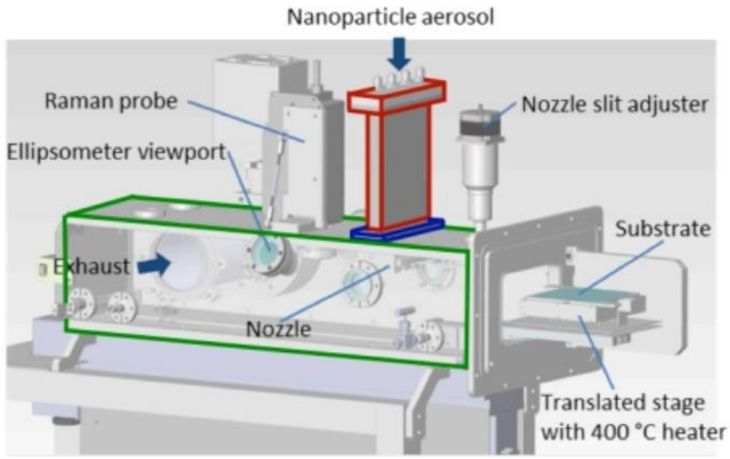

Fig 1. Aerosol spray deposition system known as " Deppy"

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in He tank and ambient air, respectively. Silane gas, air and helium gas flow rates for top layer was 200 standard cubic centimetre per minute (sccm), 1000 sccm and 5000 sccm respectively. For bottom layer it was 300 sccm, 1500 sccm and 4000 sccm respectively. Pressure at reaction chamber and deposition chamber was in the range of 6.4-10 torr and 500-1200 mtorr respectively. Additional Helium was then introduced to control the impaction velocity and thus, porosity of the deposited films. For the anti-reflection coatings used in this paper, a refractive index at 600nm of 1.15, and 1.30 with porosities of ~60% and 35% respectively, was targeted (Fig 2.).

Film thickness, porosity, and refractive index were measured using spectroscopic ellipsometer (M-2000) on polished silicon wafers. A Cauchy model was used to extract film thickness and refractive index, while a Bruggeman effective-medium-approximation (Khardani, 2009) was used to determine porosity. Top ARC layer was controlled to have thickness of 130 nm and refractive index of value 1.15 while for bottom layer, thickness of 112 nm and refractive index of 1.30 was achieved. Same double layer deposition was carried out on the other side of glass substrates too as shown in Fig. 2.

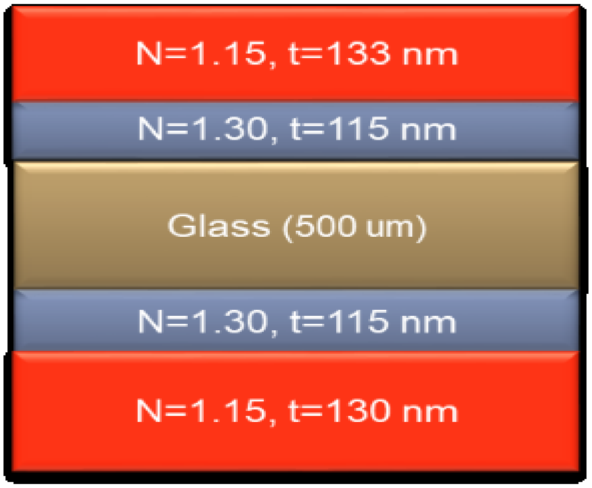

Fig.2 Thin film stack of silica nanoparticles on Glass substrate on both side modelled through MRT software

2.2 Characterization

All analysis was performed using different characterization tools during the coating process and after the coating as well. Transmission spectra was recorded using UV-NIR spectrophotometer (Lambda 950, Perkin-Elmer, USA) in range of 250-700 nm. The thickness and refractive indices of the coatings were estimated through ellipsometer (M-2000, USA) using Cauchy model.

Surface topology were examined by atomic force microscope in tapping mode (Multimode, Digital Instruments, USA) using a silicon tip with a nominal radius of 10 nm. Frequency of scanning probe image was 512 Hz and scanning size was selected 2μ by 2 μ. Three position were tested to get average value.

Electron micrographs were taken by Field Emission Scanning electron microscope (FE-SEM, USA) of coatings that were deposited on polished silicon wafers. Samples with glass as substrate were sputtered with a 5nm layer of gold to avoid charging of the substrate.

The self-cleaning properties were determined by measuring water contact angle goniometer (OCA 15, Data Physics Instruments GmbH, USA). A 4.2 μl drop of water was brought in contact with the surface of the substrate, while recording the video at the rate of 30 frames per second. The video was recorded for 5 sec and was then analyzed for one complete second. The water contact angle was measured by drawing a tangent at the drop-air interface at the touching edge of coated glass. The Contact angle was estimated at 0.5s from the instant drop. Antifogging behaviour was measured by heating the water in a beaker up to its boiling point and placing the uncoated and coated slide over it. After a minute of exposure to the rising vapours, both the slides were placed on a printed page and images were taken with a digital camera.

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3. RESULTS AND DISCUSSIONS

3.1 Anti-reflectivity

The silica nanoparticles double layer coatings were deposited on both side of glass substrate as well as on planer silicon cell. In Fig. 3a, left side graph shows the simulation result, which was taken in module ray tracer software package before experimental, work. and Fig. 3b shows transmittance result of uncoated glass slide, single ARC and double ARC coating on borosilicate glass side which was taken on UV-VIS spectrophotometer. Average transmittance result in the range of 300-1400 nm for single layer is about 96%, as it covers single wavelength not the broad range. At 600 nm the transmittance is 99.5% but at higher wavelengths, the peak comes down to 95% which is much better than uncoated glass (91%). For double layer coating, two peaks in the transmittance curve of 99.2% at 400 nm and 98.8% at 900 nm were noted, as average transmittance is greater than 98% which is much better than single layer coating. In fact, from the comparison of both figures, it is also clear that the proposed designed is good agreement of designed work results through software (Theoretical) with that of experimental work. The transmission in some regions in the experimental curve is lower than theoretical work because in the theoretical design, the film refractive indices were assumed to be constant in all wavelength and value was selected at 600 nm in the entire visible ranges. However, with change in wavelength, the refractive index changes and that leads to lower the transmittance in some part of the experimental transmission curve.

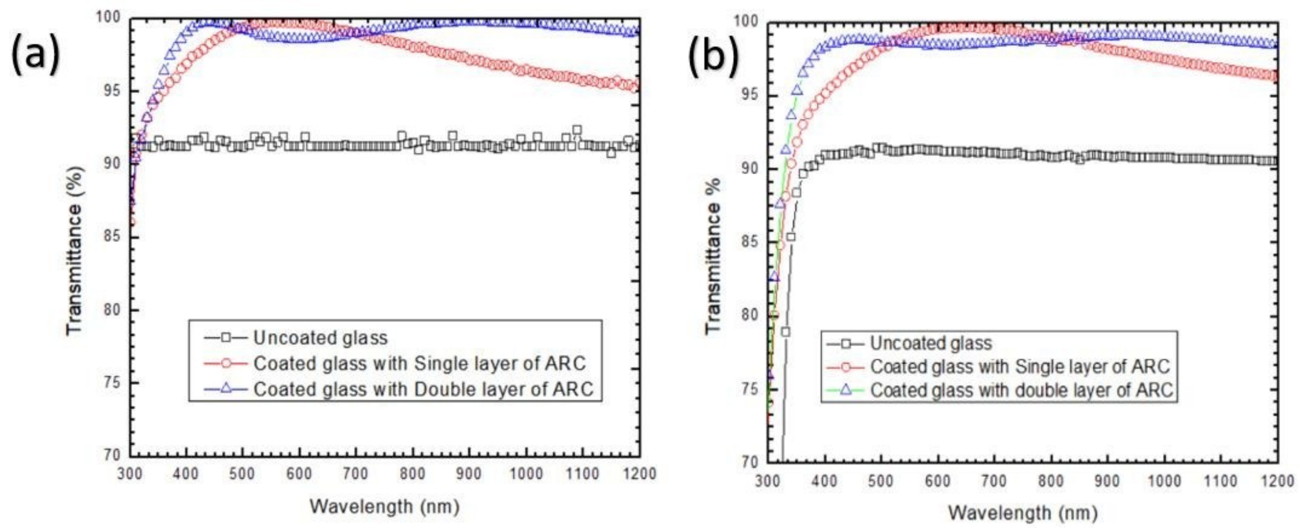

Fig 3. (a) Transmittance spectra of simulation work (b) Transmittance Spectra of Experimental work.

3.2 Morphology of the Coatings

The thickness of the silica nanoparticle coatings was evaluated using an ellipsometer and verified by cross-sectional images obtained from scanning electron microscopy (SEM, FEI, USA) as shown in fig 3b. The topology and roughness (rms) value of the coating was determined by the atomic force microscopy (tapping mode AFM, Multimode, Digital Instruments, USA), using a silicon tip with a nominal radius of 10 nm as shown in fig 3a. Surface morphology of the coatings was studied through nanoscope software images and it was indicated that coatings are highly porous indicating roughness of root mean square value

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to 28.7 nm. Due to high roughness and porosity of these films, water contact angle of uncoated glass slide decreases to 3 degrees from 45 degrees which indicates its super-hydrophilic nature.

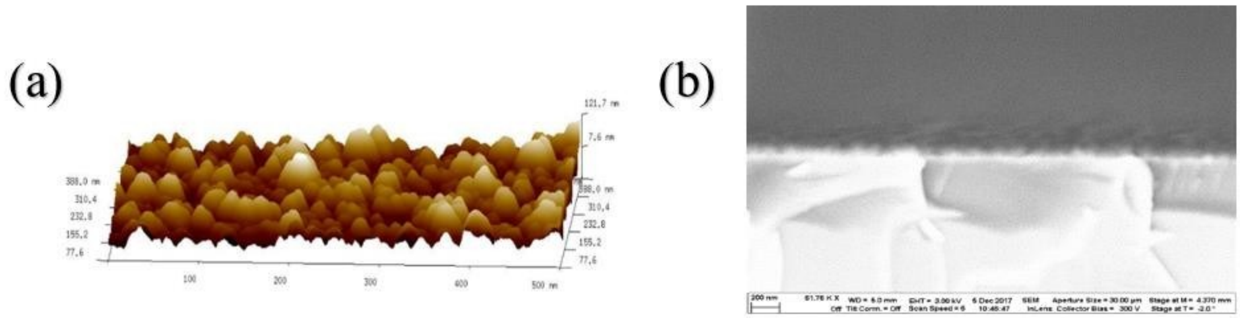

Fig 4. (a) AFM image of surface morphology of DL coating (b) SEM cross section image of Double layer coating.

3.3 Super-hydrophilicity and water contact angle

Water contact angle is the measure of wettability of a surface that accounts for self-cleaning effect if it has super-wetting ability. Normal glass has water angle of 40-45 as shown in fig. 4b. A drop of water of volume about 4.2 ml was dropped from a slit of Goniometer under the presence of a video camera which captured its water contact angle in the span of two second time. The water contact angle of coated glass was also measured through same way, however the coated glass showed superb super hydrophilic properties compared to uncoated glass, in fact it makes the glass antifogging too because of very low contact angle. Super-hydrophilicity is define as a surface having WCA less than 10^{o}. Coating the glass slide with nano-porous silica made it super-hydrophilic, decreasing its water contact angle to 5 as shown in graph 5a. According to Wenzel theory, roughness and nano-porousity of a film can increase hydrophilicity, which results in self-cleaning mechanism of surfaces (Du, 2010). Water droplets on such surface spreads via winkling effect through nanopores as shown in fig. 5c.

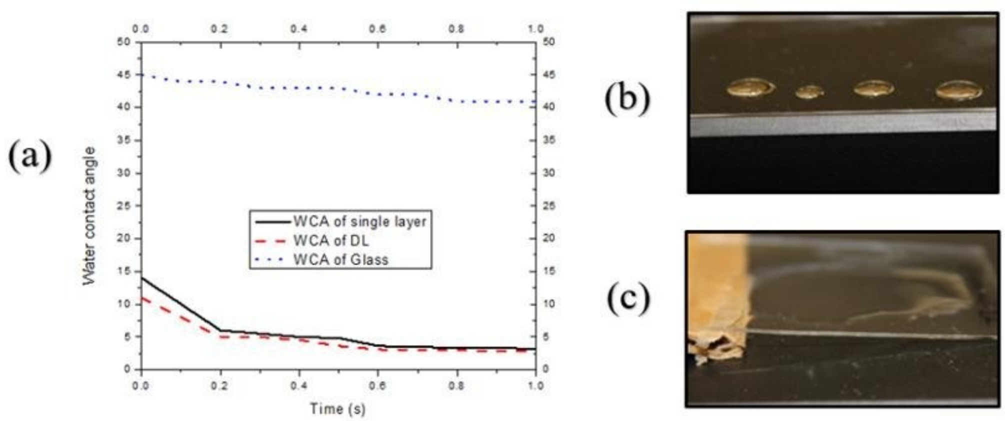

Fig 5. (a) Graph of water contact angle vs time (b) A Drop of water (4.2 ml) on uncoated glass (no-spreading) (c) A Drop of water (4.2 ml) on ARC coated glass (complete spreading)

4. CONCLUSION

In summary, we optimized porous silica nano particulate films, tuning their porosities by controlling the pressure drop across a slit-shaped nozzle. At present, the glass slide coated with a double layer of silica nanoparticles increases the transmittance

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(98.2% at the wavelength of 450 nm and 900 nm) to an average increase value of 98% which causes a 7.0% increase of mean transmittance in the wavelength range of 300-1200 nm and is super hydrophilic (WCAs after 0.5 s of spreading: 4.2) with anti-fogging behaviour This double layer broadband AR coating with excellent transmittance and super hydrophilic nature (improved self-cleaning property) has a wide range of applications as an optical coating, be it for windows, glasses, or solar cells..

5. ACKNOWLEDGEMENT

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MODELING MEDIUM AND LONG TERM ELECTRICAL ENERGY SECTOR DEMAND AND SUPPLIES OF KHYBER PAKHTUNKHWA

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ABSTARCT

Electrical energy is the backbone of socio-economic development of a country. Pakistan, as a federating unit, has given the right of energy generation at provincial scale in 18th amendment of constitution. Though rich in energy resources, Khyber Pakhtunkhwa is lagging far behind the international standards of energy access. The province contributes 50% of the national crude oil production that is 50,000 Barrels per day, 400 MMCFD of gas production and 17866 GWh per annum hydel electricity. Whereas demand for Oil is 21,704 Barrels of Oil per day, gas 204 MMCFD and electricity 11599 GWh annually. With population of 30.52 million, electrical energy consumption is 382.19kWh/person/year which is nine times less than international standard. Reliable, affordable and sustainable energy provision is indispensible in materializing a prosperous future for the province. The paper has undertaken a detailed analysis of province energy resources, electricity generation, and transmission and distribution infrastructure along with historical consumptions trends of electricity. Using, Long range energy alternative planning modeling tool shortly called as LEAP, electricity supplies and demands for upcoming two decades was projected based on historical data and growth rates of energy system, demographic, economic conditions and energy transitions. The business as usual scenario reveals that total electrical energy demand will increase by about four folds from 11599 GWh in 2015 to 33028.4 GWh by 2035 with domestic, industrial and commercial as main contributors.

1. INTRODUCTION

Energy undisputedly is the lifeline of socio-economic development of an economy. Pakistan as a developing country, with time will go up of energy ladder, fostering economic growth. However, the availability of energy at affordable prices with secure supply chain is and will indispensible for sustainable development. Khyber Pakhtunkhwa, with area of 74521Km Square and population of 30.52 million is located 34.9526 ◦N and longitude 72.3311◦E is third most populated province of Pakistan. With per capita income of US $ 5580, the gross domestic project of province accounts US $ 85 Billion which is 8% of Pakistan GDP (Finance Division , 2017). The province contributes 50% of the national crude oil production that is 50,000 Barrels per day, 400 MMCFD of gas production and 17866 GWh per annum hydel electricity. Whereas demand for Oil is 21,704 Barrels of Oil per day, gas 204 MMCFD and electricity 11599 GWh annually. In terms of supplies, nearly 70% of Pakistan hydel potential lies in the province (M. Mujahid Rafiquea, 2017) and (F. U. Qureshi, 2014).

Pakistan energy sector has historically seen significant changes, with 1994 policy of independent power producers followed by regulatory restructuring and unbundling. With the 2007 unbundling of Water and Power development authority, nine different distribution companies were created (ZAINAB KHALID MUHAMMAD, 2016). Peshawar Electric Supply Company (PESCO) owns the distribution and transmission network and provides electricity to 2.6 million consumers across Khyber Pakhtunkhwa (PESCO) whereas Pakhtunkhwa Energy Development Organization (PEDO) is responsible for development of electricity generating infrastructure. Energy is highly interwoven in human society and modern development. Forecasting the demand and supplies of future, is crucial for energy security, planning, technological adoption

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and climatic mitigation. A diverse set of methodologies are used for covering the complexities of energy system and accurately explores future energy demands. From Liner regression methods to complex models such as MArkal , TIMES and WASP are used (Mohammad Reza, 2009).

Long Range Alternative Energy planning shortly LEAP is a bottom up accounting model developed by stock Holman Environment. It is capable to track energy consumption, production and resource extraction in all sectors of economy. It is well known for greenhouse gas emissions analysis along with regional and local air pollutant tracking. LEAP primary operation mode is driven by in-built accounting for non-controversial energy and emissions whereas as in secondary operation mode, user defined data and relations are used for timely variable data (Heap, 2008). The model has been used for energy demands projection, transportation sector and greenhouse gases. (Rajesh V. Kale, 2014) Have projected electricity demand for Maharashtra province and generated scenarios for energy conservation and renewable energy penetration using LEAP (H. Yophy et al, , 2011). Has studied energy demands and emissions followed by assessments of energy efficiency and nuclear power plants retirement on Taiwan national demand pattern. (M. McPherson, 2014) analyzed energy sector of Panama via scenario tools for global warming threats and system cost. Leap model has the advantage of less data requirements, turning it suitable model for developing countries. Transport sector emission and energy demands can be projected with leap. (A. Sadri et al, 2014) Has used Leap for transport sector energy and emission in long and medium terms with limited data availability. (N.V. Emodi et al., 2017) analyzed the energy system for low carbon policy options in Nigeria and concluded that low carbon policy option will positively decrease the energy demand. Similarly sectorial analysis has been conducted by many authors using leap. (Md. Ahsan Habib et al., 2014) is exploring the option of utilizing domestic coal and renewable energies as alternatives for imported oil. It concludes that long terms emission can be significantly reduced by nullifying the oil and coal imports and enhancing renewable and domestic coal utilization. (Peng Wang et al., 2017) . In Pakistan, Leap has been used by for long terms forecasting of electricity sectors and future perspective of renewable energies (Usman, 2015).

This paper has analyzed the electricity sector in Khyber Pakhtunkhwa province of Pakistan. Though electricity is provided by the national grids to province, but the paper fundamentally works on the provincial demand and supplies. The first portion illustrates the demand side of electricity in the province and previous five year data has been presented. The transmission and distribution infrastructure strengths and weakness have been pointed along with hydel power plants operational in Khyber Pakhtunkhwa. The demand for upcoming twenty years has been projected using Long range alternative planning (Heaps, 2016). Business as usual scenario has been developed to evaluate the electricity demand and supplies trends with the exiting electricity and economy model.

2. OVERVIEW OF ENERGY SECTOR

2.1 Electricity demand sector

In Pakistan, electricity demand sector is classified into seven sub-categories as domestic, commercial, Industrial, agricultural, lighting, bulk supplies and others. In Khyber Pakhtunkhwa, number wise domestic consumers' makes the bulk about 88%, followed by commercial making 10% in 2015 as shown in Table no 1. In 2015, domestic sector was the largest consumer with consumption 4297 GWh whereas commercial sector consumes 654 GWh, industrial sector consumes 2020 GWh, agriculture sector consumes 93 GWh and a bulk supply consumes 520 GWh as shown in Table no 2. The total consumption grows from 6976 GWh in 2011 to 7471GWh in 2015 by 7.09 per cent whereas the total number of consumers grows from 2598564 in 2011 to 2956567 in 2015 by 13.77 per cent.

Table 1 Strength of Consumers across various economic groups (NEPRA, 2015)

Year	Domestic	Commercial	Industrial	Agricultural	Public Lighting	Bulk Supplies	Others	Total
2011	2281849	264582	23460	26911	843	873	46	2598564
2012	2361837	271688	28156	23190	972	875	46	2686764
2013	2447438	279479	28965	23228	1013	877	46	2781046
2014	2523470	289155	29760	23441	1028	878	46	2867778
2015	2602181	298739	30344	23328	1040	888	47	2956567

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Table 2 Sectorial Energy consumption (GWh) in KP (NEPRA, 2015)

Year	Domestic	Commercial	Industrial	Agriculture	Public Lighting	Bulk Supplies	Others	Total
2011	4041	527	1562	291	21	533	2	6976
2012	4048	553	1777	142	21	518	2	7062
2013	4048	550	1889	111	20	541	2	7162
2014	4205	622	1989	100	14	539	3	7471
2015	4297	654	2020	93	14	520	2	7599

2.2 Electricity transmission and distribution infrastructure

Khyber Pakhtunkhwa civil districts has been divided into eight circles of Bannu, Hazara 1, Hazara 2, Khyber, Mardan, Peshawar, Swabi and swat covering a total of 1,204,621 hectares of land. In base year of 2015, the electricity transmission sector is composed of 2164 Km of 132 KV lines, 841Km of 66KV lines, 171Km of 33KV lines and 33337km of 11kv lines. Total High tension lines accounts up to 36513km in length whereas total low tension lines are 43957km.The total numbers of power transformers in distribution network is 212, among which 176 are 132Kv, 29 are 66kv and 7 are 33kv. These power transformers have total capacity of 4866.9MVA. 54.24% of the power transformers are overloaded (loaded above 80%). For distribution proposes, PESCO has divided the province in eight circles, 34 division and 149 sub-divisions having total of 841 feeders of 11KV. The situation is threatening when 103feeders are above 80% loaded, 146 feeders are above 90% loaded and 194 feeders are above 100% loaded. The province has total of 97 grid stations, sub-categorized as 76 of 132KV, 17 of 66KV and 4 of 33KV. 9 grid stations of 132 KV are owned by consumers whereas reaming all are in the ownership of PESO. The ender user distribution network has total of 58458 distribution transformers, having total capacity of 4461,200 KVA.

Table 3 Transmission and Distribution infrastructure in KP (Length in Km) (NEPRA, 2015)

Year	132KV	66KV	33KV	11kv	Total HT lines	Total LT Lines
2015	2164	841	171	33337	36513	43957

2.3 Electricity supplies

In Pakistan, electricity is generated from various sources. In total installed capacity of 24,823 MW, 16,814 MW are thermal, 7116MW are hydel, 787 MW are nuclear and106 MW are wind. All the generation sources are connected with national grids, which are farther interconnected with distribution companies through national transmission and Dispatch Company. With 18th amendments, energy becomes provincial subject in generation sector only. Pakhtunkhwa Energy Development organization (PEDO) is responsible for development of energy projects. Khyber-Pakhtunkhwa, currently have no thermal power plants. Majority of hydel power stations are located in the province. The total installed capacity of hydel power plants is 4211MW which is about 60% of the country total installed hydel capacity. The flow variation results in generation variation around the year. The monthly variations of production capacity for Tarbela hydel station and Warsak Hydel station are shown in Fig.1. Under umberalla of PEDO seven projects namely Ranolia, Daral Khur,Karora,Jabori,Koto,Gorkin Matiltan ,Lawi having total capacity of 268 MW are under construction. In addition, KP is pursuing harnessing of hydel potential at different sites having total capacity of 3000MW. Among these projects , 668MW are offered for private sector having total cost of US $ 1794 million, 502 MW are planned through Frontier Works organization (FWO) having total cost of US $ 1110 million and 2157 MW are planned through China Pakistan Economic Corridor(CPEC) having total cost of US
$ 7564 million.

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Table 3 Khyber Pakhtunkhwa installed hydel power plants (NEPRA, 2015)

Project	Location	Type	Installed Capacity (MW by June 2015)	Generation (GWH) 2014-2015
Tarbela	Tarbela	Reservoir	3478	14809
Warsak	Warsak	Reservoir	243	975
Khan Khawar	Shangla	Reservoir	72	253
Ali Khawar	Battagram	Reservoir	121	462
Duber Khawar	Kohistan	Reservoir	130	613
Daragai	Dargai	ROR	20	108
Khurram Ghari	Khurram	ROR	4	19
Chitral	Chitral	ROR	1	4
Gomal Zam	South Waziristan	Reservoir	17	44
Malakand	Malakand	ROR	22	122
Malakand III	Malakand	ROR	81	408
Pehur	Swabi	--	18	49
Sishi	Chitraal	-	1.8	-
Machai	Chitral	-	2.6	-
Total	4211.4	17866		

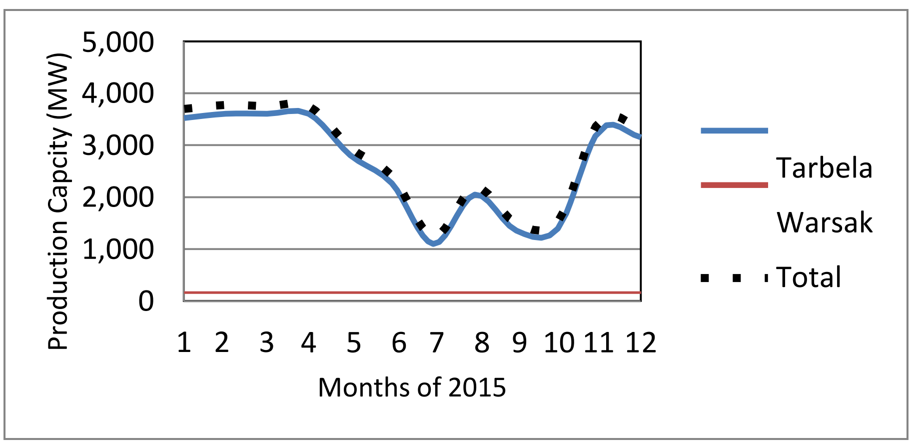

Fig.1. Monthly Variation of hydel power plants production capacity (NEPRA, 2015)

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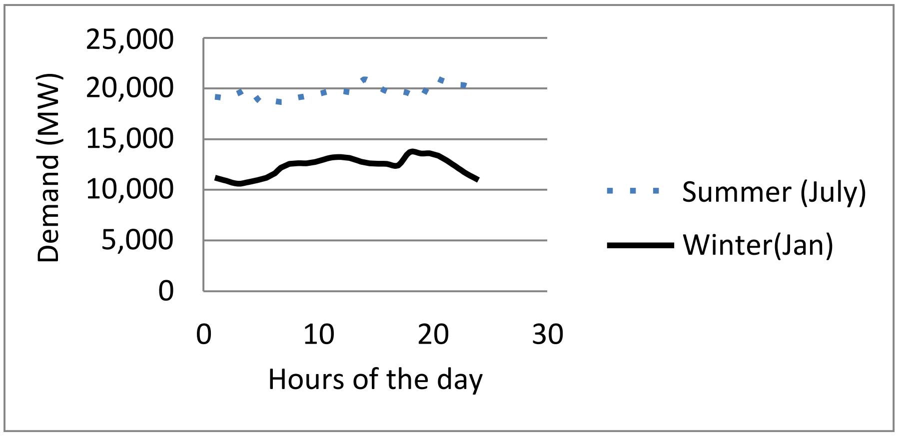

Fig. 2. Pakistan hourly Demand Variation (MPNR, 2016)

Table 4 Leap major assumptions

Parameters	Description	Reference
GDP Growth Rates	As per Economic Survey of Pakistan 2017	(Finance Division , 2017)
Population Growth Rates	As per Economic Survey of Pakistan 2017	(Finance Division , 2017)
Consumers Growth Rates	As per Report of NEPRA	(NEPRA, 2015)
Demand Growth Rates	As per Report of NEPRA	(NEPRA, 2015)
Fundamental Model	Supply-demand model	
Dispatch Rule	Merit order	(Heap, 2008)
Reserve Margin	12% as pervious authors	(Usman, 2015)
Capacity Credit	100% as pervious authors	(Rajesh V. Kale, 2014)

Table 5 Endogenous Capacity Addition (Power, 2016)

Capacity (MW)	Status
268	Under-construction
668	Offered in Private sector
506	Frontier Works Organization
2157	China-Pakistan Economic Corridor

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3. METHODOLOGY

This paper is using Long-range energy alternative planning (Leap) model for futuristic projection of electricity from base year of 2015. Long range alternative planning (Leap) is a bottom up accounting model operates on the basic principle of least net present value of costs from generation to energy services. The model integrates internalities like supplies, transmission, distributions, demands and externalities like demographics, socio-economic conditions together for projecting futuristic demands and supplies as well as emissions best in time frame of less than 30 years. The model has seven different views for data inputs and graphical outputs along with inbuilt technological database for description of important parameters of various energy generating and consuming technologies. The analysis view modular structure having modules of key assumptions, demands, transformations comprising of transmission and distribution, key stocks, primary and secondary supplies, non- energy sectors as well as key indicators covers all sectors of energy sector and economy.

In leap model framework, the key assumption encompasses population, population growth rates, gross domestic product, GDP growth rates, per capita income, and rural-urban dividend .The demand module was structured as economic categorizations as domestic, industrial, commercial, agriculture, bulk supplies, public lighting and others. The total demand per sector was calculated by multiplying the social indicator, total number of consumers with the average energy consumed per consumers. The transformation module gives flexibility of further breakdown into distribution, transmission and generation sectors. The distribution and transmission sectors major requirements for modeling are parameters like planning reserve margin, exports-imports priorities, system peak load shape, shortfall-surplus rules and transmission losses. These terms are important to model the existing system and also to incorporate reliability, efficiency and mitigation strategy for shortfalls in the planning phases. The generation sub-module covers different set of power generating technologies like coal power plants, large and small hydro, gas power plants; Oil based power plants, combined cycle power plants, nuclear, solar, and wind plants. In additional other conventional fuels used in developing and under-developed economies can be modeled animal waste, wood, kerosene and bagasse. The model requires data about fuel used, efficiency, dispatch rules, merit orders, historical consumptions, plant retirement age, planned capacity additions and percent share preferences by fuel types. The resource module extends over primary and secondary resources tracing back from transmission and distribution module. The resources are provided with details of annual production, import-export options, cost values of indigenous and imported fuels, cost of energy un-availability. Leap covers the climatic aspects of various technologies resulting in emission in the topology of electricity generation and consumptions.

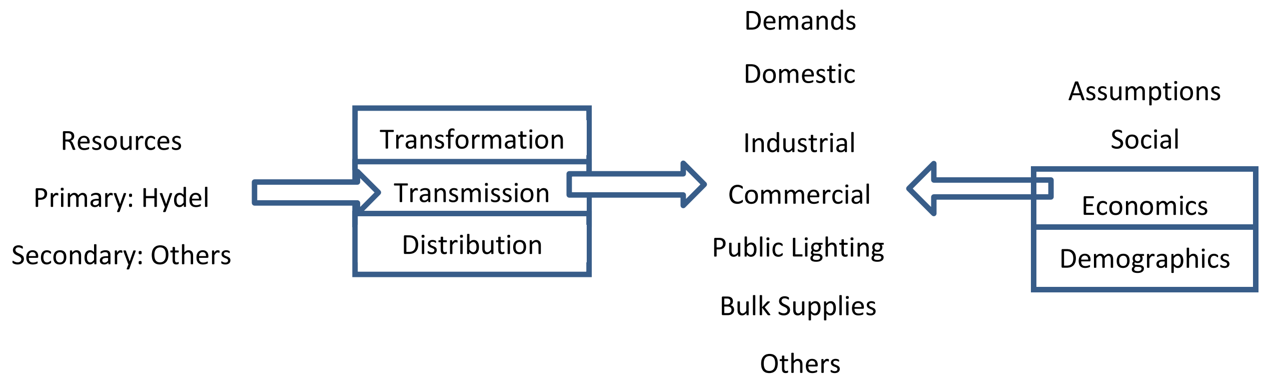

Fig. 3. Block Diagram of KP Leap model

3.1 Main assumption of KP Leap model

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The KP leap model framework input-output parameters and boundaries are represented in block diagram figure no3. The key social, economic and demographic indicators are introduced in assumptions are given in Table. Taking, 2015 as a base year, average electricity intensity per consumers is multiplied with total consumers to calculate total energy. Currently, only hydel power plants are operational in Khyber Pakhtunkhwa, so the transmission and distribution module processes were defined as hydro. Thereof the model is assuming the hydel resources only. The transmission and distribution losses are assumed as 34.81% which covers both technical and non-technical losses in PESCO domain. (NEPRA, 2015)Planning reserve margin is assumed as 12% Which is the tradeoff between system cost and reliability. (Ayza Shoukat, 2016) It ensures the availability of power at surges time above peak demand. The process dispatch rule is set to merit order, thus the power plants will operates to balance demand both nominal and instantaneous with in rated capacity limits. It was assumed that planned and under- construction power plants will comes into effects on due times, thus total of 3600 MW will be added in short, medium and long runs as shown in assumption table. (Power, 2016) The availability factor is calculated as 48.85 which is very close to the load factors of hydel power plants in Pakistan. The capacity credit is assumed as 100%. This paper considers five years as medium terms and more than five years as long term.

3.2 Scenario development

Leap offer the feature of scenario development for visualization of future with estimation of inputs parameters growth rates. The scenario tool can be used for suggesting of potential pathway for policy makers and technology developer guiding through energy, environment and economic complexities. (Craig PP et al., 2002) The business as usual scenario was developed using the existing economic and social growths. It is the continuation of existing demand and supply trends with same transmission and distribution capabilities under umbrella of existing policies of energy, technology and development (MWP, 2015) and (PLanning Comission , 2014). Numerically, Population and income growth rates were considered as 2.4% and 4.7% respectively (Finance Division , 2017). The demand growth rates for f domestic, commercial and industrial were taken as 2.18%, 4% and 7% respectively (NEPRA, 2015). The consumer's growth rates for domestic, commercial and industrial were taken as 3.11%, 7% and 3% respectively. The transmission and distribution losses were considered to reduce to 26% in coming five years and then reduce to 12% in long term (NEPRA, 2015) .The only resource considered was hydel for electricity generation.

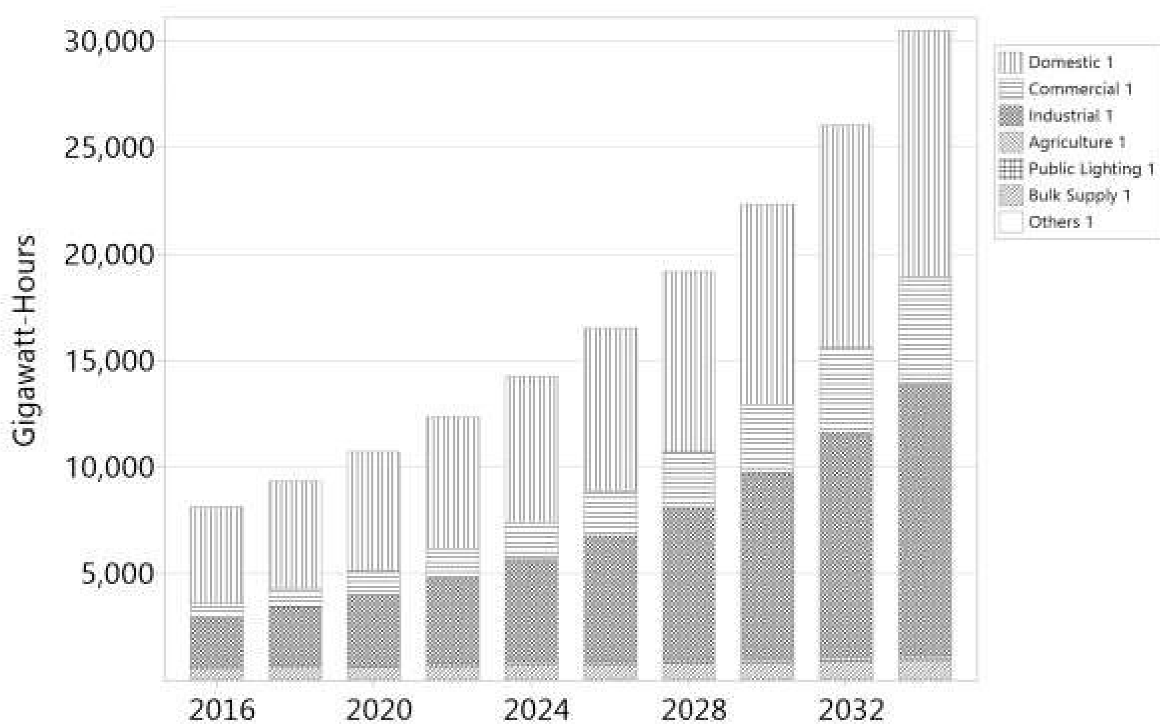

Fig. 4. Final Electricity demand across all sectors from 2016 to 2035.

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4. RESULTS

The futuristic demand for electricity was projected in business as usual scenario. The projection was made for upcoming 20 years, considering 2015 as a base year. In the medium turns till, 2025, the total demand across five economic categories was projected as shown in figure. The total demand of final electricity consumption increased from 7519GWh in 2015, to 15340 GWh in 2025 and 33028 GWh in 2035. This indicates a growth of 339.26% with reference to base year. The domestic demand will grow significantly by 183 % whereas industrial growth will be recorded as 600% in 2035 compared to 2012. The percentage demand growth in commercial, agriculture, public lighting, bulk supplies and others will be recorded as 747%, 88.7%, 90%, 84% and 56% respectively. The aggregate primary electricity required to fulfill end user demand was projected as shown in figure. A total of 50348 GWh will be required which is 187.7% higher than base year value. The primary demand significantly increases across three sectors domestic, commercial and Industrial as 195%, 662% and 5345 respectively as of 2015. In business as usual scenario, agriculture, public lighting, bulk supplies and others sectors growth increases as 83.21%, 82.5%, 160% and 715 respectively. On supply sides, the planned hydel power station addition will results in increase in the total installed capacity. Figure No 5 shows the projection of supply sides from 2015 to 2030. The electricity supplies of 17866 GWh will increase to 26435 GWh in medium term and 50348.2 GWh in long term. The per capita consumption grows from 382.19Kwh/person/year in 2015 to 1027.51 Kwh/person/year in 2035.

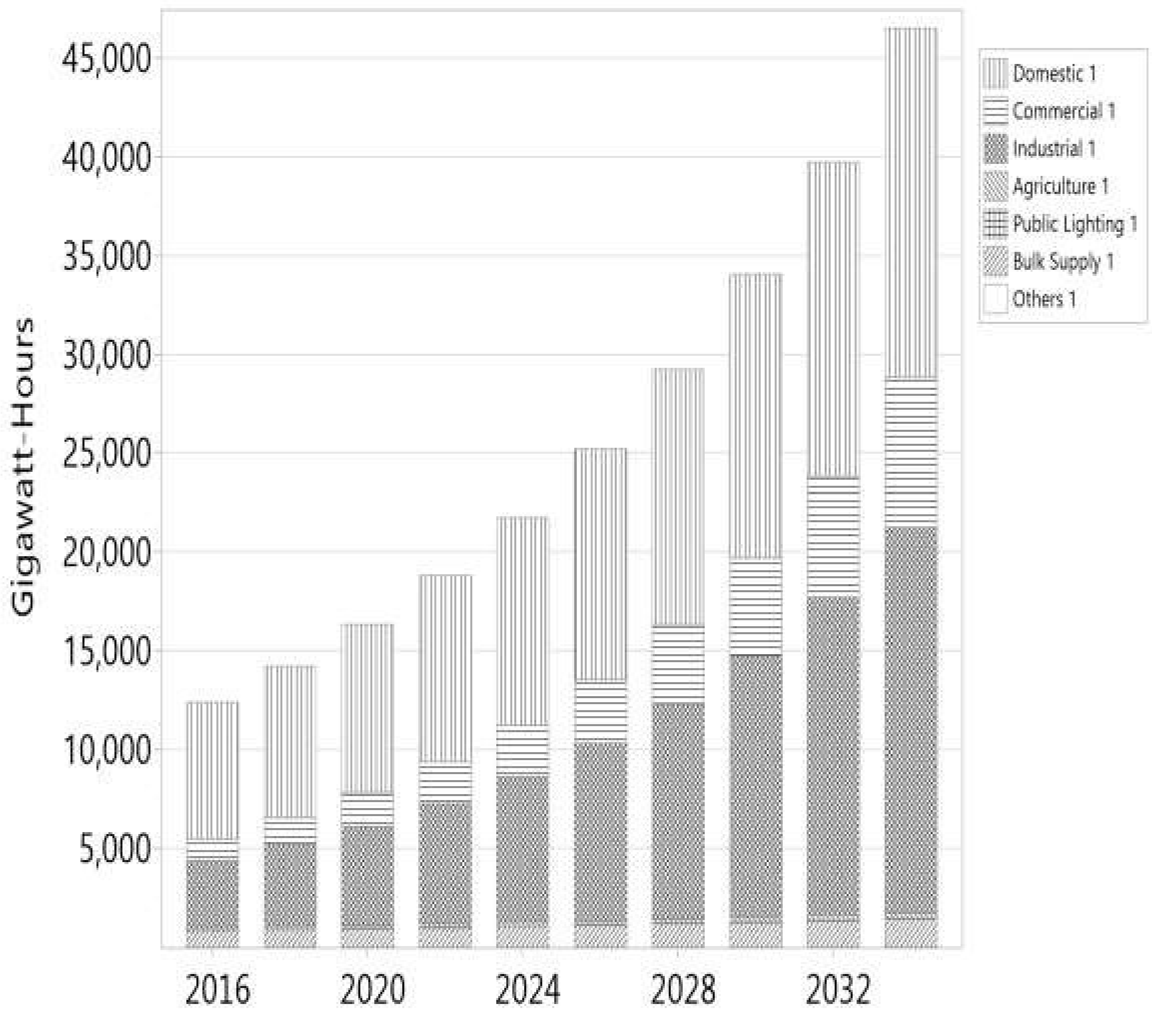

Fig. 5. Primary Energy requirement across all sectors of demand side.

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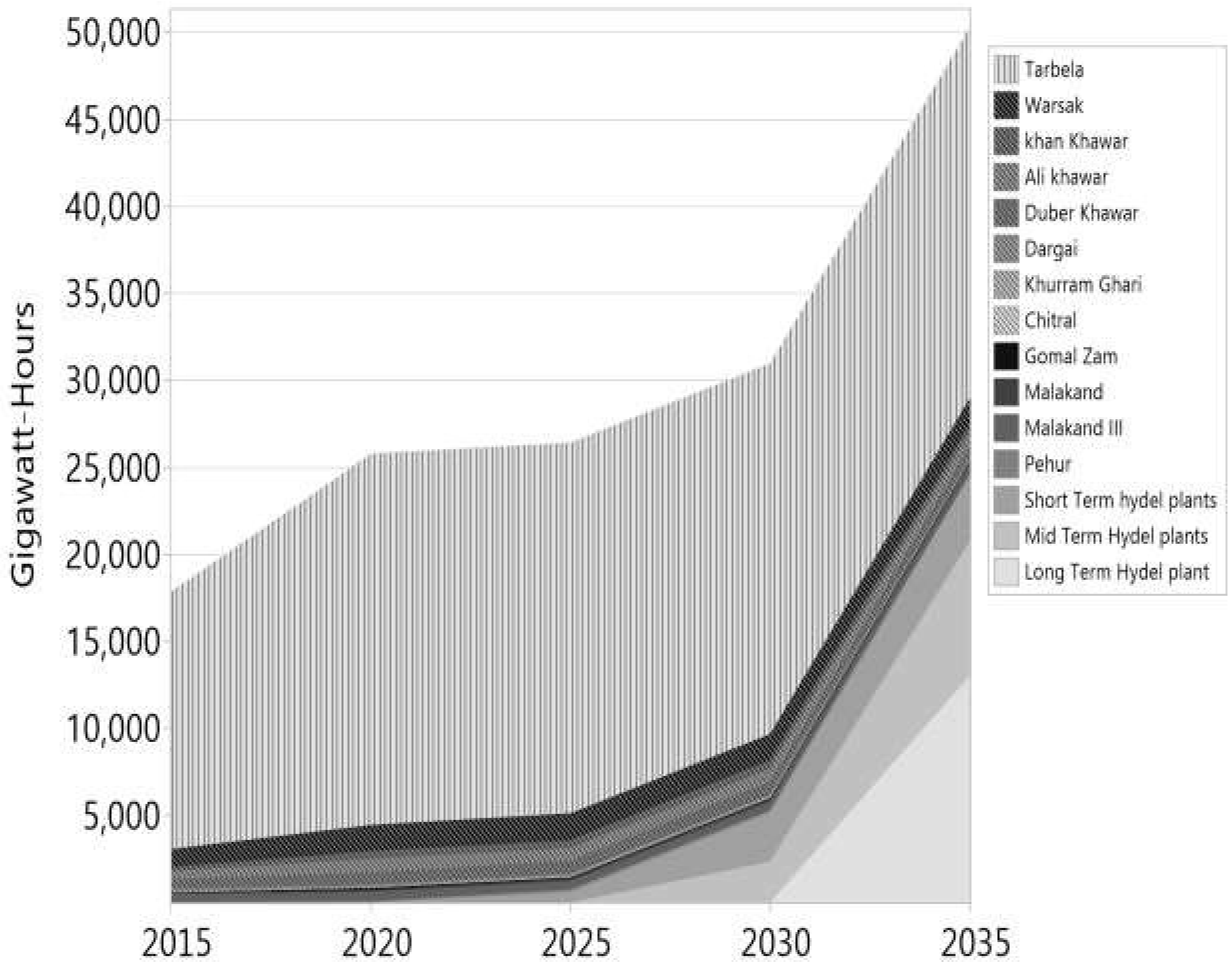

Fig. 6. Electricity supplies projection from installed and planned power plants.

4. DISCUSSION

The paper has projected the demand and supplies of electricity sector for Khyber-Pakhtunkhwa with the continuation of existing policy and development trends. The province though is powered by national grids, but for provincial model it was studied as a separate entity powered by its own generating resources. The projection indicates significant growth in electricity requirement across all sector of economy. The total demands of end user, without including the transmission and distribution losses, has increased about 5 folds from 7519 GWh in 2015 to 33028 GWh in 2035. With transmission and distribution losses counted, the total primary demand increases by 4.5 folds in 2035 compared with base year values. The demand growth across all sectors is potentially high compared agricultural demand growth of 88.7% in business as usual case. The growth is comparatively less in agriculture sector which can potentially threat the food security of rapidly growing population in province. The transmission and distribution losses include both technical and non- technical aspects in the province is as high as 34.4% though the national transmission and dispatch company has target of 26.00%. The rapid demand growth can be answered by supply sides, already overloaded transmission and distribution sector needs revamping. In the currently operational feeders of 841, 23% are loaded above 100%, to cope with the increasing demand , new distribution infrastructure extensions is indispensible. Per capita energy consumption if measured on basis of actual energy sold in province is 249 Kwh/year whereas the value stands at 382.59 Kwh/person/year if calculated on basis of electricity provided by national grids to the province. If we exclude the technical losses of 20% in the transmission and distribution sector, the per capita consumption in base year is 305 Kwh/year. The per capita consumption will grows to 1027.5khw/year in 2035, which is significantly less than international standards.

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On demand side, the planning reserve margin used in Pakistan is 12%, economically affordable but unreliable. The planning reserve margin is different in different regions ,In US the planning reserve margin are in the range of 12 to 28% (NERC, 2017) and (Fernando Almeida Prado).In turkey, the planning reserve margin is as high as 35% (Energy Market Regulatory Authority , 2010). Looking at the operating efficiencies of power plants in Pakistan as well penetration of solar and wind based renewable energies, the planning reserve margin needs to be increased. The projection for supplies were made considering in-time completion of planned power projects in hydel sector in short, medium and long terms. This will needs as estimated investment of US $ 10,468 million in energy sector, China –Pakistan Economic Corridor can be materialized for the hydel power projects developments. Historically, power projects has faced delays in-time completion, (Aysha Batoola, 2017) a comprehensive framework development with the concerns and consents of all national and provincial stakeholder involved, may be helpful in reducing the un-necessary delays of power sector project.

5. CONCLUSION

In this paper, the electricity sector in Khyber-Pakhtunkhwa has been analyzed and presented in detail. This is the first paper, modeling the provincial electricity sector as dis-integrated sub-sector of national grid in Pakistan in known literature. The historical demand and supply trends, existing electricity transmission and distribution infrastructure, future planned energy projects and socio- economic drivers were examined to predict the medium and long terms thirst of electricity. The paper has used long range alternative planning (Leap) to forecast the growths as business as usual scenario using base year of 2015 to 2035. The demand in various economic groups like domestic, industrial, commercial, agriculture and others was projected, with significant growth noted. Demand for electricity in commercial, industrial and domestic sectors increases by 747%, 600% and 183% respectively. The agriculture demand growth was noted as 84% which may prove threat for provincial food security. The consumers' growth of 339.2% has been noted in the upcoming two decades. The existing growth rates are though significant, but are not capable to cope with the international standard of energy access. The supply and demand both grows exponentially, whereas the existing transmission and distribution infrastructure is highly overloaded and incompetent, thus needs timely up gradation and extension. On generation side, hydel potential is the only sources harnessed for electricity generation. The paper has looked into the seasonal variations, existing various power stations performance and planned projects. Though the supply side is capable to answer the growing demand, in the dis-integrated provincial model, yet the delay of pipeline projects can rot the situation. It is suggested to reduce the transmission and distribution losses, improve planning reserve margin, reduce the project delay and most importantly, enhance agricultural activity to balance food-energy nexus.

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RENEWABLE ENERGY RESOURCES IN PAKISTAN A CASE STUDY OF SOLAR ENERGY POTENTIAL IN KPK

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ABSTRACT

Solar energy resources have great potential to contribute towards the long-lasting energy deficiency problems being faced by Pakistan. The aim of this study was to utilize 22 years (1983-2005) satellite based data sets of Direct Normal Irradiation (Wh/m^2/day), Global Horizontal Irradiation (Wh/m^2/day), Day Light Hours, Cloud Amount (%) and Linke Turbidity Factor for six districts of KPK (Chitral, Peshawar, Dir, Dera Ismail Khan (DIK), Buner and Mansehra) respectively. In case of the monthly averages for DNI except Chitral and DIK other districts appeared with similar patterns with two maximum peaks one between April to June and the other peak between October to November. Comparison of monthly averages for GHI one peak appeared for all districts between June and July. It should be noted that Peshawar and Buner districts were identified with significant high irradiation (DNI and GHI) all over the year as compared to other districts. Multi-criteria Analysis involved, creating suitable criteria for selected variables then classification (based on each variable magnitude), score were then assigned to each class. Based on methodology (MCA) applied in this research,

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Peshawar district appeared as the best location for exploiting in terms of solar power.

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Keywords— Solar Potential Site KPK, Irradiance (DNI & GHI), Day Light Hours, Linke Turbidity Factor, Multi-Criteria Analysis

1. INTRODUCTION

Energy is essential for human beings, but current non-renewable energy resources are considered to be insufficient in the coming years with noticeable destructive effect on the environment. Renewable energy is emerging as a solution for an environment friendly sustainable and long lasting, cost-effective source of energy for the future. Renewable energy have the ability of replacing the non-renewable sources of energy in most of their implementation at competitive long term prices [1, 2, 10]. Globally there is an energy deficiency due to the immense rise in the consumption of energy coupled with the fossil fuel exhaustion. Pakistan is also facing problems because of insufficient energy to meet the needs of the country. It has relied only on non-renewable energy resources such as fossil fuels (coal, oil and natural gas) which release harmful gases in the environment, therefore contribute towards the global warming and are not sufficient to overcome the energy deficiency [11]. There is general awakening to avoid the pollutant energy resources; Pakistan should pay attention towards its abundant renewable energy resources such as solar, wind, hydropower, biomass and geothermal resources. Amongst all the clean technologies, solar energy is the most promising renewable energy source to contribute towards the control of the greenhouse gases emissions and helps to reduce global warming [12, 14]. According to data of Eurostates, Germany was the greatest generator of solar energy in Europe during 2012, with 2.26 Million toe (tonnes of oil equivalent) generated, followed by Italy (1.62 Million toe), and Spain (0.7 Million toe). Some more countries with high capability for solar energy generation were France, Greece and the United Kingdom generated largest amounts in 2012, with respectively 0.345, 0.145 and 0.102 Million toe [5]. Pakistan also receives 5.5 Wh m^{-2} d^{-1} solar insolation with annual mean sunshine duration of 8–10 h d^{-1} throughout the country. Therefore considering the potential importance of solar energy, globally many studies has been conducted using the satellite based data [12, 14, 6, 4]. However, such studies over Pakistan (study area) are scant. Therefore it is the first time to use the NASA Surface meteorology and Solar Energy (SSE) and Photovoltaic Geographical Information System (PVGIS) datasets to identify the areas for solar energy potential in KPK,

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Pakistan.

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The structure of this paper is as follows. Firstly, section 2.1 comprises a general description of the study area , section 2.2 describe the data used and description and section 2.3 presents the methodology adopted for this study, while section 3 presents results and discussion followed by some conclusions in section 4.

2. STUDY AREA, DATA USED, GENERAL DESCRIPTION AND METHODOLOGY

2.1. Study Area

Khyber Pakhtunkhwa (30^O-35^ON & 67^O-72^OE), one of the four provinces of Pakistan is located on the Iranian plateau and Eurasian land plate with an area of 74, 521 km^2. Geographically, it splits into two zones with northern one from Hindu Kush to Peshawar and southern one from Peshawar to Derajat basin. The climate of KPK changes from extremely cold (such as Chitral) to extremely hot (such as DIK) areas. The study areas are the six districts of KPK such as Peshawar, Dir, Chitral, DIK, Buner and Mansehra as shown in the figure 1. Chitral district temperature alters from 30^OC (86^OF) to 0^OC (32^OF) in the months of July and January respectively. The temperature of Buner varies from 44^OC during the summer season to -2^OC during the winter season. Peshawar climate is

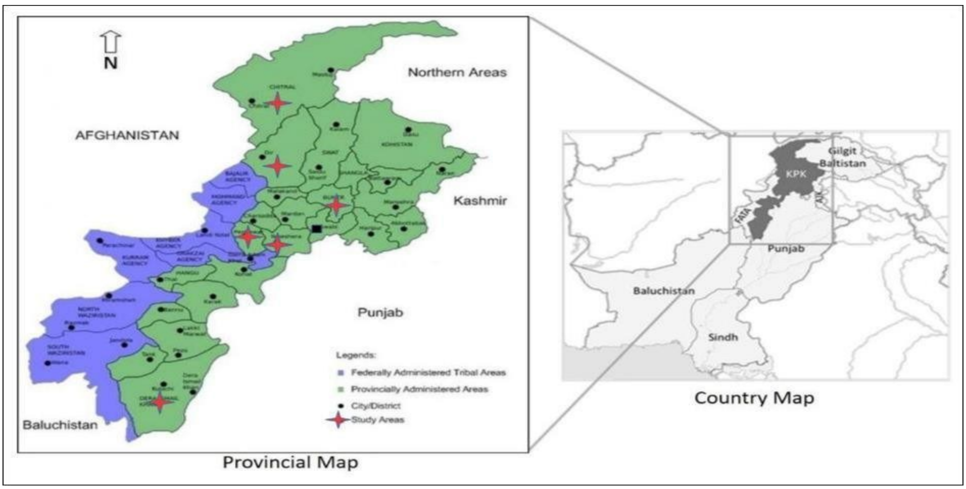

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Figure. 1 Study Area

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semi-arid with intense hot summers (40^{O}C) and mild winters (18^{O}C). DIK has usually extremely hot and dry summers with low rainfall in the region. Dir district climate is intensively humid subtropical and it has a very penetrative monsoonal periods along with the heavy thunderstorms.
The Mansehra district of KPK climate is warm in summer and cold in winter with temperature ranges from 2^{O}C to 36^{O}C [9].

2.2. Data used & Data Description

- ***Surface meteorology and Solar Energy (SSE)***

Surface meteorology and Solar Energy (SSE) is a renewable energy resource website which is sponsored by the NASA's Applied Science Program in the Science Mission Directorate developed by Power (Prediction of Worldwide Energy Resource Project). It contains over 200 satellite- acquired meteorology and solar energy parameters with monthly averaged from 22 years of data and data tables for a specific site [16]. Its data sets are continuous and stable 10-year world's climatology of insolation and meteorology data on a 1^{O} x 1^{O} grid system. The SSE data sets are not for the purpose of replacing the ground measurement data but are to fill the space where the ground data are not present [13]. The original SSE data-conveyance website, is intended to supply an easiest way to obtain the parameters required in the renewable energy industry (such as solar and wind energy) [17]. The data sets (such as direct normal irradiation, global horizontal irradiation, day light hours and cloud amount) for the study are obtained from the SSE website https://eosweb.larc.nasa.gov/cgi-bin/sse/sse.cgi?skip@larc.nasa.gov+s01#s01.

- ***Photovoltaic Geographical Information System (PVGIS)***

PVGIS is a research, demonstration and policy-support instrument for geographical assessment of the solar energy resource in the context of integrated management of distributed energy generation. Primary data source for PVGIS is HelioClim database produced by Mines Paris Tech which is based on Heliosat method. The Heliosat method converts images acquired by meteorological geostationary satellites, such as Meteosat (Europe), GOES (USA) or GMS (Japan), into data and maps of solar radiation received at ground level. It is available from 1985-2004, the original spatial resolution is 15 x 15 arcminute, i.e. ca. 30 km x 30 km on the equator.

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Data Source	Parameters	Temporal Resolution	Spatial Resolution	Period Covered
SSE NASA	Direct Normal Irradiation ($Wh/m^2/day$)	Monthly Avg.	$1^o x1^o$	1983-2005
SSE NASA	Global Horizontal Irradiation ($Wh/m^2/day$)	Monthly Avg.	$1^o x1^o$	1983-2005
SSE NASA	Day Light Hours	Monthly Avg.	$1^o x1^o$	1983-2005
SSE NASA	Cloud Amount (%)	Monthly Avg.	$1^o x1^o$	1983-2005
PVGIS	Linke Turbidity Factor	Daily	15x15 Arc-minute	1985-2004
PVGIS	Direct Normal Irradiation ($Wh/m^2/day$)	Daily	15x15 Arc-minute	1985-2004
PVGIS	Global Horizontal Irradiation ($Wh/m^2/day$)	Daily	15x15 Arc-minute	1985-2004

Table. 1: List of parameters with corresponding data source used in study

2.3. Methodology

The study aims to utilize free of cost satellite derived data sets in open source Geographical Information System (GIS) environment for the identification of best sites possessing maximum solar energy potential within study area. The adopted methodology is briefly described as follows,

1. Long Term Temporal Irradiation (SSE data)

Historical (from 1983 to 2005) Irradiation data (DNI & GHI) for 06 districts were from SSE.
Annual and Monthly averages of DNI & GHI for each district were calculated and then mapped.

2. Multi Criteria Analysis

Traditional single criteria assessment approaches can no longer handle the complexity of system [18] and therefore not suitable approach for such problem considering in this study, whereas multi-criteria assessment methods (MCAM) provide a simple and flexible criteria [19] to handle and bring together a wide range of variables in different ways and thus offer useful alternative and hence provide solution of the problem.

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MCA performed via the following procedure;

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- Classification (based on corresponding variable`s magnitude)
- Scores were then assigned to each class accordingly.
- Identification of best location (district) with maximum total score

	Variable	Method	Ideal Condition
1	GHI (Wh/m^2/day)	Average/Classification	Maximum Values (Class)
2	DNI (Wh/m^2/day)	Average/Classification	Maximum Values (Class)
3	Day Light Hours	Average/Classification	Maximum Values (Class)
4	Cloud Amount (%)	Average/Classification	Least Values (Class)
5	Linke Turbidity Factor	Average/Classification	Least Values (Class)

Table. 2: Multi Criteria Analysis: Identified Criteria for selected variables

3. RESULTS AND DISCUSSION

Solar energy is the clean (environment friendly), sustainable and inexhaustible energy resource [12, 14]. Long term comprehensive apprehension of the potential sites is needed for the progression of this energy resource, in order to initiate the solar farms at a large scale. Pakistan having the indigenous amount of solar energy resources is therefore suitable for the harvesting and progress of solar energy. The goal of this study was to identify the solar potential sites in KPK; Pakistan using the multi criteria based approach.

3.1. Average Irradiation over KPK regions

Table 3 shows the 22 years (i.e. 1983-2005) annual average irradiation (DNI & GHI) for six districts of KPK, Pakistan. Among all districts, Peshawar and Buner districts were identified with maximum DNI and GHI.

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Study Area (Districts)		Average –DNI $Wh/m^2/day$	Average –GHI $Wh/m^2/day$
1	Dir	5.66	4.75
2	Chitral	5.62	4.69
3	D.I.K	6.09	5.06
4	Buner	6.62	5.24
5	Mansehra	6.39	5.08
6	Peshawar	6.67	5.22

Table. 3: 22 Years Average of Irradiation (DNI & GHI) .

Figure 2 & 3 depicts the 22 years (i.e. 1983-2005) monthly average irradiation (DNI & GHI). In case of the monthly averages for DNI except Chitral and DIK, other districts appeared with similar patterns with two maximum peaks one between April to June and the other peak between October to November. Only one peak appeared for district Chitral between June to August, whereas three peaks appeared for district DIK in April, June and between October to November respectively. Comparison of monthly averages for GHI one peak appeared for all districts between June and July. It should be noted that Peshawar and Buner districts were identified with significant high irradiation (DNI and GHI) all over the year as compared to other districts. Similar results have been discussed for different countries [15,3].

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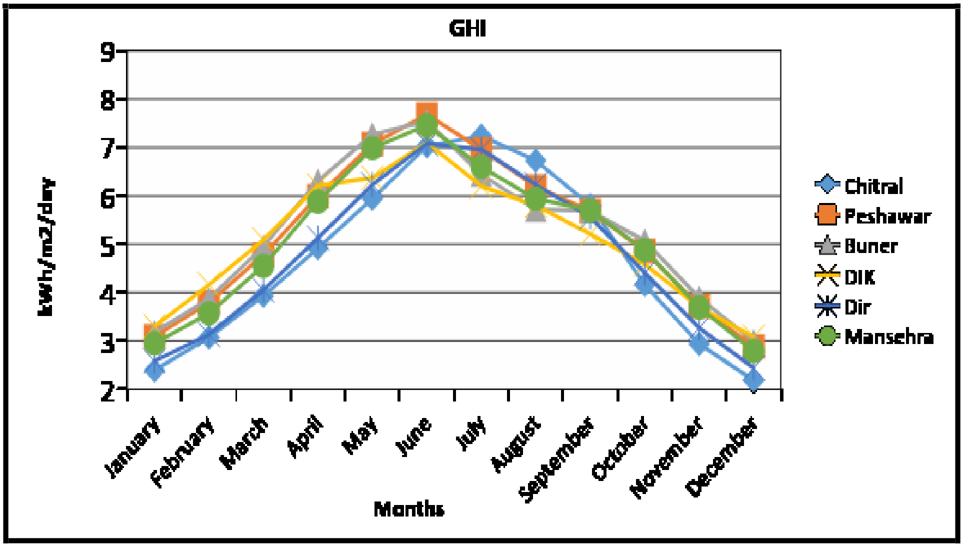

Figure 2. Monthly Average (22 yrs) Global Horizontal Irradiation (GHI)
(Data source: SSE-NASA)

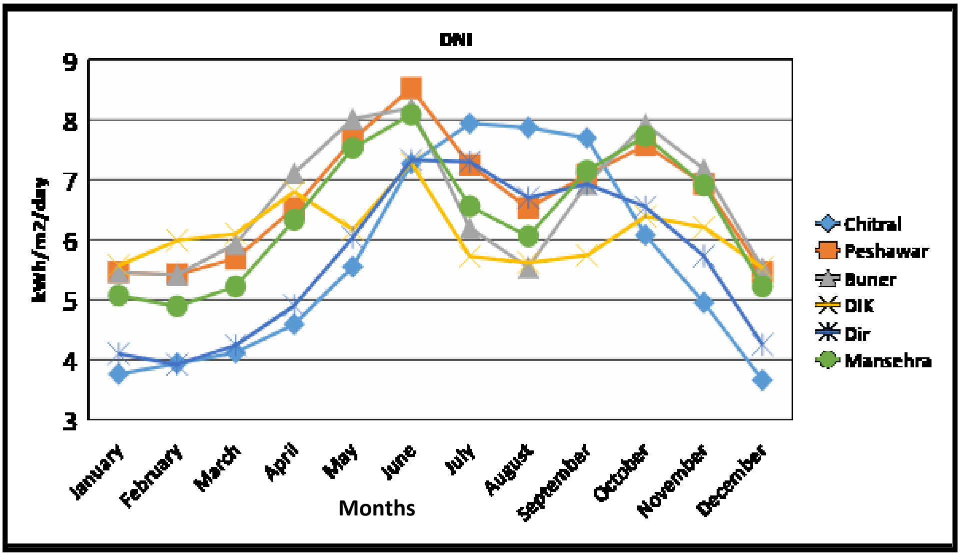

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Figure 3. Monthly Average (22 yrs) Direct Normal Irradiation (DNI)
(Data source: SSE-NASA)

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3.2. Multi Criteria Analysis

Criteria Analysis was then applied for each district individually. Parameters selected for MCA were distributed in five categories. Category 1 comprised variable of **DNI**: Monthly averages of DNI were classified and then scores were assigned to each class (as shown in table 4). Category 2 comprised variable **GHI**: Monthly averages of GHI were classified and scores were assigned to each class accordingly. Category 3 comprised variable **Day Light Hours**: Monthly averages of Day Light Hours were classified and scores were assigned to each class accordingly. Category 4 comprised variable **Cloud Amount**: Monthly averages of Cloud Amount were classified, since clouds are the main obstacle which stops the solar irradiation to reach the surface, therefore reverse order scores were assigned to each class (as shown in table 5). Category 5 comprised variable **Linke Turbidity Factor**: Monthly averages of Linke Turbidity Factor were classified, this variable also cause hindrance for solar irradiation to reach surface therefore similar procedure adopt to assign scores for each class as adopted for variable Cloud Amount. Based on total score of each district, Peshawar district was identified with maximum total score.

Globally studies have been carried out using the multi criteria analysis for the selection of suitable solar potential sites [8, 7].

Insolation: Direct Normal Irradiation (DNI)

Districts	Chitral	Peshawar	Buner	DIK	Dir
Months					
January	3.76	5.46	5.46	5.57	4.1
February	3.94	5.42	5.42	5.99	3.92
March	4.12	5.69	5.93	6.1	4.24
April	4.59	6.53	7.11	6.8	4.9

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May	5.55	7.67	8.02	6.17	6.04
June	7.27	8.53	8.2	7.28	7.33

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July	7.94	7.25	6.2	5.72	7.3
August	7.87	6.53	5.54	5.62	6.7
September	7.7	7.08	6.93	5.74	6.93
October	6.08	7.58	7.93	6.39	6.55
November	4.95	6.93	7.18	6.21	5.73
December	3.66	5.46	5.53	5.53	4.25
Annual Average	5.63	6.68	6.62	6.09	5.67

Classification of data according to the following criteria:

Mini	3.66		
Max	8.53		
Classes(3)	(Max-Mini)/3	1.623333	
Class I	Mini+1.623333	5.283333	(Lowest Class)3.66 to 5.283333=1
Class II	Class I+1.623333	6.906667	(Middle Class)5.283333 to6.906667=2
Class III	ClassII+1.623333	8.53	(Highest Class)6.906667 to 8.53=3

Table 4. Classification of Monthly Isolation: Direct Normal Irradiation (22 yrs Average) of selected districts

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Cloud Amount(CA)

Districts	Chitral	Peshawar	Buner	DIK	Dir	Mansehra
Months						
January	74.3	48.1	41.4	38.2	71.6	55.1
February	79.4	54.6	46.8	43.1	76.4	61
March	83.2	61.3	52.1	51.6	78.9	64.4
April	83.8	58.1	47.9	50.9	77.4	60.1
May	78.8	54.9	44.8	33.7	74.7	54.8
June	71.9	48.8	41.3	50.2	65.3	50.5
July	66.6	55.2	52.3	48.8	64.7	57.9
August	67.8	52.4	47.2	45.7	61.7	52.4
September	67.2	43.1	29.9	32.6	57.2	38.5
October	73.7	35.3	19.8	23.9	60.4	32.8
November	72.5	35	24.5	24.2	61	35.5
December	73.7	46	39.2	35	68.8	50.6
Annual Average	74.4	49.4	40.6	39.8	68.1	51.1

Classification of data according to the following criteria:

Mini	19.8		
Max	83.8		
Classes(3)	(Max-Mini)/3	21.33333333	
Class I	Mini+21.33333	41.13333333	(Highest Class)19.8 to 41.13333=3
Class II	Class I+21.33333	62.46666667	(Middle Class)41.13333 to 62.46667=2

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Class III	Class II+21.33333	83.8	(Lowest Class)62.46667 to 83.8=1

Table 5. Classification of Monthly Cloud Amount (22 yrs Average) of selected districts

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4. CONCLUSIONS

In spite of having vast potential of energy resources, Pakistan is still an energy deficient country and has only depended on its fossil fuels for the fulfillment of its energy demand. The impetus of this study was to make use of multi criteria analysis for the identification of solar potential sites in KPK, Pakistan by analyzing the monthly 22 years (1983-2005) and annual average irradiation (DNI & GHI) for the six districts respectively. The 22 years (i.e. 1983-2005) annual average irradiation (DNI & GHI) showed that among all districts, Peshawar and Buner districts were identified with maximum DNI and GHI. Monthly average irradiation (DNI & GHI) exhibited that for DNI except Chitral and DIK, other districts appeared with similar patterns with two maximum peaks one between April to June and the other peak between October to November. For GHI, one peak appeared for all districts between June and July. It should be noted that Peshawar and Buner districts were identified with significant high irradiation (DNI and GHI) all over the year as compared to other districts. Based on the multi criteria analysis total score of each district, Peshawar district was identified with maximum total score. It can be concluded that based on methodology applied in this research, Peshawar district appeared as the best location for exploiting in terms of solar power. Government should give its full attention towards solar energy resources to overcome the energy crises and therefore help to improve the economic condition of the country.

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SUSTAINABLE AND LOW-COST HEATING AND COOLING SOLUTION FOR BUILDINGS

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ABSTRACT

Promoting energy efficient building and harvesting alternative and green energy resources are keys to achieve sustainable energy goals. Several technologies have been used to make the building more energy efficient. Among those geothermal energy has potential to lessen the energy utilization for air conditioning and ventilation of the building, however, its performance relies on various geometric parameters, boundaries and climatic conditions. In this study Earth to air heat exchangers (EAHX) is studied using mathematical models under the climate of Peshawar, K.P.K. Parametric analysis of geometric parameters (tube length, tube diameter, air flow) is carried out using Mathematical models. Beside this optimal design parameter of Earth to air heat exchanger (EAHE) is developed using an optimization technique called Response Surface Method. The mathematical model is validated against experimental results.

Table 1 Nomenclature

T(t,z)	Soil temperature °C at time t (day) and depth z (m)	ρ_s	Density of soil (kg/m3)
Tmean	Yearly mean temperature °C	C_s	Specific Heat of Soil (J/kg K)
Tamp	Yearly temperature amplitude	w	Moisture content (%)
Z	Depth (m)	T_f	Fluid temperature (°C)
A	Thermal diffusivity m^2/s	T_s	Soil temperature (°C)
T	Time (day) of the year	R_t	Total thermal Resistivity (m^2 .°C /W)
t_o	Phase constant (maximum recorded temperature from the start of the year	R_{convec}	Thermal Resistivity due to convection (m^2 .°C /W)
Ks	Soil thermal conductivity (W/m. °C)	R_{soil}	Thermal Resistivity due to Soil annulus (m^2 .°C /W)
R_{pipe}	Thermal Resistivity due to pipe (m^2.°C /W)	R_1	Inner radius of the pipe (m)
R_2	Total Radius of the pipe (m)	R_3	Soil annulus radius equal to the pipe total radius
Hc	Convective heat transfer coefficient (W/m. °C)	Nu	Nusselt numbers
Kair	Thermal conductivity of air (W/m. °C)	Re	Reynold Numbers
F	Friction coefficient of pipe	Pr	Prandtl Number
Kp	Thermal conductivity of pipe (W/m. °C)	Ut	Over all thermal conductivity of pipe (W/m. °C)
Tamb	Ambient air temperature °C	m	Mass flow rate of air (kg/s)
C_a	Specific Heat of air (J/kg K)	ΔT	Temperature drop

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1. INTRODUCTION

The global conventional energy resources are alarmingly endangered and economically unstable. They are slated to run out with the rate being it is consumed. With increase in energy demand each year, the prices of the fossil fuels are hiking rapidly. Pakistan is currently facing severe energy crises. Pakistan's domestic consumption share of energy pie is skewed on the top side in contrast to the developed world. Almost 45% of the total energy consumption is for domestic use followed by Industrial sector which consumed 27 % of the total energy consumption. More than half of the total energy consumed is used for heating and cooling of the buildings which is much higher as compared to European countries and China where 25 to 30 % is used for the same purpose (Ahmad Sohail, 2011). The National Energy Conservation Centre of Pakistan has set goal to reduce the household energy consumption up to 30%. Therefore, keeping in view the importance of energy efficiency in domestic sector of Pakistan, this goal can be achieved by promoting green buildings (Khurshid Ahmad et al., 2014).

In achieving sustainable energy goals, promotion of energy efficient buildings is important which can be achieved by installations of passive techniques introduced in HVAC. These passive technologies consume very low energy as compared to conventional HVAC which consumes energy generated by the fossil fuels based powerplants (M. Santamouris et al., 1994). Some of these passive technology is the use of solar energy directly or indirectly in the form of electricity, geothermal energy stored inside the earth surface which can be used by earth tempering. Earth's temperature below the depth 2m attains a certain constant value all year around, which can be used to heat/cool air by passing it through a network of pipes buried beneath the 2-meter mark (Bansal, 1981). The temperature of outlet air determines if it can be fed directly to the building or conventional air conditioning cycle to bring it to the comfort level temperature. Literature indicates that EAHEs are best suited to buildings for passive air conditioning purposes. The main controlling conditions for the EAHEs are the surface temperature, earth type and moisture content of the soil (R. Kumar et al., 2006). Consequently, the site identification for EAHEs are based on physical and thermal considerations such as soil's diffusivity, density and thermal conductivity; water bed depth; and bedrock depth (Y. Chen et al., 2006).

EAHEs are classified on the basis of system structure in to open and closed loop EAHE, with open loop EAHEs drawing in fresh air from outside atmosphere continuously in contrast to closed loop EAHEs where the same air is circulated through the system for multiple cycles (Bisoniya et al., 2013). Earth air heat exchangers have the capacity to prove an alternative to the conventional cooling/heating systems, in the meantime giving simplicity of design, mitigating environmental concerns associated with the conventional systems and decreasing maintenance and operational expenditures (Pfafferott, 2003).

Further improvement in the standardization of parameters through mathematical modeling will help mainstreaming the EAHE technology. Currently used mathematical models indicate that they all perform in the same quadrant of accuracy when predicting the pipe lengths, depth, air velocity and other parameters by utilizing the one-dimensional model (A. Tzaferis et al., 1992). One such model was developed using Fourier integral of the temperature and could be used for predicting air and ground temperature commensurate with the experimental data (Kabashnikovet al., 2002). This model is accurate enough to be consulted in the design of EAHE systems. Similarly, another model can facilitate in the calculation of the daily load and the contribution of the buried pipes to the overall air conditioning load of a building by utilizing the temperature balance point. The model is validated against data from TRNSYS after running extensive performance simulation of the EAHE and found fairly accurate for design purpose (M. Santamouris et al., 1995).

As the surface temperatures and its variation with depth depends upon the locality, soil surface, and type of climatic conditions, one model was developed for grassy surfaces and forecasted the temperature matrix of the system accurately when validated against the experimental and Fourier analysis data (G. Mihalakakou et al., 1997). Soil temperature prediction models for the Sfax, Tunisia region were also developed and validated by real life values. This in association with the earth fluid pipe model is capable of energy dynamic performance projections (Kanoun et al., 2010). This model was improved upon for predicting soil temperature change vs time

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and depth by incorporating transient heat flow with certain assumptions and contrasting the predictions against experimental data found an accuracy of 85 to 90 percent depending upon the depth (O. Ozgener et al., 2013). In a similar study another model was formulated for air earth-rock system, which comprised of a convection diffusion part combined with the conduction between rock and pipes in a 1D setting. The system also takes the humidity in to consideration with 90% accuracy and temperature can be forecasted in a range of 1.4°C (H. Su et al., 2012).

A study on comparison of ground air collector and earth air heat exchanger systems for application in greenhouse systems revealed a 2-3 °C better performance for ground air collector system, while both the system results were in complete harmony with the experimental results (M. K. Ghosa et al., 2005).
As pipe burial depth is a prominent parameter for EAHE systems, a 1D model incorporating depth, Reynold's number, and form factor (pipe length's ration to pipe diameter) asserts an inverse relation between the burial depth and outlet temperature, whereas the Reynold's number is proportional to the outlet temperature (A. Sehli et al., 2012).

Thermohydraulic performance of an EAHE was investigated in a similar study and the resulting model gauges the thermal performance in conjunction with pressure drop. The model arrives at a design process which juggles both the pressure drop and temperature to come up with the optimum bargain between the two for the most optimum system output. The best solution for such configuration is a system with small diameter with more parallel pipe passes (Janssens et al., 2003). In one such model adiabatic/isothermal conditions were assumed and an analytical solution was derived at. The model validated using the finite difference simulation performed well against the experimental results (Hollmuller, 2003).

Using Green's function and principle of superposition a model can be formulated by solving heat and mass balances for pipes in ground and shows a satisfactory conformation to the experimental results (M. Cucumo et al., 2008). A comparison of three EAHXs concluded that a higher specific energy gain can be obtained by small surface area while the systems targeted at higher temperature gains should go for higher specific surface area (Pfafferott, 2003). The performance of EAHE can be enhanced using multiple layers configuration, and comparison with single layer system asserts that multiple layers up till the depth of 3 m increases the energy gain with the condition of 1.5 m separation between adjacent layers (A. De Jesus Freire et. al., 2013). Simulation of EAHE module in Energy-Plus program revealed strong performance dependence on pipe length and depth and can lead to 50% of total cooling load in various cases as compared with conventional cooling systems (Strand et al., 2008). Impact of environment on the EAHE systems has also been investigated in various studies. In hot arid climate of Kuwait a model was developed which posits that an EAHE system alone is unable to provide thermal comfort in these environments but performs well in combination with conventional systems (F. Al-Ajmi et al., 2006). EAHE models have been developed for various applications for example an Aquifer Coupled Cavity Flow Heat Exchanger (ACCFHES) which dumps the energy into deep aquifer water at the ground surface through irrigation tube wells which are at 24°C all year around. The model predicts a temperature loss of 7-8K. the model incorporates C++ simulation for predicting the green house and room temperature to which it was applied and are in strong agreement with experimental data (Sharma, 2007).

1.1 Response Surface Method

The Response Surface Method was first developed by Box. and Wilson. It is an optimization technique based on mathematical and statistical models to analyze and optimize the engineering problems. An objective function (Response) of interest influenced by several variables can be optimized for an engineering application (Hong Gao et al., 2009). The Response Surface method consist of the following general steps (Tung-Hsu Hou et al., 2007)

- Designing experiments and measuring reliable and adequate responses against different levels of variables.
- Development of first and second order response surface with perfect fittings.
- Identification of process parameters that gives the maximum and minimum value of responses.

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- Finding the direct and interactive influence of the process parameters through two and three-dimensional plots.
- Development of regression equation that predicts the response on different values of significant parameters.

The general representation of the response surface as a function of independent and continuous variables assumed to be measurable as follows;

$$Y(x) = f(x_1, x_2, x_3 \dots \dots \dots \; x_n) \qquad (1)$$

where n is the number of variables.

The prime goal is to optimize the response variable. It is necessary to develop a valid functional relationship between variables and the response surface.

The main objective of this research is to investigate, analyze and optimize the Earth to air heat exchanger for thermal comfort of the building under the conditions of Peshawar region. This study is performed for the month of July where the demand of energy for thermal comfort of the building is at peak. One dimensional model is augmented to investigate the thermal performance of the building. A parametric study was carried out to determine the levels of different geometrical parameters on the output parameters such as temperature drop at the outlet of the Earth to air heat exchanger. After determination of different input parameters levels on output response, Response Surface method is used to analyze and optimize the input parameters. Mathematical model developed is used to investigate the output responses for different input parameters.

2. MATHEMATICAL MODEL

2.1. Soil model

The mathematical model to predict the sub soil temperature is based on the heat conduction theory. It is applied to semi-infinite homogeneous solid (Kusuda TO, 1983) and (K, 1989). This model can be used to predict the soil temperature at various depths and time of the year. The ground surface temperature can be assumed equal to ambient air temperature. It is an acceptable assumption in most design considerations (ASHRAE, 2012) and (Sharan, 2002).

$$\mathrm{T(t,z)} = \mathrm{Tmean} + \mathrm{Tamp} * e^{-z\sqrt{\frac{\pi}{365*\alpha}}} . \cos\left(\frac{2\pi}{365}\left(\mathrm{t} - \mathrm{to} - \frac{z}{2}\sqrt{\frac{365}{\alpha * \pi}}\right)\right) \qquad (2)$$

Thermal diffusivity α can be calculated by the following equation (3); (ASHRAE, 2012)

$$\alpha = \frac{86.4 * Ks}{\rho_s[C_s + 4.18(^{W}/_{100})} \qquad (3)$$

The thermal conductivity of soil K_s can be found by equation (4) (M S, 1949) if the moisture content is greater than 7 % and Clay is more than 50 % in the soil composition.

$$Ks = 0.145(0.9 \; \log_{10} w - 0.2) * 10^{.621*10^{-3}\rho_s} \qquad (4)$$

2.2. Earth to air heat exchanger model

The model of earth to air heat exchanger is developed considering the following assumptions.

- One dimensional heat transfer problem is considered
- The soil surrounding the pipe has homogeneous thermal properties.
- The pipe cross section is uniform.
- The soil thermal effect is insignificant and not affected by the presence of pipe after a space equal to the double of the radius of the pipe.

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A PVC pipe with the Length L, inside radius of the pipe R_1 and outside radius R_2 is considered. The ambient air flows through this pipe buried at known depth with known soil temperature around the pipe in a soil layer of radius equal to the double of the radius of the pipe.

The heat exchanged between the soil and the air flowing through pipe is equal to the overall temperature difference divided by the total thermal resistance given by the equation (5) (ASHRAE, 2012).

$$q = {T_f - T_s}/{R_t} \tag{5}$$

The total thermal resistance is given by the following equation (6)

$$R_t = R_{conv} + R_{pipe} + R_{soil} \tag{6}$$

$$R_{conv} = \frac{1}{2\pi R1\ hc} \tag{7}$$

$$h_c = \frac{Nu * k_{air}}{Diameter\ of\ pipe} \tag{8}$$

The Nusselt number for air flowing through a circular pipe is given by equation (9) (Gnielinski V et al., 1976) as;

$$Nu = \frac{(\frac{f}{8})(Re - 1000)Pr}{1 + 12.7(\frac{f}{8})^{0.5}(Pr^{0.66} - 1)} \tag{9}$$

Where friction (f) to the flow of air through smooth pipe can be determined by equation (10) (Incropera, 1996),

$$f = (1.82 \log Re - 1.64)^{-2} \tag{10}$$

$$Rpipe = \frac{1}{2\pi k_p} \ln \frac{R_1 + R_2}{R_1} \tag{11}$$

$$Rsoil = \frac{1}{2\pi k_s} \ln \frac{R_1 + R_2 + R_3}{R_1 + R_2} \tag{12}$$

$$U_t = \frac{1}{Rt} \tag{13}$$

The heat transfer between the air inside the pipe and soil is equal to the amount of heat gain or loss by the air to the pipe is given by the equation (14) (F. Al-Ajmi et al., 2006);

$$U_t d_y [T_{out}(y) - T_{(t,z)}] = -m\ Ca\ [d\dot{T}_{out}(y)] \tag{14}$$

By solving the above equation for air temperature inside the pipe, the temperature of air leaving the outlet of the pipe can be determined.

In case $T_{amb} > T_{(t,z)}$

$$T_{out} = T_{(t,z)} + e^A \tag{15}$$

In case $T_{amb} = T_{(t,z)}$

$$T_{out} = T_{(t,z)} \tag{16}$$

In case $T_{amb} < T_{(t,z)}$

$$T_{out} = T_{(t,z)} - e^A \tag{17}$$

Where

$$A = \frac{\dot{m}\ \ C_a \ln|T_{amb} - T_{(t,z)}| - U_t L}{\dot{m}\ \ C_a}.$$

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2.3. Response Surface Design

Response Surface Methodology is a statistical technique. It is used to analyze and optimize, the response surface of interest that is influenced by variables. In this study, Central Composite Design (CCD) is used to optimize the Response (Objective function). In central composite design, face centered composite design (FCC) is used which consist of three levels for each factor. A Minitab software was used to create, analyze and optimize the Response Surface design. The responses were generated through mathematical models using the climatic and soil conditions of Hayatabad Town, Peshawar.

3. MODEL VALIDATION

The model presented earlier is validated against the two experimental results carried out by (Bansal V et al., 2010) and (Shingari, 1995). The input parameters for experimental studies are outlined in Table 2. Bansal performed experiment on April 8th, 2009 at Ajmer, India. As seen from the results, the EAHE model developed shows good agreement with the experimental results for both experiments. In both experiments correlation between the air flow and outlet temperature was examined.

Table 2 Model Validation

Model Validation				
Model Validation with Bansal Experimental Work				
	EAHE Parameters	Length= 23.42	Diameter=15 cm	Tsoil=26.7
Air velocity	Ambiant Temp	Tout (Bansal)	Tout (My model)	Relative Error (%)
2	43.4	33.1	33.2	0.302114804
3	42.5	33.1	33.9	2.416918429
4	42.3	33.5	34.8	3.820895522
5	42.2	34.2	35.5	3.684210526
	Model Validation with Shingari Experimental Work			
	EAHE Parameters	Length= 13	Diameter= 20cm	Tsoil= 20
Air velocity	Ambient Temp	Tout (Shingari)	Tout (My model)	Relative Error (%)
0.5	33.6	30.3	28.13	7.161716172
1.3	38.6	31.1	32.18	3.47266881
4.5	37.5	33.5	34.07	1.701492537
10.5	39.6	35.4	37.51	5.960451977

The maximum relative error is less than 5 % for different air flow and different ambient temperatures. Similarly, the maximum relative error for Shingari experimental measurement is under 5 % for air velocity greater than 2 m/s. In addition, for less than 2 m/s air velocity, the relative error shows an error of less than 10 %. It can be concluded that the EAHE model can predict good enough thermal performance with minimal error. Thus, it can be used for feasibility studies and design analysis of the EAHE.

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4. DATA ACQUISITION

The data required for the soil model is the annual weather of the selected site and the soil texture and moisture content in the soil. For this purpose, the weather data of Peshawar for the year 2014-16 was acquired from Pakistan Metrological Data Centre, Karachi. The Annual mean temperature for Peshawar for the year 2014-16 was 23.95 °C and the annual amplitude variation was 6.23 °C. Soil texturing and moisture content testing was conducted in Soil Lab, UET, Peshawar. The moisture content and maximum dry density for the soil sample for three different sites and different depths was determined using soil proctor test. The average soil dry density was 1900 Kg/m^3 and the average moisture content of the collected samples was 9.11 %. These soil properties input values were used in soil model equations to determine soil parameters such as soil thermal conductivity, soil thermal diffusivity and sub-soil temperatures at different depths.

5. RESULTS AND DISCUSSION

To install the Earth to air heat exchanger and to save the excavation cost, the optimal depth and soil temperature at these depths should be determined. The soil model equation presented earlier is used to determine temperature at various depths. The input parameters for the soil model equation is given in the Table 3 below

Table 3 Soil Model Input Parameters

Input parameter	Tmean	Tamp	Phase Constant (t_o)	Thermal conductivity(K) W/(m.°C)	Depth (z) meter
Values	23.95 °C	6.20 °C	139	1.45	1 to 5

It is evident from the Fig. 1; that temperature variation decreases with increase in the depth. The temperature variation lines become flatter with little variations as the depth increases. The temperature variation lies between 22 °C and 26 °C for 3 meter which is temperature range for thermal comfort in the buildings. So, our depth of

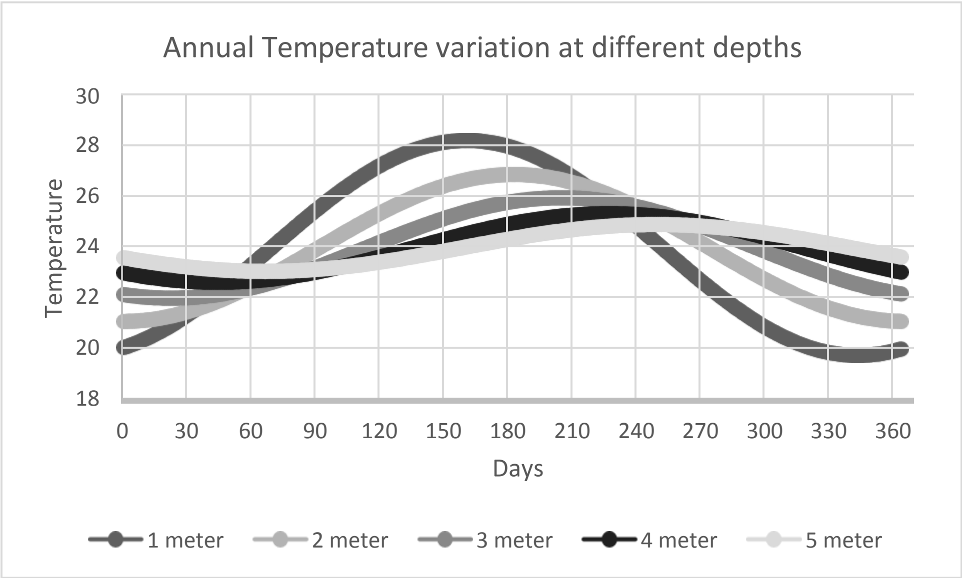

Fig. 1: Annual temperature variation at different depths

EAHE installation will be at 3 meter with maximum soil temperature of 26 °C and minimum temperature of 22 °C. The temperature fluctuates between 26 °C and 22 °C throughout the year. In this study month of July is

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selected which is the hottest month with highest temperature of 44 C recorded on 5th July, 2016 and monthly mean temperature of 39.5 °C is recorded.

5.1. Influence of Various parameters on EAHE system

The EAHE model developed is used to study the influence of various parameters on the performance of EAHE system. Three important parameters were selected and its influence on temperature drop and pressure drop is investigated. The base value for each variable is set and fixed. The values are given in the Table 4.

Table 4 EAHE model Parameters

Parameter	Length (m)	Air velocity (m/s)	Diameter (m)	Soil depth (m)	Ambient Temp (°C)	Soil Temp (°C)
Base value	60	5	0.15	3	44	26

5.1.1. Influence of Length

Fig. 2 shows the effect of length on temperature drop. It is quite evident from the graph that temperature drop increases as the length of the pipe increases. As the length of the pipe increase it provides longer length to the air flowing inside the pipe for heat transfer. The maximum and effective temperature drop is between the length of 20 and 60-meter length as the line shows in the graph. After 55-65 meter, increasing the length does not have significant amount of change in temperature drop. Thus, significant drop of temperature drop lies between the ranges of 20 to 60 meter.

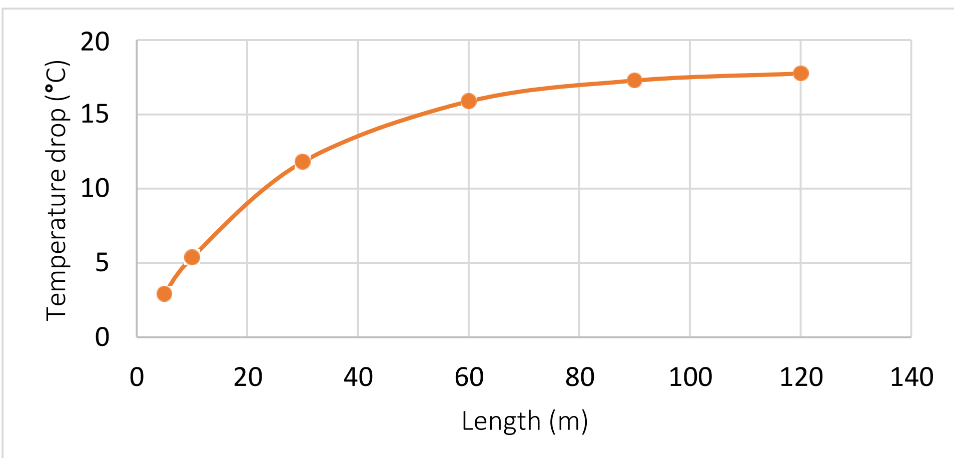

Fig. 2. Length effect on the temperature drop

5.1.2. Influence of Diameter

Fig 3; presents the effect of diameter on the temperature drop. The graph shows that temperature drop decreases with increase in diameter of the pipe. It is because that increasing the diameter of the pipe decrease the convective heat transfers between the air flowing through the pipe and inside surface of the pipe. The overall convective heat transfer decreases with increase in diameter of the pipe resulting in less temperature drop. The graph illustrates that the effective temperature drop occurs between the range of 10 cm and 30 cm.

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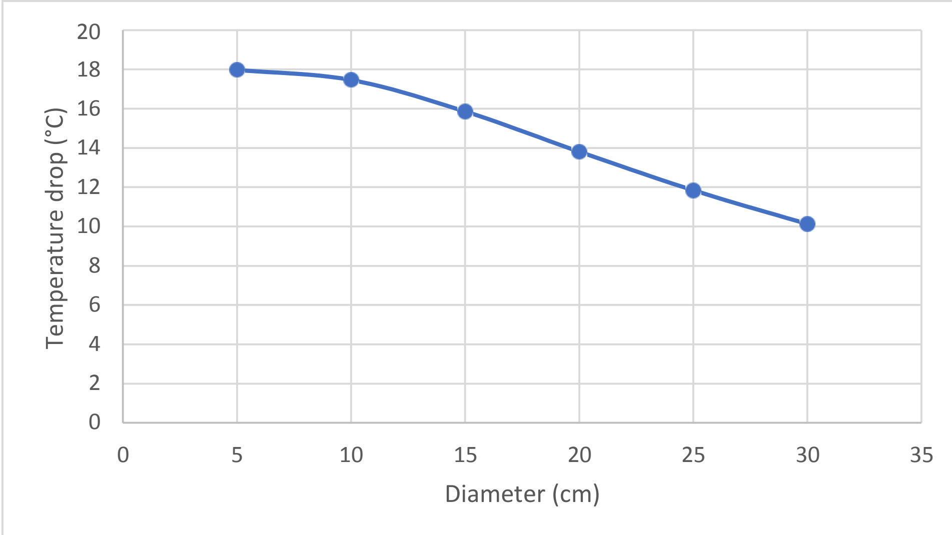

Fig. 3. Diameter effect on the temperature drop

5.1.3 Influence of Air velocity

Fig.4; illustrates the effect of air velocity on the outlet temperature. With increasing the air velocity, the temperature drop decreases, it is because the convective heat transfer between the pipe inside surface and air flowing through it decreases. Also increasing the air velocity cause the pressure drop of the air flowing through the pipe. The graph shows that effective temperature drop occurs between the velocity of 2-6 m/s with lesser pressure drop in the flow.

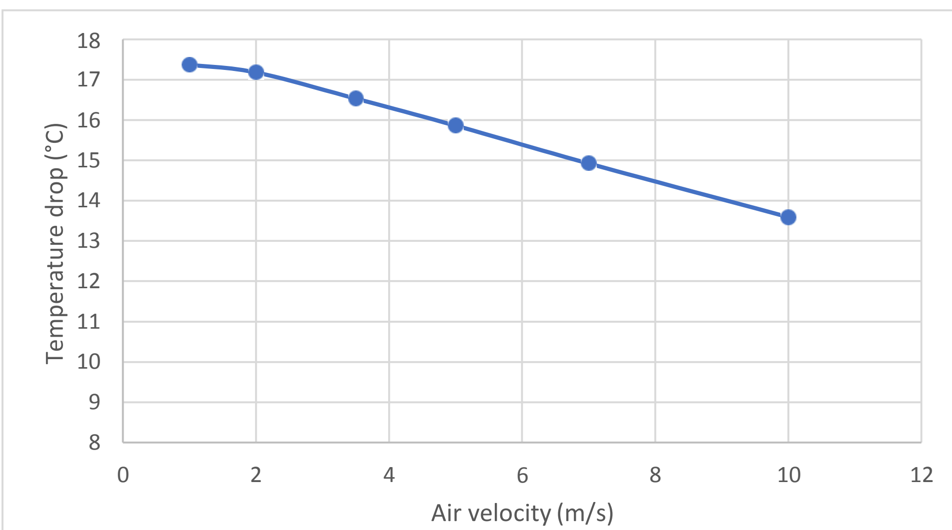

Fig. 4. Air Flow rate effect on the temperature drop

The parametric study evoked the limits of the influencing variable on the temperature drop. This study helped in determining the ranges of design parameters for the length, diameter and air velocity. These ranges of various parameters are further used for designing the Response surface design matrix.

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5.2 Response Surface method results

The Response surface method investigate the performance of Earth to air Heat exchanger under three independent parameter Length, Diameter and air velocity on the output response i.e. temperature drop. The Response surface design matrix gives 20 runs for three levels of each factor. The responses for each of these runs are determined using the experimentally validated mathematical model for earth to air heat exchanger. The full quadratic order is elected for the analysis of the data. The Analysis of Variance (ANOVA) of the model is given in the Table 5. The result of ANOVA depicts that the model proposed is highly significant. Also, the model summary shown in the ANOVA table shows that R-sq (adj) and R-sq (prd) are quite in agreement to each other which confirms that the proposed model is significant. The values of P are very less than 0.05 which shows that the model is highly significant and can be used for the analysis and optimization. The P values which are less than 0.05 indicates that the terms are significant. The P values greater than 0.05 indicates terms are insignificant. All the parameters selected for the study on output response i.e. length, diameter and air velocity are highly significant. Similarly, two-interaction effect significantly exists between the length and diameter and between the air velocity and diameter. The interaction effect between the length and air velocity is not significant.

Temperature drop = 14.69 + 0.1829 Length - 63.70 Dia + 0.956 Air velocity + 71.0 Dia*Dia - 0.1464 Air velocity*Air velocity + 0.1669 Length*Dia - 2.206 Dia*Air velocity (18)

Table 5 Analysis of Variance (ANOVA)

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Model	9	233.672	25.964	204.92	0.000
Linear	3	228.627	76.209	601.49	0.000
Length	1	77.618	77.618	612.61	0.000
Dia	1	140.400	140.400	1108.13	0.000
Air velocity	1	10.609	10.609	83.73	0.000
Square	3	2.437	0.812	6.41	0.011
Length*Length	1	0.570	0.570	4.50	0.060
Dia*Dia	1	1.385	1.385	10.93	0.008
Air velocity*Air velocity	1	0.943	0.943	7.44	0.021
2-Way Interaction	3	2.608	0.869	6.86	0.009
Length*Dia	1	0.891	0.891	7.03	0.024
Length*Air velocity	1	0.160	0.160	1.26	0.288
Dia*Air velocity	1	1.558	1.558	12.29	0.006
Error	10	1.267	0.127		
Lack-of-Fit	5	1.267	0.253		
Pure Error	5	0.000	0.000		
Total	19	234.939			
Model Summary					
S	R-sq	R-sq(adj)	R-sq(pred)		
0.355950	99.46%	98.98%	93.77%		

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The regression equation obtained for the temperature drop an output response as a function of significant influencing variable using RSM is given by equation (18);

The regression equation gives the value of output response which is temperature drop for any values of interest of selected parameters. Any predicated response can be determined for any desirable value of the parameter. Fig. 5; illustrates the comparison between the actual responses generated by the mathematical model developed and the predicated values generated using the regression equation obtained by using RSM approach. A quite good agreement exists between the predicted value and the actual values with reasonable accuracy.

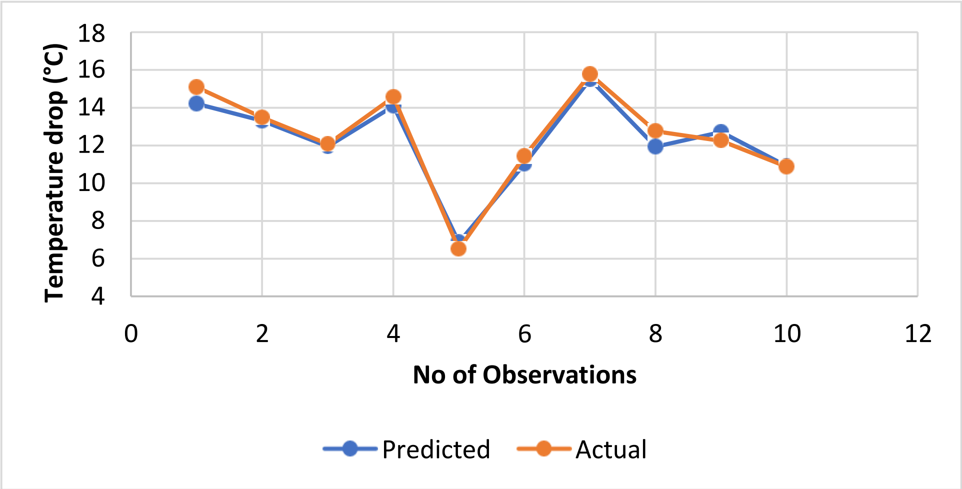

Fig. 5. Actual vs Predicted Responses

Fig. 6; shows the relationship between two influencing parameters holding the third parameter constant on output response. The response area is differentiated through different contour regions with dark blue showing the lowest temperature drop and dark green region shows the highest temperature drop.

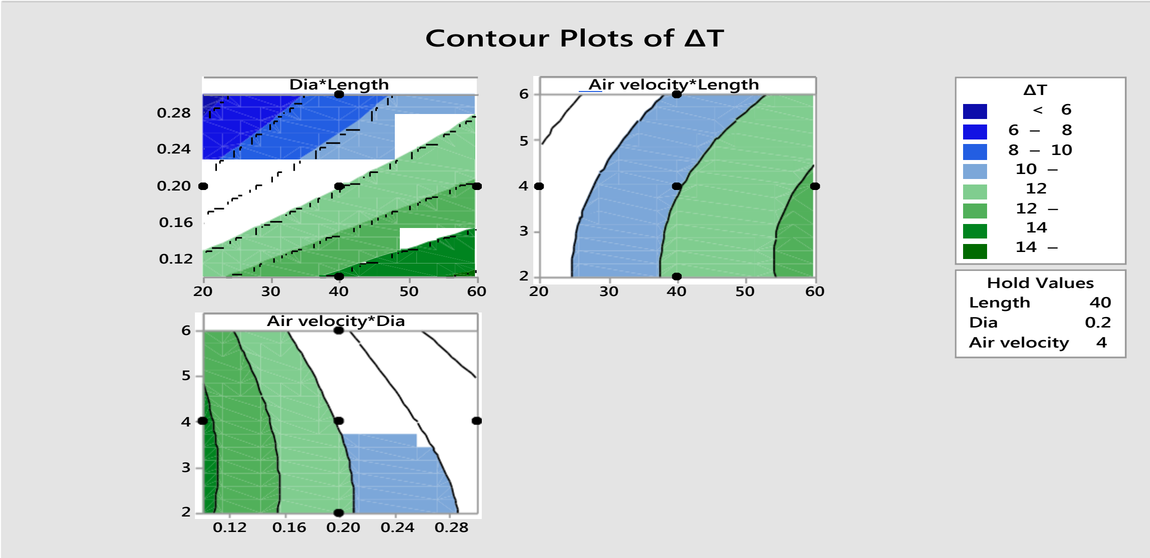

Fig. 6. Contour plot for output response

In contour plot of dia*length the temperature drop of 16-18 °C occurs for diameter between 0.10-0.14 m

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and length between 38-60 holding the air velocity constant at 4 m/s. Similarly, for air velocity*length contour plot

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the maximum temperature drop occurs between 14-16 °C for the air velocity value between 2 to 4.2 m/s and length values between 55-60 meter while keeping the diameter value at 0.2 m. Likewise, the contour plot for air velocity*dia shows that temperature drop greater than 14 °C occurs between air velocity value of 2-6m/s and diameter value of 0.10-0.16 m holding the length of the pipe at 40 m.

6. CONCLUSION

In this paper, the Earth to air Heat exchanger performance was studied for the soil condition of Hayatabad Town ship in the Peshawar region climatic conditions. For this purpose, mathematical model is developed and validated against two experimental results. The experimental model and mathematical model results were in good agreement to each other with relative error percentage of around 5%. Hence, this model can be used for further analytical and design study of Earth to air heat exchanger under the climatic conditions of Peshawar region. Using the model developed, three parameters influence length, diameter and air velocity effect on temperature drop was studied. The mathematical model developed led to the following findings.

- The variation of 4 °C and the yearly sub-soil temperature lies between 22-26 °C at the depth of 3 meter. So, the optimal depth, in order to achieve the thermal comfort with little variation in the yearly temperature and to minimize the excavation cost for installation of Earth to air heat exchanger is 3 meters.
- The effective of the design parameters were determined. The effective length for earth to air heat exchanger, for which significant amount of temperature drop occurs lies between 20-60 m. Similarly, the effective diameter that significantly influence the temperature drop lies between 0.1 to 0.3 m.
- Using the Response Surface method, it was found that all the three deign parameter have significant effect on the output response and the model used is significant. Regression equation obtained can be used to predict the output responses using any value of input parameters. The predicted values and the actual values show good agreement with reasonable accuracy.
- Likewise, using the RSM approach, the optimum regions were found for two variable output parameters holding the third one constant. The results showed that maximum temperature drop occurs between the length of 40 -45, diameter of 0.1-0.14 and air velocity of 3-4 m/s

It can be concluded that model developed can be used for the design and analysis Earth to air heat exchanger. Using RSM approach performance of earth to air heat exchanger can be predicted. Also, we can find the optimum values for designing parameters for earth to air heat exchanger using RSM. Hence, it is evident from this study that Earth to air heat exchanger can be used for buildings in in the Peshawar climate. It has the capability to reduce the energy consumption for thermal comforts in the buildings.

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FACTORS EFFECTING FUEL CONSUMPTION OF SI ENGINE - A CASE STUDY

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ABSTRACT

Efficiency of an engine decreases over time due to numerous reasons such as excessive heat generation, bad maintenance, outdated cooling system, deformed mechanical parts, oil leakage from seals and hard driving conditions. In this paper, vehicles of a specific manufacturer (Honda Civic I-Vtech Automatic: 2010-2012) were analyzed to comprehend the decrease in fuel efficiency over time with respect to different manageable factors such as vehicle's mileage, tire running mileage, frequency of Engine oil replacement, frequency of maintenance and total numbers of drivers that previously owned the vehicle. Data was collected through self-respondent surveys from drivers of 250 vehicles from three major cities of Pakistan (Islamabad, Lahore & Karachi). The response rate of 32 % was achieved through the surveys i.e. 80 cases were retained for model estimation. The effect of the above mentioned factors were analyzed by documenting the previous history of vehicle's maintenance, faults & failures if any and vehicle's present condition. Moreover the most predominant factors were identified based on their impact on defining the overall fuel economy. It was revealed that among all the considered factors, Timeline for Engine oil replacement, Total number of previous owners and Vehicle's mileage contributed significantly in demarcating the overall fuel efficiency with a combined impact of 98.2%.

Index Terms— Fuel efficiency, Mileage, Engine oil, SI engine, Heat, Driving, Consumption, Transportation Engineering

1. INTRODUCTION

In today's automobile industry, automobile manufacturers while designing a vehicle concentrate laboriously on fuel consumption of the vehicle. Efforts are being made to manufacture vehicles that are light weighted, highly aerodynamic and fuel efficient. Previous studies have stated some common factors that affect the fuel efficiency. Some evaluated the factors while others highlighted the impact of those factors. One such was Gautam (2010), who explored that the vehicle type and vehicle's weight predominantly define the fuel consumption of the vehicle. Her findings were that a 10% decrease in vehicles weigh results in 14.4% increase in vehicles fuel economy. Similarly, Varghese (2013) simulated tires pressure and observed its effect on overall fuel efficiency of vehicle, his simulated model resulted in 5.2 % decrease in fuel consumption when tires pressure was increased from 2 bars to 3 bars. Likewise, West et al., (2009) carried out a study to analyze the effect of air filter replacement on fuel consumption which indicated that the vehicles equipped with closed loop control for fuel injection showed only an increase of 5-6 % with the replacement of new air filter compared to a fully clogged air filter. However the vehicles equipped with carbureted engine showed an increase of 15 % with the new air filter. Likewise the effect of engine lubrication oil on fuel consumption of an automobile engine was carried out by Wang & Zhou at al., (2015), the findings showcased that engine oils of formula 5W-20 resulted in 12.45% decrease in friction losses and 2.33 % increase in fuel economy. Similarly another study considered the effect of Vehicle's speed and recognized the most efficient speed of a vehicle to be 70-80 km/hr (Badran at, al. 2007). Another study evaluated the effect of driving style on fuel consumption of the vehicle, suggesting the aggressive derivers (that drive at moderate performance) to drive with lower acceleration to maximize fuel economy (Michelle at.al 2010). In all these studies the effect of individual factors identified and evaluated for their impact on the fuel consumption of the vehicle. There was no such study that evaluated effect of vehicle mileage and the cumulative effect of tire mileage, Engine oil replacement, air filter replacement, vehicle mileage and number of ownership on the overall fuel efficiency.

In this paper, a comprehensive survey was conducted from the owners of Honda civic (I-V-tech automatic) so as to ensure homogenous vehicle. For this purpose, self-respondent questionnaire survey was conducted from 80 respondents across three major cities of Pakistan (Islamabad, Lahore & Karachi). Surveys enquired about the total mileage of the vehicle, total life of tires in mileage, timeline of maintenance, total numbers of owners of the vehicle and frequency of Engine oil replacement. Furthermore, to provide an apt statistical understanding of the collected survey, a statistical model was estimated so that the

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factors that significantly contribute to the variation in fuel consumption could be comprehended. It was revealed that among different examined factors, total mileage of the vehicle, total numbers of owners of the vehicle and frequency of Engine oil replacement were predominant in delineating the fuel economy.

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2. METHODOLOGY

Present study utilized self-reported survey to analyze factors that predominantly effect fuel consumption. The factors evaluated under this scope are discussed in the ensuing headings.

2.1. Effect of Maintenance

Basic Maintenance of a vehicle includes engine tuning, parts repair and replacement, Tire alignment & pressure check, and lubricants replacement. We specified our research to the routine maintenance that included air filter change, tire pressure, tire alignment and cleansing of spark plugs among which the impact of air filter replacement was the most significant. Standard timeline for air filter replacement as identified by Honda vehicle manual (Honda, 2015) is 10,000 km however the dusty atmospheric conditions throughout Pakistan restricts that timeline to only 3,000-5,000 km. Moreover, clogged up air filters cause significant decrease in engine's power (Sudden lag & thrusts during acceleration) and decreased fuel efficiency. Our findings were in lined with the research of West et al., (2009) who stated that the replacement of fully clogged air filter resulted in 5-6% increase in fuel economy. Analysis of our research revealed the following trend in Fuel economy in km/Liter.

1. 15.39 Km/liter: At or before 2000 km drive averaged to 15.39 km/lit
2. 14.65 Km/Liter: Between 2,000-3,500 km drive averaged to 14.65 km/liter
3. 14.00 Km/Liter: After 4000 km driver

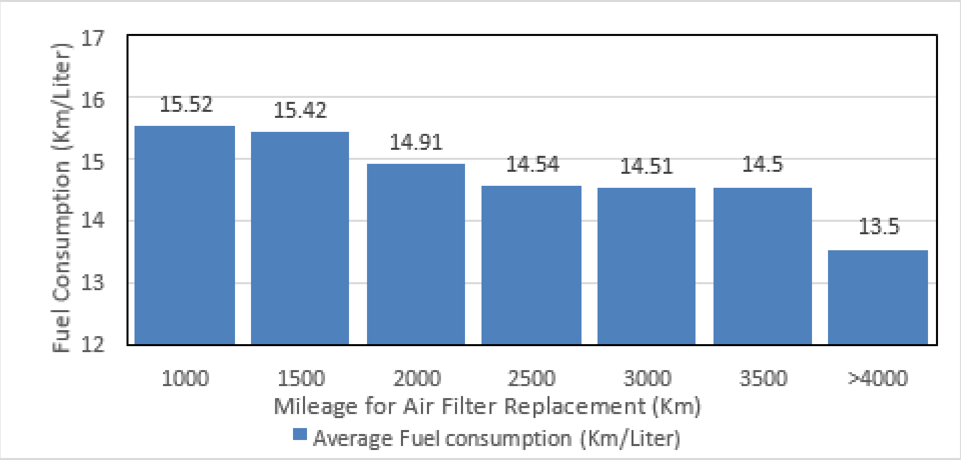

Figure 1: Relation between Air Filter Replacements and Fuel Consumption (Km/Liter)

2.2. Effect of Mileage of Tires

Normal speed for a passenger car on highway as suggested by Motorway Rules is 110-120 km/hr. At such high speed, a weak Tire could result in extremely hazardous accident that might lead to sever casualties and fatalities. Tire manufacturers therefore recommend a compulsory tire check-up after every 5000-6000 km drive and a complete replacement after 40,000-60,000 km mileage or 3 years of use. The annual manual report of Bridgestone highlighted that their premier tires could last up to 5 years of usage on normal road conditions (Bridgestone, 2016). Present research identified the average fuel consumption of 15.32km/liter for tires of running mileage between 5,000- 10,000 km. A decrease of 4.2% was observed for vehicles of Tire mileage between 20,000 –30,000km. However, when the Tire mileage surpassed 40,000 km, the data revealed an average fuel consumption of 13.6 km/liter ascertaining a decrease of 11.8%.

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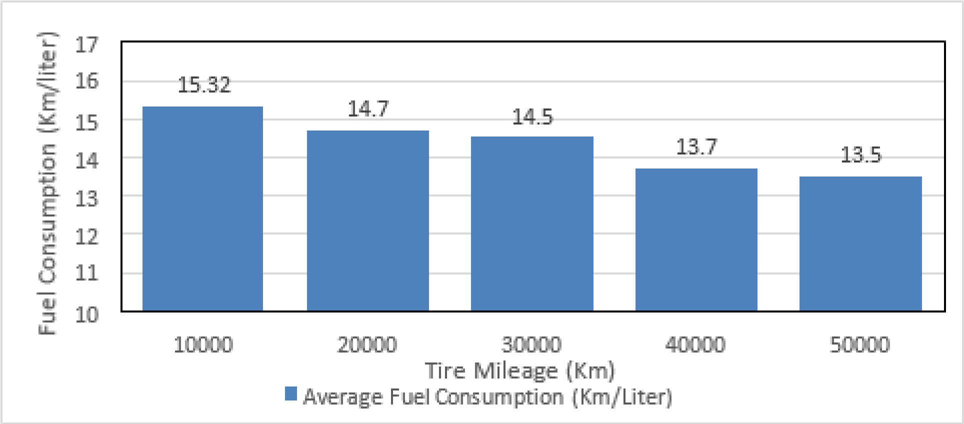

Figure 2: Relation between Tire Mileage and Fuel Consumption (Km/Liter)

2.3. Effect of Engine Oil

Engine's life is significantly dependent on the type of Engine oil used and the timeline of its replacement. According to a research conducted by Forbes columnist Gorzelany at al., (2013) Honda Civic i-Vtech has a life expectancy of 400,000 km on normal fully paved carpeted roads. This Mileage can only be reached with careful maintenance of the vehicle especially with regard to Engine oil replacement. Present research indicates that for vehicles having mileage of 50,000 km or below, the timeline of Engine oil replacement can reach up to 5000km. However, for vehicles with mileage exceeding 50,000 km, the fuel consumption increased significantly with the increase in timeline of Engine oil replacement, ultimately reaching down to an average of 10 km/liter. When the relationship of Engine oil replacement with fuel consumption was compared and analyzed with other factors, it was revealed that the effect of Engine oil replacement was the most significant among all. Moreover the data revealed that the vehicles with oil change at 5000 km provided an average Fuel consumption of 13.4 which is 28.1% higher than the fuel consumption of vehicles with average Timeline of Engine oil replacement at 2500 Km. On the other hand, vehicles With Engine oil replacement below 2500 km revealed a minute impact of .05% increase on Fuel efficiency.

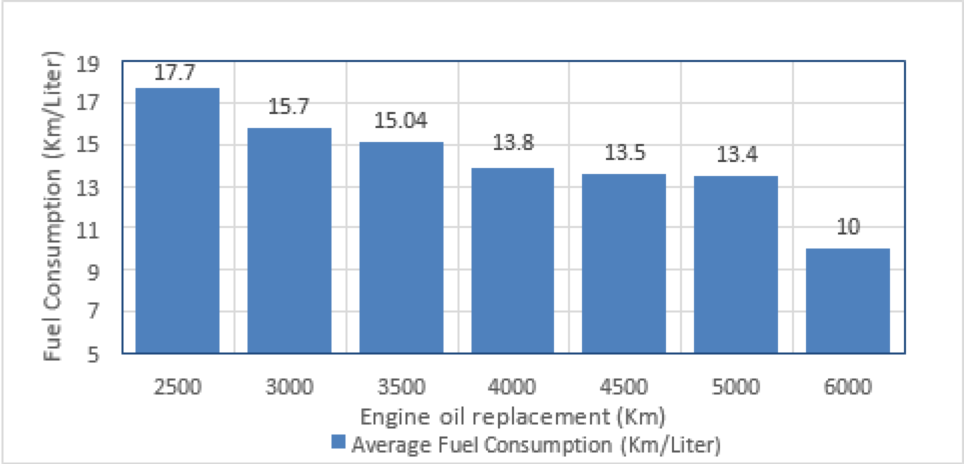

Figure 3: Relationship between Engine Oil Replacement and Fuel Consumption (Km/Liter)

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2.4. Effect of Vehicle's Mileage

Technological development has obligated automobile manufacturers to design vehicles with engines that could last more than 400,000 km of mileage under normal circumstances (Jim, at.al 2013). An automobile can surpass the design mileage only when manufacturer's driving manual is taken in consideration regarding maintenance of SI engine, it parts and lubricant replacements. When any of the factors are overlooked, the life of the engine deprecates in the long run. According to the data base of an online automobile dealers like TRED, vehicles surpassing 160,000 km are prone to engine repair and parts replacement. Hence 160,000 km should be the maximum limit for purchasing a used vehicle (TRED 2013). In a similar manner, the present study established 160,000 km as the maximum mileage limit for the test model. Evaluation of the data revealed that from 40,000-100,000 km the vehicles exhibited a steep decrease of 24.1% in fuel efficiency, starting from 17.5 km/liters to 14.1 km/liters. However vehicles with mileage of 100,000-130,000 km demonstrated a continual fuel consumption of 14 km/liter, which further ascended to 13 km/liter after surpassing 140,000 km, indicating an overall decrease of 34.6%.

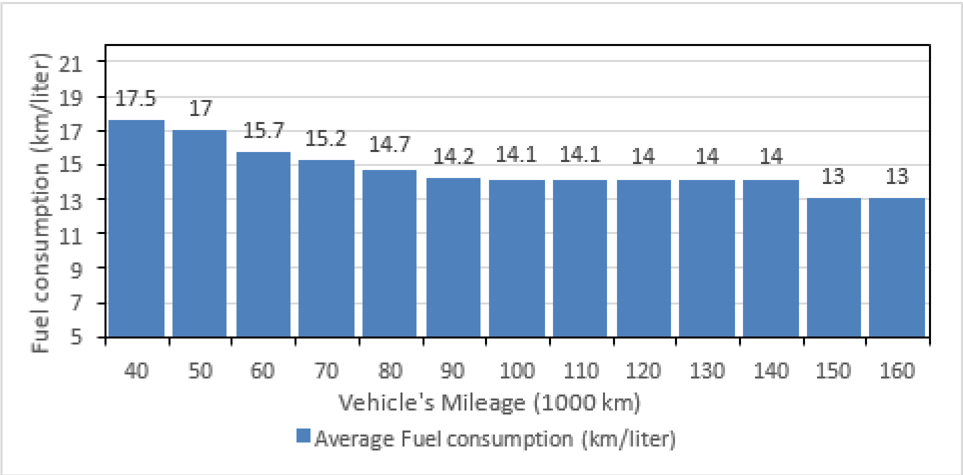

Figure 4: Relationship between Vehicle's Mileage and Fuel Consumption (Km/Liter)

2.5. Effect of Ownership

In the inception of the research, it was anticipated that the status of current ownership would not have a significant impact on engine's life and fuel efficiency. However, the observed cases revealed that among the major factors that considerably affect the fuel efficiency, vehicle ownership is also one of them. On the basis of ownership as in the total number of owners that had previously owned the vehicle, the sample was divided into two model categories.

1. Model A: The vehicles that were previously owned by 2 or less individuals
2. Model B: The vehicles with were previously owned by 3 or more individuals

Analysis of model A revealed an average fuel consumption of 15.2 km/liter while Model B, indicated a decline of 6.7 % at average fuel consumption of 13.8 km/liter.

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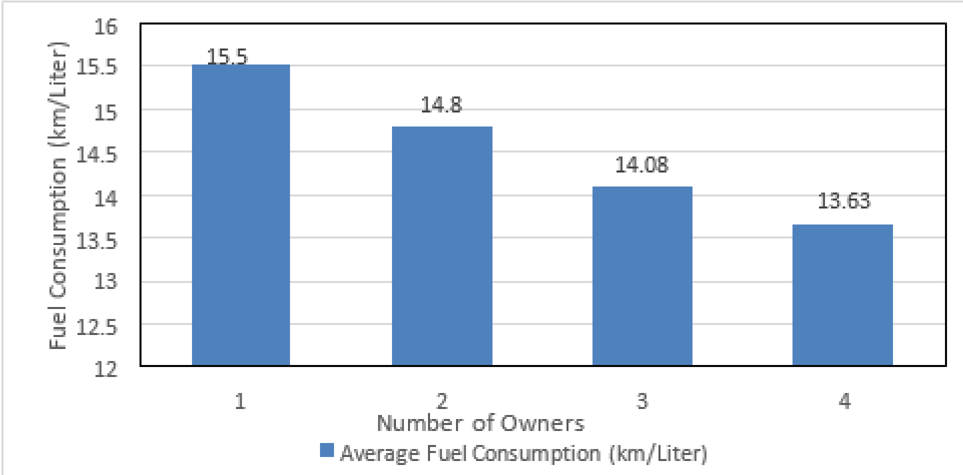

Figure 5: Relation between vehicle's Total Number of Owners and Fuel Consumption (Km/Liter)

It can be observed that as the owners increased, the fuel economy decreased significantly from 15.5 Km/Liter with 1st owner to 13.63 Km/Liter with 4th owner, indicating a decrease of 14 %. Mega car dealers like TRED (2015) identified that a vehicle is normally sold out by first owner at average mileage of 50-60,000 km or 3 years or whatever comes first, If, during this time the vehicle is sold more than twice, then there could be numerous non-controllable faults and failures in the vehicle that adversely affect the fuel economy and the life span of the engine, compelling owners to sell the vehicle in shortest time. In the present research numerous cases were observed in which the vehicles of Model B, even though having running mileage of 70,000-80,000 Km showed a considerable decline in Fuel efficiency when the number of owners exceeded 3, suggesting a pattern similar to the one noticed in the research conducted by TRED (TRED 2015).

3. DISCUSSION

In order to deliver an adequate statistical insight of the data collected through surveys, descriptive statistics were applied on the data in its initial stages (Table 1). In addition, to evaluate the multi-Collinearity between independent variables, tolerance and variance inflation factors were computed and those variables were excluded which had VIF >10 and TOL <0.1 (Table 2).

Table 1: Descriptive Statistics of Response Variable and Predictors

Variables	Mean	Std. Deviation
Fuel Efficiency	14.81	2.27
Mileage	89.91	26.74
Ownership	2.36	0.96
Tire mileage	24.25	10.98
Engine oil replacement	3.91	0.783
General Maintenance	2.42	1.115

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Table 2: Multi-Collinearity Diagnostics Indexes

Independent Variables	Collinearity Statistics	
	Tolerance	VIF
Mileage	0.820	1.220
Oil Change	0.906	1.104
Maintenance	0.802	1.243
Tires Running Mileage	0.906	1.1043
Total number of owners	0.836	1.194

Table 3: Results of Linear Regression at 95% Confidence level

Independent Variables	Coeff B	Std. Error	t-stat	sig	95% Confidence Interval for B	
					Lower Bound	Upper Bound
Constant	23.377	1.253	18.651	.000	20.874	25.874
Mileage	-0.022	0.008	-1.463	0.011	-0.03	0.005
Oil Change	-1.328	0.275	-4.685	0.000	-1.836	-0.74
Maintenance	-0.017	0.216	-0.081	0.960	-0.447	0.412
Tires Running Mileage	-0.004	0.02	-0.152	0.844	-0.043	0.037
Total number of owners	-0.575	0.242	-2.309	0.015	-1.039	-0.076

The model results revealed that among five examined variables, three variables were the most significant and thus were retained at 95 % confidence interval. Moreover, it was indicated that with an increase in the mileage of the vehicle, a decreased level of fuel efficiency was observed. Similarly, the model gave intuitive results for cases where the life of tires in mileage were a predominant factor of the reduced level of fuel efficiency.

4. RESULTS & CONCLUSION

The present research evaluated the impact of Vehicle's mileage, Timeline for Engine oil replacement & General Maintenance, Tires Mileage & Number of owners. The results identified the most important factor based on their significance in defining the overall fuel consumption of the vehicle. The data evaluated through regression model revealed that Engine oil replacement contributed 68.24 % while ownership as in No of owners that owned the vehicle, contributed 29.96 % in outlining the fuel consumption. However vehicle's mileage contributed 0.94%, air filter replacement contributed 0.66%, and tire's mileage contributed only 0.2% in defining the overall fuel efficiency of the test model. Hence this present research revealed that the vehicle's Fuel efficiency depends upon mileage which in turn profoundly depends on the timeline of Engine oil replacement and previous number of owners. Likewise the results suggest that the vehicles with Engine oil replacement before 2500 km on a persistent basis with total mileage below 100,000 km having maximum of 2 owners in the past would yield the highest fuel efficiency. Together these three factors contribute 99.14 % in defining the overall fuel efficiency of the vehicle. Moreover the average Fuel consumption in km/Liters can be predicted for any vehicle of mileage between 40,000-160,000 km by mean of the statistical equation obtained through linear regression.

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Fuel Consumption Equation (FC):

FC = $23.377 - 0.022\beta^1 - 1.328\beta^2 - 0.017\beta^3 - .004\beta^4 - .575\beta^5$

Here

β^1= Vehicle's Mileage (1000 Km)

β^2= Oil Change (1000 Km)

β^3= Maintenance: Air Filter replacement (1000 Km)

β^4= Tire Running Mileage (1000 Km)

β^5= Total Number of Owners

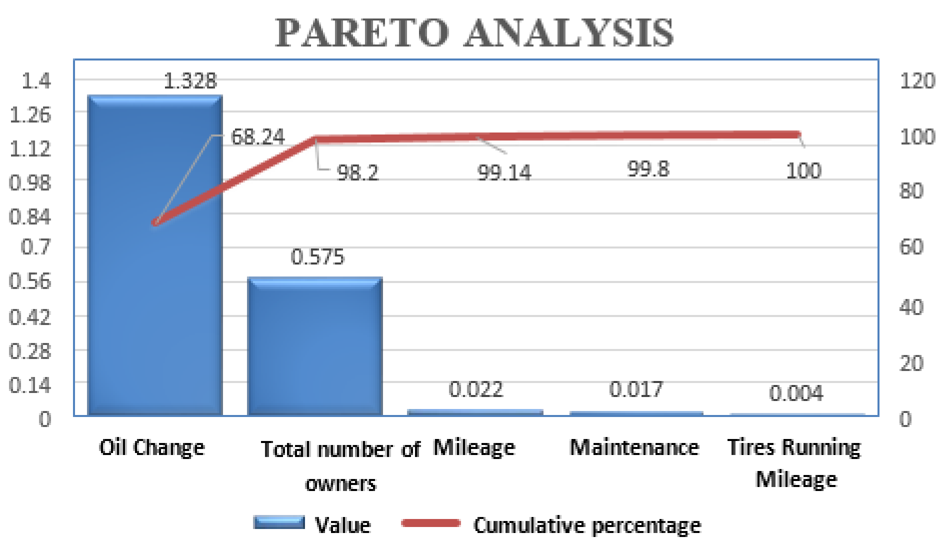

Figure 6: Individual and Cumulative Significance of Factors in Defining Fuel Efficiency

5. FUTURE WORK

Considering the effect of number of owners on fuel efficiency, it is recommended that further research should be conducted to evaluate the effect of driving behavior and driving conditions on fuel consumption. Moreover a study should be made to identify the effect of RPM on fuel economy, since Engine oil replacement is significantly dependent on the heat generation inside the engine that predominantly relies on RPM, which in turns depends upon the driving behavior of the driver. Hence a comprehensive study should be made to identify the relation between Driving behavior and RPM and their impact on fuel economy.

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ULTRASONIC SENSORS BASED AUTONOMOUS CAR PARKING SYSTEM

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ABSTRACT

In Modern era, many automobile companies are exploring the idea of fully automated vehicles and providing the customer the ease of comfortable driving. This paper presents an ultrasonic sensor based autonomous car parking system. The system has the ability to self-park the vehicle with coordination between the sensors and to likewise park the car through mobile phone application remote control. To achieve the purpose of autonomous parking the system searches for appropriate parking space, performs obstacle detection, PWM signals from the controller to the servo motors achieve parking. The car parking system proposed is a compact module that can be integrated into any vehicle.

Index Terms— Autonomous vehicles, autonomous car parking system, wireless controlled vehicle.

1. INTRODUCTION

A car or automobile is wheeled motor vehicle used for transportation. There are many types of cars in modern era such as manual car, semi autonomous, fully autonomous and hybrid car. Transportation is one of the main facilities that everyone needs in their daily life. After invention of car in late 1800s, the number of production of cars is growing rapidly [1] [2].

For most of the drivers parking a car in a small space seems difficult because it requires a series of forward and reverse motions and turns. Parking is always a great problem for aged people and unskilled driver. They cannot park a car properly especially in overcrowded area. Most humans find parallel parking to be difficult to master. There are many reasons for this, but this difficulty and the fact that many conscious parking spaces in urban environments require parallel parking and have lead to be the prime area of research for autonomous vehicles. Another issue of parking occurs during bad weather condition. Drivers can hardly find parking lot in this condition. So they often park a car improperly or usually collide with other object damaging their car. To overcome the above problems and make drivers comfortable, we will introduce and work on self-parking car system or autonomous car parking system. The proposed study will assist the driver in moving a vehicle from a traffic lane into parking spot. This new system could virtually revolutionize parking. According to research and literature review, many researchers have put their effort in developing in automated car parking system.

First ever prototype of autonomous parking was introduced 20 years ago by French institute INRIA. Most manufacturers such as BMW, Mercedes Benz, Audi, has introduced semi-automated parking system in their cars. Most major companies are still working on fully automated parking system. Few companies such as Nissan, Audi, Tesla has shown fully autonomous prototype but industries are expecting fully automated vehicle to begin availability by 2020 [3]. However, those systems are complicated, expensive and required expert maintenance. Therefore, it is necessary to design a module which is simple, cheap and can easily be installed in a car. There are different techniques to make self parking car possible. Some of the techniques used are fuzzy logic system [4], GPS technology [5], Bio-Inspired 1-D Optical Flow Sensors [6], LiDAR [7], Real time Image Processing [8].

The remaining of this paper is organized as following: Section 2 presents Materials and Methods followed by experimentation in Section 3.and finally Section 4 concludes the article.

2. MATERIAL AND METHODOLOGY

The proposed project will assist the driver in moving a vehicle from a traffic lane into parking spot. Many researchers have put their effort in developing an automated car parking system. However, their systems are complicated, expensive and require expert maintenance. Therefore, our final design will be a compact module of system which offers simple, low cost, easy to install and requires less maintenance.

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2.1. Control Architecture of Prototype

In Fig.1Vehicle Drive Unit is shown. Vehicle use DC gear motors of rear tires for driving purpose, these motors are inversely wired up with H-bridge, the rating of DC gears motor are 12V and 6.6 amps that makes it 80W which is then connected to controller. Secondly Steering Mechanism Unit is shown in fig. 1 where Vehicle use DC gear motor for front wheel and Steering mechanism, the motor is connected to mechanical structure which are parallel connected to both wheels and wheels turn simultaneously, the rating of DC gear motor are 12V and 4 amps on load that makes it approximately 48W, the DC gear motor is controlled through H-Bridge. The steering mechanism has 3 types of defined angle controlled by the microcontroller that is Extreme right turned steering, straight steering and Extreme left turned steering.

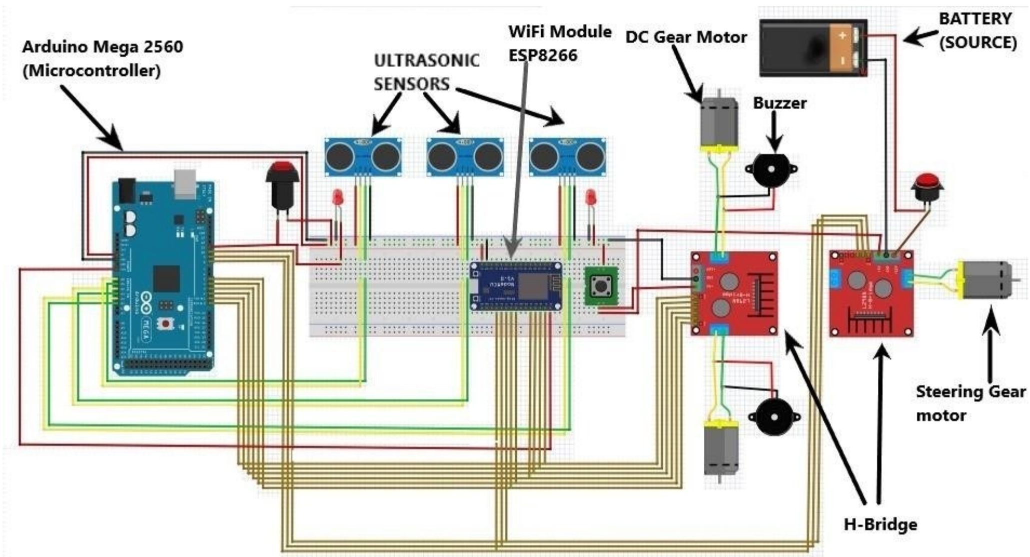

Fig.1. Initial Circuit diagram

Arduino Uno was used in experimentation, which is a microcontroller board based on the ATmega328. It has 14 digital input/output pins, 6 analog inputs. Arduino Uno is used as a master microcontroller to control Arduino Mega and ESP8266 NodeMCU. Similarly, the Arduino Mega 2560 is a microcontroller board based on the ATmega2560. It has 54 digital input/output pins, 16 analog inputs. Arduino Mega is slave controller in the project it is used to read data from Sensors and then give response to the H-bridge. H-bridge is being installed. The Shifting (reverse and forward, CW and ACW) of wheels and steering are controlled by H-bridge. The microcontroller gives electric signal pulse to H-bridge and similarly the H- bridge operates the DC gear motors. The most important component is Ultrasonic sensor. It measures the distance by sending out a sound wave at a specific frequency. The ultrasonic sensors are used for the obstacle detection and for searching appropriate empty space in the parking zone. Total eight sensors are used in the car, three sensors on left and right side of the car, one at the front and back of the car as shown in Fig 2.

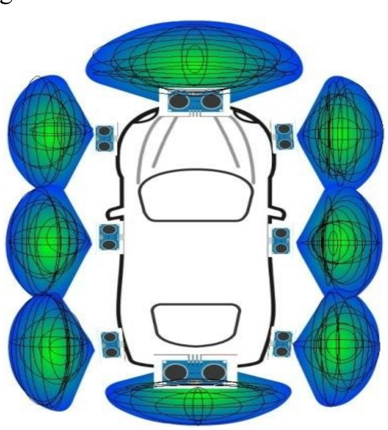

Fig.2. Ultrasonic sensors using in car

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2.2. Through Ultrasonic sensors

In this paper an intelligence parking system has been developed through Arduino controller. This will enable a car to perform a self-parking strategy, which is shown in Fig 3.

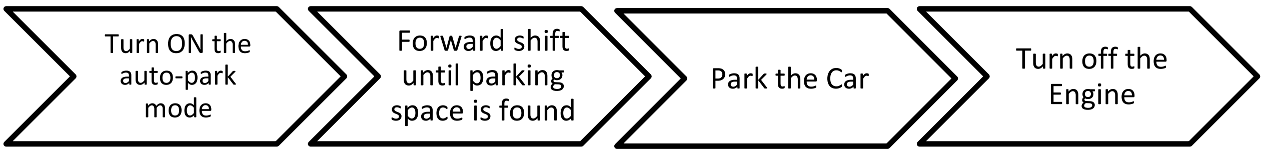

Fig.3. Parking Technique

2.3. Through Wi-Fi Module

ESP8266 NodeMCU is an open source Information of Technology (IOT) platform. It includes firmware which runs in ESP8266 Wi-Fi. The ESP8266 NodeMCU is used to control the vehicle through an IOS app.

The most important and complicated task for the vehicle is to understand its position and location and what to do next, to respond to these questions a vehicle has to self-localize the position, the driver has to provide some information regarding parking area and have to rest the vehicle parallel to other parked vehicle, while the sensors would start its own sensing of various measurements and detection.

The parking module has an activation button which calls the parking loop as shown in Fig 4. After activating all the sensors, the vehicle searches for the empty space such that the space is 1.8 times the actual length of the vehicle, if the free space is less then 1.8 times the actual length of the vehicle, then it tends to find other free space. Thus the vehicle parks itself in the desired free location in parking lot.

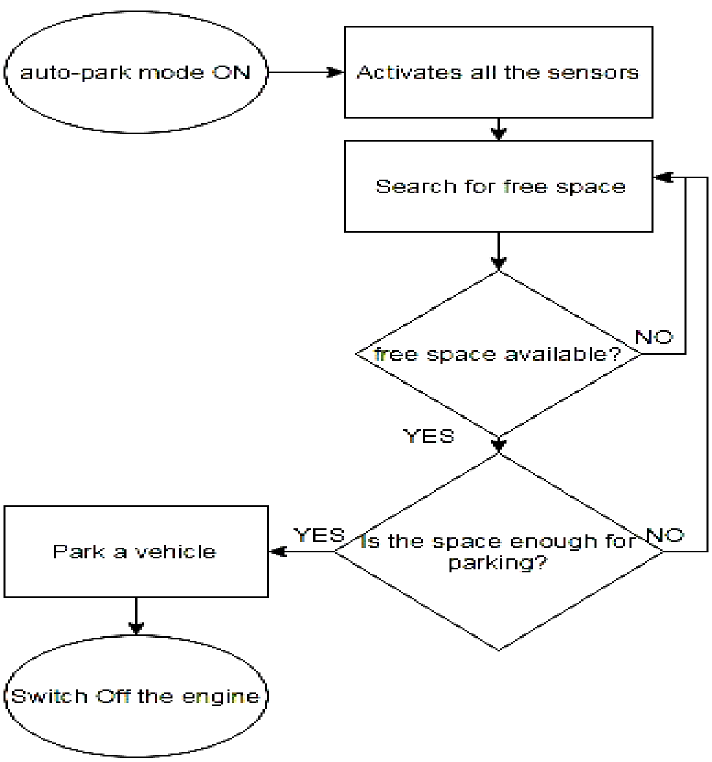

Fig.4. Flowchart Diagram

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3. EXPERIMENTATION

In this paper a prototype is being developed which can perform an autonomous parking system test. The same experimentation can be applied to a real car. In this experiment the test is based on final destination of a car. This experiment is performed through different stages. In first stage, the car searches for an empty space in parking lot. In second stage, it measures the empty space, whether the space is enough for parking or not. In the final stage it follow the command given through coding which allows the car to park by it-self. It follows the route given through different command and reaches its final destination as shown in Fig 5.

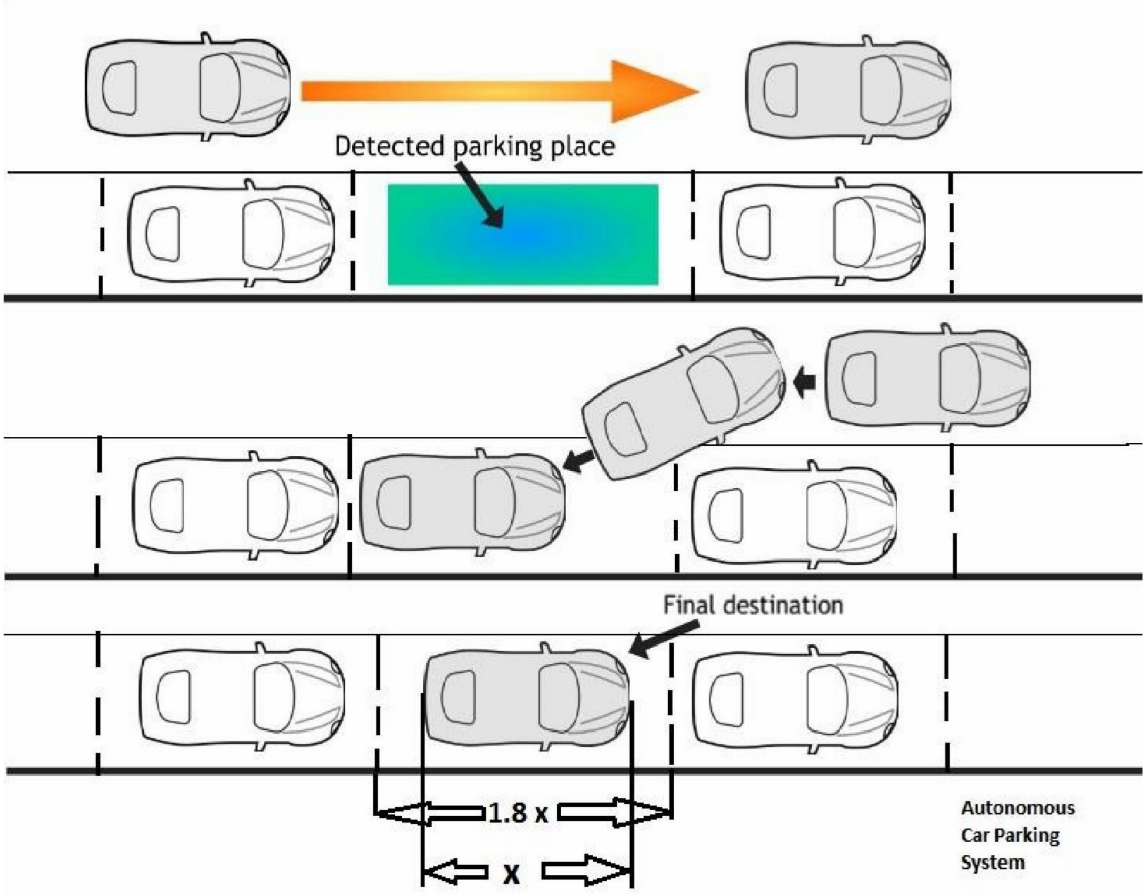

Fig.5. Parallel Parking Process (Undefined Space)

In first stage, whether ultrasonic sensors can differentiate between empty space and non-empty space. In second stage, it measured the availability of space available for car. The measurements were successfully taken and results were approximately equal to real measurement. In the final stage mechanism is controlled through Arduino. Following the commands, the car follows the route and is parked at final position. On Wi-Fi module the car was easily controllable through mobile app. It easily adjusted the car in small area through mobile application.

The proposed project is applicable and could be installed in any type of vehicle used in our daily life. The new drivers, disabled people, female drivers and especially aged drivers can take benefit from this system and also those who faces challenges in parking their vehicle during night. It is hopeful that this new system will virtually revolutionize parking scenario in future.

4. CONCLUSION

In this paper, work on prototype is being focused for autonomous car parking system. This simple module, which is explained in this paper, can easily be installed in a real car. This is a low computational-cost method for detecting and tracking a parking spot in real time based on ultrasonic sensors. The efficiency of this system can also be increased. Also self parking system is being implemented through remote control. This experiment showed that this requires less energy and can

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save huge amount of time. To avail this self-parking feature in a car one has to purchase a car by well known companies, so our project will make it easy for them to have this feature.

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CONTROL SYSTEM TO SELF REGULATE ADSORPTION & DESORPTION PROCESSES FOR SOLID DESICCANT DEHYDRATION UNIT

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ABSTRACT

Raw natural gas mostly carries significant amount of water contents due to existence of connate water in cavities of sedimentary reservoir rock. Hence, the natural gas must be treated to meet the gas sales contract and to supply high quality dry and clean natural gas to consumers. Various gas dehydration technologies are employed in industries which include liquid desiccant absorption and solid desiccant adsorption. If cryogenic conditions are envisaged in LPG/LNG units downstream of dehydration where significantly lower water content is required, solid desiccant dehydration units are the first preference. Most solid desiccant dehydrators operate in a preset sequence based on fixed cycle time. As the capacity of the desiccant decreases with the passage of time, hence fixed timer based dehydration units may result in poor dehydration that could be a potential hazard to downstream cryogenic equipments. In this research a self-regulating control system is designed for optimizing the solid desiccant dehydrators by continuously monitoring internal health of the unit. Implementation of the proposed system will yield in efficient removal of water contents from natural gas along with more reliable operation and extended life of the desiccant.

Keywords: Control system, DCS, dehydration, cryogenic, desiccant, regeneration gas.

1. INTRODUCTION

Oil and gas reservoirs mainly comprises of multiphase stream of liquid and gaseous hydrocarbons that are initially separated in a separation unit. Once separated, gas stream mainly constitutes of raw natural gas in conjunction with several other hydrocarbons that mostly includes ethane, propane, butane, pentane etc. It also contains non-organic compounds such as hydrogen sulphide (H_2S), carbon dioxide (CO_2), nitrogen, helium etc. It is worth mentioning that natural gas mostly contains substantial amount of water vapors due to the presence of connate water in holes of sedimentary reservoir rock (Gandhidasan et al., 2001). Natural gas processing comprises of separating various hydrocarbons and associated fluids from the raw natural gas to produce and deliver high quality dry natural gas. Water vapors in natural gas during its processing and transmission can cause several operational hitches including pipeline blockage due to creation of gas hydrates, reduction in capacity of pipeline due to existence of liquid water and corrosion of pipeline network (Ahmadi et al., 2014). Additionally, the heating value of natural gas reduces because of non- combustible nature of water if present in high concentration (Kurz et al., 2004). Therefore, dehydration of natural gas is essential to overcome the adverse impacts associated with the presence of water in natural gas.

Dehydration process results in drop of natural gas water dew point, which refers to “The temperature and pressure at which first drop of water vapor condenses into a liquid.” Thus, dew point alteration is an important treatment process for the natural gas that is used for reducing water contents (Rahimpour et al., 2013). Further, it is widely used as a parameter for quantifying water contents in the natural gas that decreases as water vapors are removed and vice versa.

Dehydration units are used for removal of water contents from the natural gas to lower its water dew point. Various natural gas dehydration technologies are employed but the two major options available in industry to perform dehydration is liquid desiccant absorption and solid desiccant adsorption (Farag et al., 2011). Both liquid & solid desiccants have affinity towards water molecules in the gas phase, causing mass transfer of water to the desiccant. Irrespective of the selected technology, the dehydration process performance is favored at high pressure and low temperature (Anyadiegwu et al., 2014).

Additionally, removal of water contents from the natural gas is necessary to meet gas sales contract and to provide dry and clean natural gas to consumers. Globally, requirement of minimum acceptable level of water contents in the natural gas is not fixed but varies in different regions. As per international standards, the minimum amount of water contents in Southern

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USA, Southeast Asia, Southern Europe, West Africa and Australia is 4-7lbs./mmscfd (pounds of water per million standard cubic feet per day). In Northern USA, Canada, Northern Europe, Northern &

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Central Asia it is 2-4 lbs./mmscfd. In addition to this, the requirement for cryogenic processes (LPG/LNG plants) is less than 0.05 lbs./mmscfd.
For recovery of liquefied petroleum gas (LPG) from the natural gas (if present) and production of liquefied natural gas (LNG), a significantly lower water content is required as cryogenic conditions are visualized in LPG/LNG units downstream of dehydration. This is to prevent the risk of damaging the cryogenic unit equipments (e.g. turbo expander, chillers, cold boxes (heat exchangers)) as a result of icing or hydrate formation (Klinkenbijl et al., 1999). Liquid desiccant absorption technology cannot meet such lower natural gas water dew point, whereas solid desiccant adsorption has the capacity of achieving extremely low specifications making them feasible to be employed upstream of LPG/LNG units for removal of water contents. In solid desiccant dehydration process the desiccant adsorb water contents during adsorption cycle and subsequently regenerated with hot dry gas during desorption cycle (Akpabio and Aimikhe, 2012). It is a batch process that requires multiple dryers in which adsorption and desorption cycles are switched accordingly. It is worth mentioning that focus of the ongoing research is on choosing the most suitable desiccant to optimize the natural gas drying process. In addition to this, the operation of most solid desiccant dehydrators is based on fixed cycle time. However, the desiccant capacity is not fixed but it changes with time that arise the need for designing a self-regulating control system for optimizing the solid desiccant dehydration units. In the current research a control system is designed for switching adsorption and desorption cycles between dryers based on real time process parameters.
In the following section the background of the dehydration process, various types of dehydration units are revealed and two types which are widely employed in industries have been briefly examined. In section 3, the “AS-IS” system is briefly discussed and its short comings emphasized. Furthermore, in section 4, the proposed “TO-BE” system, methodology, design scheme and control philosophy are discussed and a brief description is given. In section 5, results and discussion is given. Conclusion and future work is presented in section 6 followed by acknowledgment and references.

2. BACKGROUND

In oil and gas sector several techniques are employed for dehydration of natural gas that includes liquid desiccant dehydration, solid desiccant dehydration and refrigeration or condensation. The first two methods involve mass transfer of water contents to liquid or solid desiccant while in third method natural gas is cooled down to liquefy water contents and subsequently knock out the liquid water in a separator. Additionally, there are other specialized dehydration technologies that are less commonly utilized such as membrane technology, vortex tube and supersonic processes. It is worth mentioning that liquid desiccant and solid desiccant dehydration are the preferred methods that are widely used in industries and are briefly explained:

2.1 Liquid Desiccant Based Dehydration Units

In liquid desiccant dehydration units raw natural gas is passed in counter flow direction through certain liquids that have tendency towards water. As a result, water contents are absorbed by the contacting liquid. This process is called absorption. A number of liquids such as $CaCl_2$, LiCl (lithium chloride) and glycols can be utilized as a liquid desiccant. Most widely used liquid desiccants throughout oil and gas industry are glycols because of their high hygroscopic nature and low vapor pressure. Additionally, they have high boiling points along with low solubility in natural gas. TEG (tri-ethylene glycol) being the most useful, reliable and cost effective desiccant having greater ability to achieve required dew points at low operating cost has gained worldwide recognition (Gandhidasan et al., 2001). The process of absorption is carried out in a glycol contacting tower having multiple trays installed to increase the contact time of raw wet natural gas & TEG, both flowing in counter flow direction. TEG is sprayed from the top inside the contacting tower that absorbs water contents from natural gas and flows out from bottom of the contacting tower as shown in Figure 1. Enriched TEG is then passed through an internal heat exchanger, installed at the top of still column. To separate the flash gases from TEG, it flows into a flash separator. After separation, TEG is then passed through cold side of the TEG/TEG heat exchanger and subsequently into the reboiler where temperature of TEG is increased to vaporize the water. However, care must be taken not to heat TEG beyond its decomposition temperature. Once the TEG is free of water contents it is send back to the top of contacting tower by means of a pump through hot side of the TEG/TEG and natural gas/TEG heat exchangers. The entire process briefly explained above is shown in Figure 1.
However, several working issues are associated with dehydration units using glycol as a desiccant. Glycols are degraded due to presence of any type of foreign matter such as dirt, filth, scale and iron oxide. Glycols could lose its effectiveness if heated at high temperature producing decomposition products in the form of sludge. If any liquid hydrocarbon along with natural gas enters the glycol dehydrator, severe foaming of glycol solution may possibly take place. Pumping of viscous glycol is not easy, as very concentrated glycol solutions at extremely low temperatures turn out to be more viscous. Moreover, fugitive emissions, soil pollution and used glycol discarding issues are the major environmental and safety hazards associated with glycol dehydrators. Research is presently in progress to devise certain procedures for reducing these emissions and methods for proper disposal of used chemicals (Rueter, 1996).

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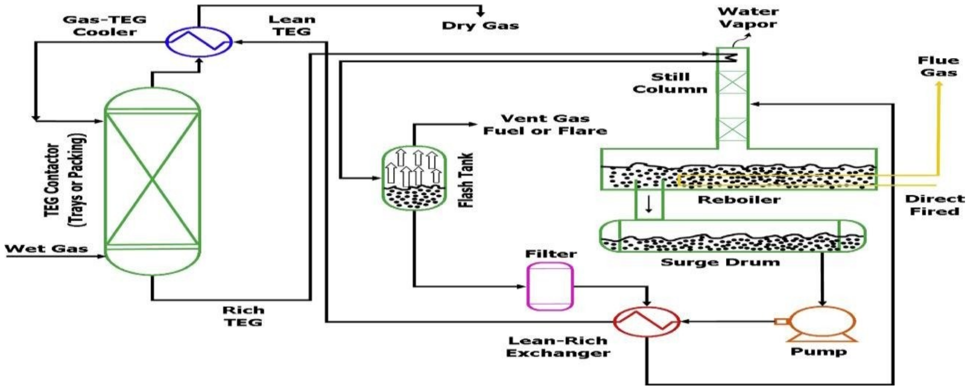

Figure 1. Scheme of absorption dehydration "Adopted from (Ahmadi et al., 2014)"

2.2 Solid Desiccant Based Dehydration Units

Adsorption is a process in which molecules of wet gas interact with solid desiccants that have affinity towards water molecules eventually results in condensation of water vapors on its surface. In natural gas dehydration using solid desiccant, water molecules are adsorbed by the desiccant thereby knocking it out from the natural gas. It is worth noting that interaction of water content with the desiccant surface is due to physical force of attraction. The capacity of the desiccant is directly proportional to natural gas pressure and declines with its temperature (Netusil and Ditl, 2011). Most often, there are requirements of very low water contents in natural gas that can only be achieved by the process of adsorption as it is capable of attaining extremely low dew points (as low as -256°F) over a wide range of working conditions (Nastaj and Ambrożek, 2015).

Desiccant is a strong solid drying material having high bulk density with enormous number of small pores on its surface to hold huge amount of water vapors in minimum possible time. Desiccants are easily and economically regenerated. Due to high mechanical strength, the desiccant retains its shape and volume over a large time period. They also possess very small resistance to gas flow across the dryer bed, hence pressure drop across the dryer is minimum (Nastaj and Ambrożek, 2009). Alumina/Silica based desiccants and molecular sieves (synthetic zeolites) are the most frequently used solid desiccants in oil and gas industry (Gandhidasan et al., 2001).

Natural gas drying is a continuous operation so the adsorption unit typically consist of multiple dryers in cyclic operation as shown in Figure 2. Two different cycles must be consecutively accomplished in every dryer including adsorption and desorption. In solid desiccant dehydration units, dryers always work intermittently. Normally, one bed dries the incoming wet natural gas in adsorption cycle while the other is being heated and afterwards cooled to remove the adsorbed water vapors in desorption cycle. A hot oil heater is usually installed to provide required heat for desorption. To avoid floating and channeling of desiccant bed as a result of high velocity of feed gas, the wet natural gas is injected from top of the dryer. Regeneration gas that is normally at high temperature is introduced from bottom of the dryer to ensure complete removal of water contents during desorption cycle. For efficient dehydration, the dryer must be swapped to desorption cycle before it becomes saturated with water. The efficiency of desorption cycle depends on the flow and temperature of regeneration gas that is a side stream of dry natural gas taken from downstream of the dryer (Ruud H. M. Herold, 2017). Regeneration gas flow requirement may be increased and adsorption cycle may require early swapping of dryers once the solid desiccant adsorption unit is not capable of meeting reduced water dew point (Netusil and Ditl, 2011). The complete process in solid desiccant adsorption unit is illustrated in Figure 2.

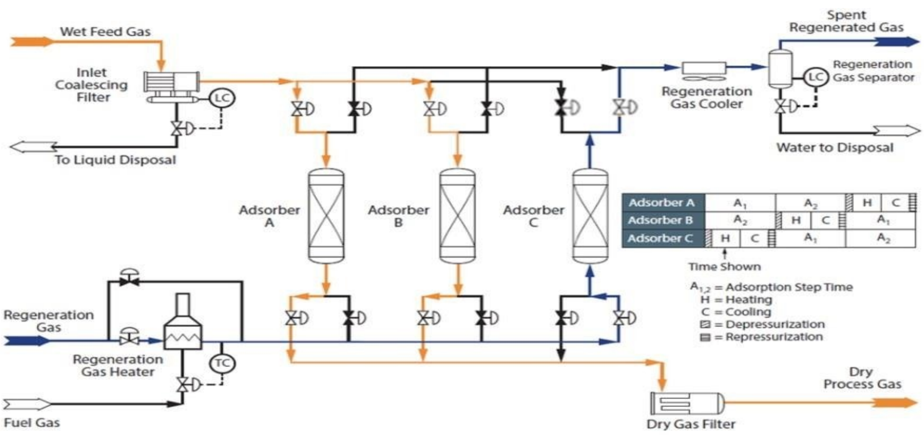

Figure 2. Scheme of adsorption dehydration "Adopted from (Malino, 2015)"

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Solid desiccant based dehydration technologies have already been widely used throughout industry for decades to separate water contents from the natural gas. The emphasis is usually at the core of the adsorption process, i.e. selecting the best and appropriate desiccant to optimize the drying process (Aronen, 2011). Currently in solid desiccant dehydration units, efforts are being carried out on choosing the most suitable desiccant and predicting its performance for achieving the desired results. In addition to this, different studies have been performed for estimation of water contents in natural gas and improvement of dehydration performance by optimization of operating conditions (Baghban et al., 2016). To some extent, work has been done on automation of switching the dryer on adsorption mode from adsorption phase into regeneration heating and then cooling phase in a preset sequence based on fixed cycle time (Yin et al., 2014).

3. AS-IS SYSTEM

Presently all sequences of different cycles in solid desiccant dehydration units also known as molecular sieve adsorption units are controlled based on timers. Several switching valves are installed at the inlet and outlet of each dryer to control the cycles involved. These valves plays a very vital role in guiding streams of natural gas in between dryers, hence switching dryers from an adsorption phase into regeneration heating & then cooling phase in a preset sequence. These valves are sometimes called sequencing valves. Depending on the installed molecular sieve adsorption system, cycling frequency may fluctuate. Usually, switching valves operates three to four times a day depending upon the cycle time. The timer based control system is designed so that the adsorption cycle will run for a fixed amount of time, controller will switch the dryer from adsorption to regeneration heating mode of desorption cycle once the time is completed, where heating of natural gas is carried out with hot oil heater (shell and tube type heat exchanger). Subsequently, regeneration heating mode will also be switched to cooling mode of desorption cycle after a preset amount of time, where cooling of the dryer bed is carried out through dry natural gas that is taken from the downstream of dryer. As the process of adsorption is favored at high pressure and low temperature, hence chilling units are usually installed upstream of dehydration unit that reduces the temperature of feed gas (normally 75-95 °F). Typical timer values of different cycles for the "AS-IS" system are: a) Adsorption or drying cycle = 8 hours, b) Regeneration or heating cycle = 4 hours and
c) Cooling cycle = 4 hours.

When the desiccants are fresh, excess capacity is available for adsorption but due to fixed cycle time, it is not fully utilized as shown in Figure 3. Under-capacity operation of the natural gas drying unit will increase number of regeneration cycles that eventually results in reduced life of the desiccant. It is also worth mentioning that water removal capacity of the desiccant decreases with the passage of time (Ruud H. M. Herold, 2017), so operation of switching valves based on a fixed cycle time (timer based) will result in poor dehydration that can be a potential hazard to downstream cryogenic equipments. Proper designing of dehydration unit is important to enhance the lifetime of dryers while steadily meeting the performance requirements in terms of achieving required dew point, internal health monitoring, adsorption time and timely switching cycles accordingly (Terrigeol et al., 2015).

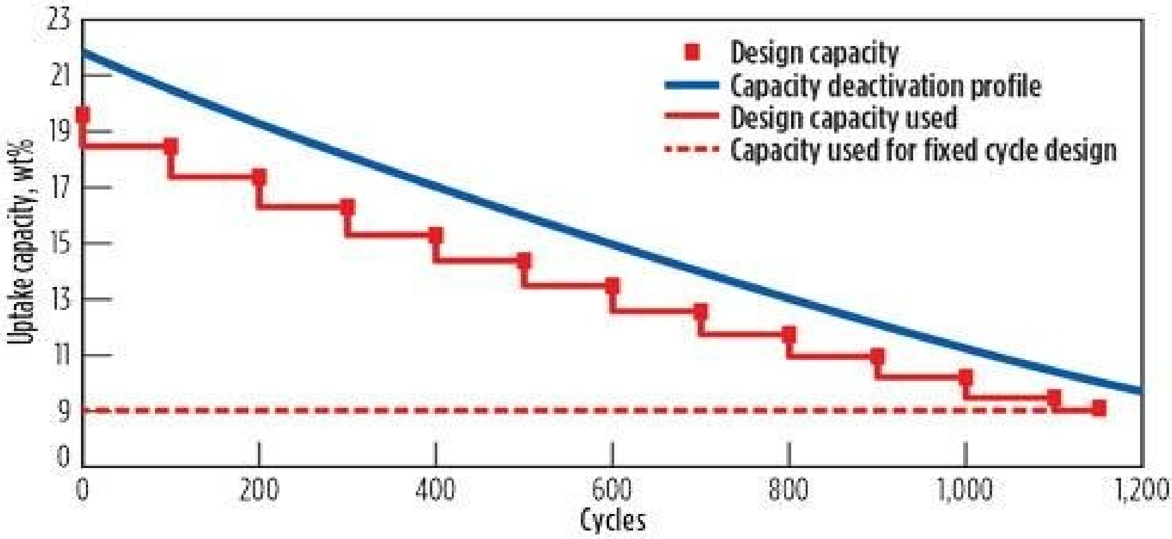

Figure 3. Capacity of the desiccant "Adopted from (Ruud H. M. Herold, 2017)"

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4. PROPOSED TO-BE SYSTEM

As in the existing system design, adsorption and desorption cycles are swapped in between dryers based on fixed cycle time where the role of real time control based on process parameters is not considered. Additionally, monitoring of internal health of the desiccant is not performed which is a potential threat to downstream cryogenic plants. Henceforth, in the proposed system, continuous monitoring of internal health of the desiccant and control of switching valves for swapping different cycles between dryers through real time process parameters will support the use and development of more reliable, cost effective and efficient dehydration process that is very critical for achieving the required dew point and safety of downstream cryogenic equipments. Implementing the proposed system will also result in extended life of the desiccant.

4.1 Proposed Methodology

As in oil and gas industry there are huge numbers of I/O's so concept of distributed control system (DCS) is mostly followed. Based on existing practices, the proposed system will be designed following the same concept of distributed control system. Hence, self-regulating control architecture will be designed and implemented using DCS. The data from field sensors & actuators that are directly connected to the DCS will be taken and processed. Control logic will be triggered based on the data received for switching from adsorption cycle to regeneration heating and then cooling phase of desorption cycle by swapping dryers accordingly. Subsequently modelling and simulation will be carried out in DCS to verify various plant parameters. Further to make different process parameters visible, graphical user interface (HMI) will be designed and developed in DCS. The block diagram for the proposed methodology is shown in Figure 4:

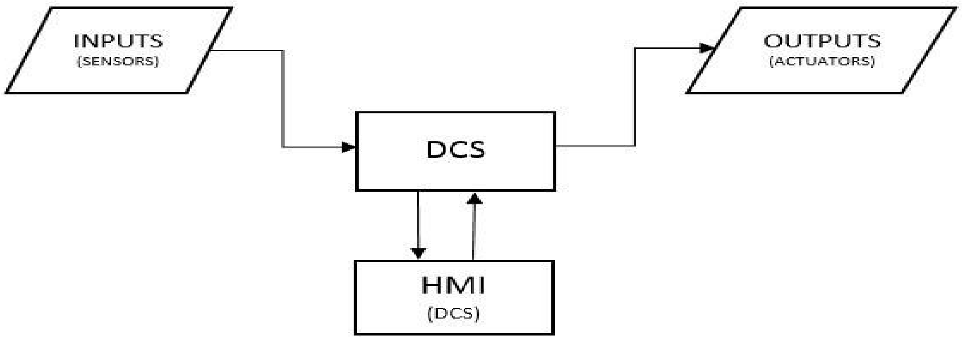

Figure 4. Proposed block diagram

4.2 Proposed Design Scheme

The proposed design consist of three molecular sieve dryers working simultaneously, swapping and self-regulating based on real time process conditions. The molecular sieve dryers are working on temperature swing adsorption (TSA) process. Each dryer has four control valves for directing the feed gas and regeneration gas streams. Three moisture analyzers are proposed at 50%, 70% and 90% of dryer bed length to continuously monitor the internal health of desiccant. These moisture analyzers are key indicators for swapping different cycles in between available dryers. Pressure transmitters are proposed to be installed at feed gas inlet of each dryer. Temperature transmitters are also proposed at both regeneration gas inlet and outlet of each dryer. To detect the blockage of molecular sieve dryers differential pressure transmitters are also proposed at each dryer. In addition to this, the scheme for desorption cycle consist of two compression units (one operational, one standby) for boosting the pressure of regeneration gas for reinjection in the system. A hot oil heater along with a preheater is also proposed for rising the temperature of regeneration gas. A cooler is proposed for condensing the water contents after dryer and a knock out vessel for separating the condensed water from the regeneration gas so that dry gas can be reinjected back in the system. Additionally, four control valves are also installed for isolating the heater, preheater, both heat sources and whole dehydration unit. The proposed design scheme is shown in Figure 5.

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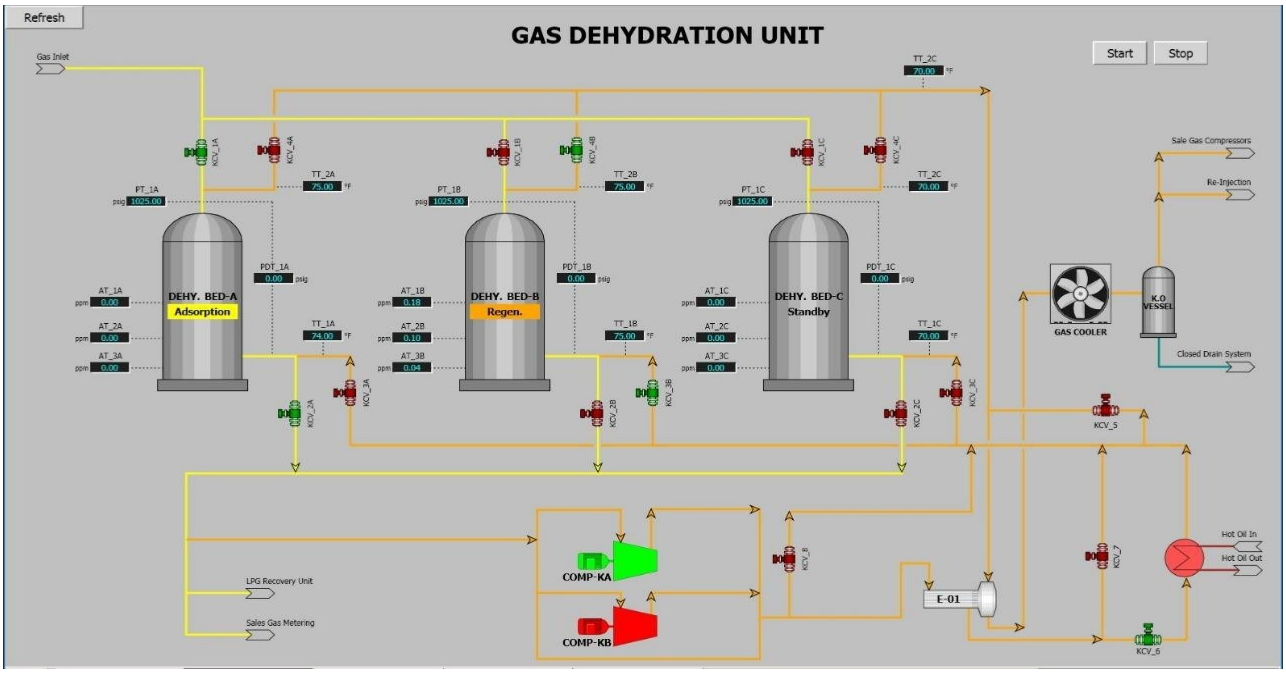

Figure 5. Proposed design scheme for gas dehydration unit

4.3 Proposed Control Philosophy

To start the gas dehydration unit, initially all switching valves will be closed. It is assumed that dryer A is ready to take the raw/wet natural gas feed while dryer B needs to be regenerated. At the start signal, feed gas inlet and outlet valves of dryer A will be opened putting it on adsorption mode while inlet and outlet valves of dryer B will be opened putting it on regeneration heating mode as shown in Figure 5. Regeneration gas is taken from downstream of dehydration unit and is passed through a hot oil heater to increase its temperature before entering dryer B. At the beginning of hot blowing, water vapor adsorbed in the molecular sieve will be heated and took away by regeneration gas, so initially the regeneration gas temperature at the outlet will not rise because of latent heat of vaporization required for water contents to vaporize, but it will rise gradually as hot blowing continues. When the outlet temperature of regeneration gas no longer rises, it indicates complete removal of water contents from the dryer. As regeneration gas temperature difference between molecular sieve dryer B inlet and outlet is equal to 30^0F, hot blowing can be stopped, control logic will be triggered and heater will be isolated. Now desorption cycle of dryer B enters in the cooling mode. Cooling process is performed by the same regeneration gas as it is already at low temperature due to chilling unit installed upstream of dehydration unit to knock out heavier hydrocarbon in liquid form. Molecular sieve dryer temperature will gradually start to decrease as heat is taken away by the cooling gas. As the temperature of regeneration gas at outlet of dryer B equals to 80 ^{0}F, control logic will send the signal to open the regeneration gas bypass valve to divert the regeneration gas flow from the molecular sieve dryers, consequently regeneration gas inlet and outlet valves of dryer B will be closed putting dryer B in standby mode. When the moisture analyzer installed at 90 % of dryer A bed length reaches a value of 0.1ppm (part per million) then the control logic will monitor the value of moisture analyzer installed at 70% of dryer A bed length. As the value increases from 0.15ppm, control logic will terminate the adsorption cycle of dryer A and will swap the adsorption cycle to that dryer whose regeneration gas inlet valve is closed and which achieved standby mode earlier.

In the current sequence regeneration gas inlet valve of both dryer B and C are closed, in response the control logic will check the standby mode status of each dryer (currently dryer C attain standby mode earlier) and will switch the adsorption cycle to dryer C by opening feed gas inlet and outlet valves of dryer C and subsequently closing feed gas inlet and outlet valves of dryer A. Control logic will put dryer A on regeneration heating mode of desorption cycle by opening the dryer A regeneration gas inlet and outlet valves. Again, control logic will wait for regeneration gas temperature difference across dryer A. As the temperature difference equals to 30^0F, hot oil heater will be isolated and the dryer A will be switched to cooling mode. Subsequently, control logic will be triggered once the temperature of regeneration gas at outlet of dryer A equals to 80^0F, regeneration gas will be bypassed from the molecular sieve dryers. Thereafter, regeneration gas inlet and outlet valves of dryer A will be closed and dryer will switch to standby mode.

The adsorption cycle of dryer C will be terminated once the moisture analyzers installed at dryer C triggers the control logic and cycle will be switched again to that dryer whose regeneration gas inlet valve is closed and which achieves standby mode earlier. Presently dryer B satisfies the condition and will be set on adsorption mode. As soon as dryer B is on adsorption, control logic will put dryer C on regeneration mode. Hereafter, dryer C will be switched to standby mode after completion of desorption cycle. Dryer B adsorption cycle will be terminated by control logic and the procedure will continue in the same pattern accordingly. The control philosophy is illustrated in Figure 6.

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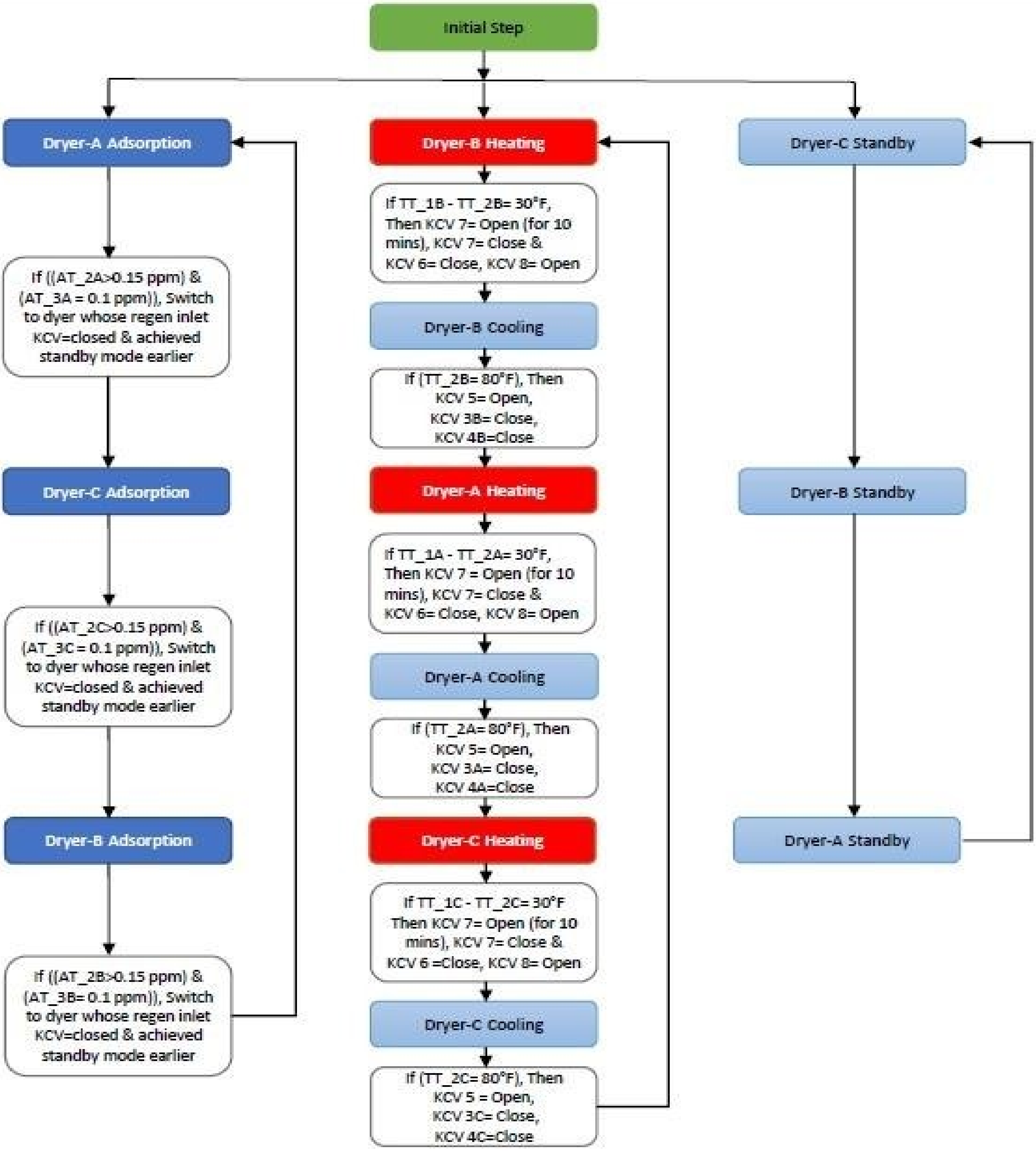

Figure 6. Proposed logic diagram for gas dehydration unit

5. RESULTS AND DISCUSSION

The capacity of the desiccant was determined experimentally by fabricating a test bench dryer as shown in Figure 7. The test dryer was regenerated by flowing high temperature natural gas having same operating parameters of "AS-IS" system. The water contents downstream of test dryer were measured by portable moisture analyzer. When the desiccant was completely regenerated, the weight of the test dryer was measured. Wet natural gas was then passed through the test dryer. Once the test dryer becomes saturated with water as detected by portable moisture analyzer, the final weight of the test dryer was again measured. The difference in weight of the test dryer is the quantity of adsorbed water contents by the desiccant. The quantity of desiccant loaded in the "AS-IS" system was already known and accordingly the water adsorbing capacity was calculated. Henceforth, utilizing 70% length of the dryer bed, results in significant increase in the length of the adsorption cycle.

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Figure 7. Fabricated test dryer

The development of control system to self-regulate the adsorption and desorption processes yields efficient removal of water vapors from the stream of natural gas along with reliable operation by continuously monitoring the internal health of the dehydration unit. Real time control based on operational parameters increased the length of the adsorption cycle thereby reducing the number of regeneration cycles as shown in Figure 8. The life of desiccants decreases over time as a function of number of thermal cycles, hence lifetime of dryers is significantly enhanced due to reduction of regeneration cycles. In addition, unplanned shutdown of the unit that could result in significant loss of production is minimized ultimately saving the company's revenue.

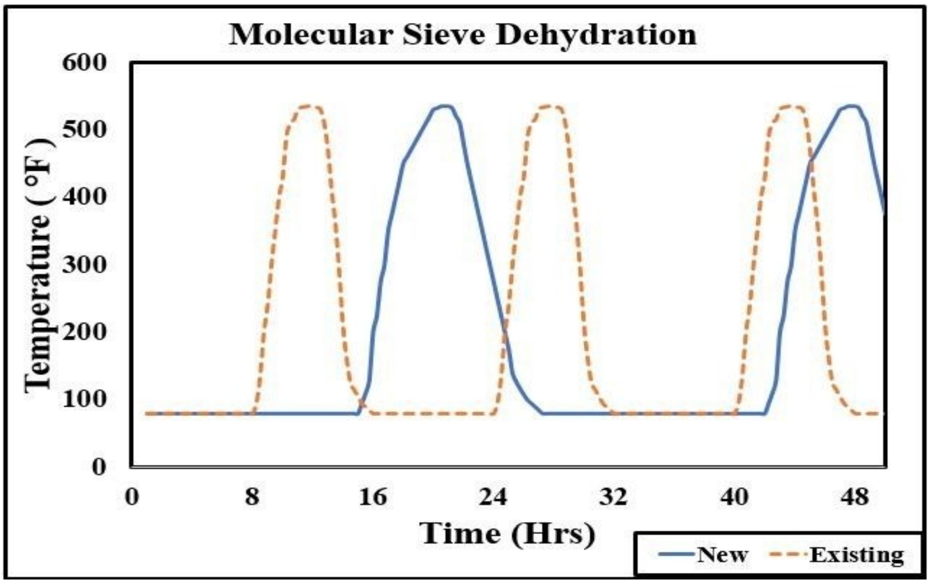

Figure 8. Comparison of "AS-IS" & "TO-BE" systems

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6. CONCULSION AND FUTUREWORK

Currently adsorption and desorption cycles in solid desiccant dehydration units are switched between dryers based on fixed cycle time where the role of real time control is not considered. Moreover, as monitoring of internal health of the desiccant is not performed which could jeopardize downstream cryogenic operations. Keeping in view the importance of dehydration process in LPG/LNG plants, there is a need for designing a control system framework required for the dehydration unit for continuous monitoring of real time process parameters and taking decisions accordingly. In the current research appropriate control system is designed for solid desiccant dehydration unit that is a key to optimize the dehydration process. Capacity of the desiccant was measured experimentally using a test bench dryer. Accordingly, the capacity of "AS-IS" system was calculated that revealed significant increase in length of adsorption cycle. Implementing the proposed system has significant potential to enhance the lifetime of dryers while efficiently meeting the requirements in terms of dew point, internal health monitoring, length of adsorption and desorption cycles, and timely swapping the cycles between dryers accordingly. In future, the proposed control system will be tested at a natural gas processing facility in collaboration with OGDCL Pakistan.

7. ACKNOWLEDGEMENT

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GRID-CONNECTED PHOTOVOLTAIC POWER SYNCHRONIZING SYSTEM

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ABSTRACT

Life needs energy for sustainability. Recently, energy demands have been considerably increased globally. Meanwhile, the resources of fossil fuels is depleting day by day. This situation appeals research community to pay attention to alternate resources, such as renewable (wind, tidal, solar etc.) energy. This study investigates integration and synchronization of national grid power and photovoltaic (PV) (acquired from solar panels). A novel approach, zero crossing detection technique is used for phase estimation and frequency calculation. Simulation results reveal the possibility of mixing and synchronizing of PV and grid power effectively.

Index Terms— Renewable energy, power electronics, synchronization.

1. INTRODUCTION

Energy has importance in everyone's life, weather noticed or not. The significance of energy has also increased in this industrialized era. Electricity is a primary need to run industries. Conventionally, electricity is generated from hydro-generators and fossil fuels. Since the industrial revolution in Great Britain, much carbon dioxide (CO_2) has been emitted by combusting fossil fuels. CO_2 concentration in the air has increased by 25% in the past 200 years (Waleed et al. 2014). This combustion of gases compels the 4.6 billion old earth to a critical challenge i.e. global warming. The great challenges regarding energy, for today's world are, escalating climate change, energy security, depletion of fossil fuel resources and meeting the increasing global demand for electrical energy. Energy demand for the next three decades will be almost triple globally while the existing fossil fuel are able to provide energy for two centuries (Waleed et al. 2014; Heinberg 2005). This situation appeals the research community to pay attention to alternate resources, such as renewable (wind, tidal, solar etc.) energy.

Solar energy (solar radiations) is an everlasting resource for tomorrow because it is free, practically inexhaustible, and involves no polluting residues or green house gases emission (Narendrasinh et al. 2015). A solar system with 10% efficiency covering 0.16% of earth would provide 20TW energy which is about twice the world consumption rate of fossils energy (Mousazadeh et al. 2009; Nault 2005).

Pakistan lies in a region where solar energy is available throughout the year with annual mean sunshine duration of 8-8.5h/day (Mirza et al. 2003). In Pakistan, sum of global irradiance is approximately 2000KWh/m^2 annually, as shown in Figure 1. In most cities sun-rise hours ranges 2200 – 2500 yearly (Waleed et al. 2014).

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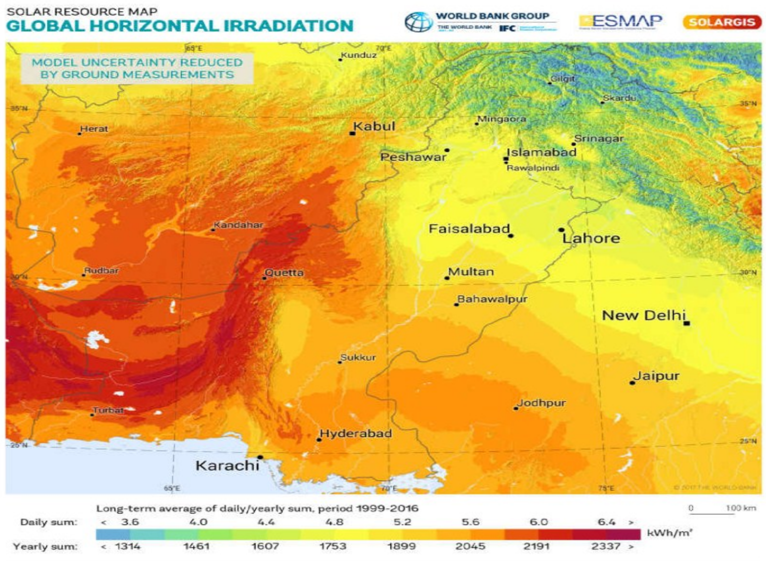

Figure 1: Multi-yearly mean of irradiance for Pakistan (1999-2011) in kWh/m^2 (Anon n.d.).

Pakistan is facing an acute shortage of electricity. In 2001, the share of power sector in consuming petroleum products was 37.8%, which is now 40.82% mainly because the number of electricity consumers has increased from 17.9 million to 21.7 million (Sher et al. 2015). According to Pakistan power sector, the peak demand on 22 July, 2012 was 17861 Mega Watt (MW) while the generation capacity was 14317 MW so, the shortfall was 3544 MW (Anon n.d.). To cut the ever widening gap between supply and demand of electricity in Pakistan, government is establishing distributed power generation systems throughout the country. In this regard, Quaid-e- Azam solar park (QASP), a Photovoltaic power plant with initial production capacity of 100 MW was constructed in March, 2015 (Khaliq et al. 2015).

PV delivers direct energy while all the utility appliances run over alternating energy; inverter is needed to get the desire energy format. It is not possible to rely all the time on solar energy due to its unavailability at night and cloudy weather. It would be interesting if we integrate PV energy with national grid line. In this connection, we proposed a system which provides the potential solution for mixing and synchronization of PV power with grid. To combine two alternative power sources on a single output line, make sure that they are synchronized with each other. They will be in-phase, their frequencies will match with each other and voltage amplitudes will be same (Tong et al. 2015; Sen 2013), (Li et al. 2017).

The remaining paper is organized as: First part of this paper presents a brief introduction of solar energy, its importance and status in Pakistan. State of art literature review is presented in the second part while design and simulation of each component of synchronizer circuit is explained in third part. The fourth part consists of discussion over the results of synchronization of grid and PV power. The last part concludes the whole work.

2. LITERATURE REVIEW

Grid connected PV systems are gaining the attention of research and business community globally due to free availability, echo friendly and everlasting nature of solar energy There are many issues related to grid-connected distributed power generation system (DPGS) which should be properly addressed. One of the major issues is lack of synchronization between DPGS and utility power line (Parvez et al. 2017). Various techniques are adopted to mitigate this problem. Following are some of the well known synchronization methods, which are explained in detail in literature.

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2.1 Zero crossing detection technique (ZCD).

In this technique, synchronization is based on detection of phase of a reference signal. A circuit is used that detects the zero crossing of a reference signal and frequency (Khan et al. 2013).

2.2 Phase locked loop (PLL) technique.

In this technique an input signal is considered as "reference" and output signal is generated according to that reference signal. The frequency of the oscillator is set in such-a-way that the derived signal phase and reference signal phase are matched with each other. Synchronous Reference Frame (SRF) PLL, double Synchronous Reference Frame (DSRF) PLL and unbalanced harmonic based (UH) PLL are the advance types of PLL technique(Jaalam et al. 2016), (Bendrat et al. 2017).

C. Ramos et al. have used ZCD technique in synchronizing renewable energy sources in distributed generation systems (Ramos et al. 2005). A prototype of 200 KW power converter is used that connects a wind generator to the grid to validate the proposed method. (Kim et al. 2006) also investigated a same synchronization technique for PV-Wind hybrid renewable energy DGPS. (Khan et al. 2013) have also used the ZCD technique in designing grid connected PV inverter. Various auto-synchronization techniques for grid connected solar photovoltaic are analyzed by (Dineshbabu et al. 2015). Phase locked loop techniques are also popular due to their reliability or immunity for distortion. (Freijedo et al. 2011) overviewed PLL synchronization techniques for single phase distributed power generation system. Francisco et al. applied the different PLL techniques in AC grids of various frequencies to check its performance or reliability (Freijedo et al. 2011). Grid frequencies of 50, 60 and 400 Hz were tested in normal and distorted condition and the results were discussed. For single phase grid Yao-Nan et al. describes some of synchronization methods in (Tong et al. 2015). Designing and simulation for synchronization and mixing of PV and grid power is presented in this paper which is based on ZCD technique.

3. DESIGN AND SIMULATION

Synchronizer circuit is designed and simulations are carried out for various input parameters. Phase, frequency and voltage are the key input parameters in the proposed designed circuit. The general schematic of synchronizer circuit is shown in Figure 2. DC-DC converter with MPPT technique is needed for steady state flow of current. Inverter is used to get the desired alternating power because the domestic appliances are usually run over alternating current. Frequency, voltage and Phase are some of the challenges in synchronization at a point of common coupling (PCC) (Dineshbabu et al. 2015). A zero crossing detection technique (ZCD) has been used for phase estimation and frequency calculation in this research work. An amplifier is used to get the desired amplitude signal. The proposed circuit will deliver the information regarding the aforementioned characteristics to inverter and the inverter should be capable to adapt itself to changes in grid without compromising on its performance. Each characteristic (Phase, Frequency and Voltage) of grid power is investigated through a separate circuit. The PV power after successful synchronization is injected into grid at PCC as shown in figure 2. Detail is listed in the forthcoming sections.

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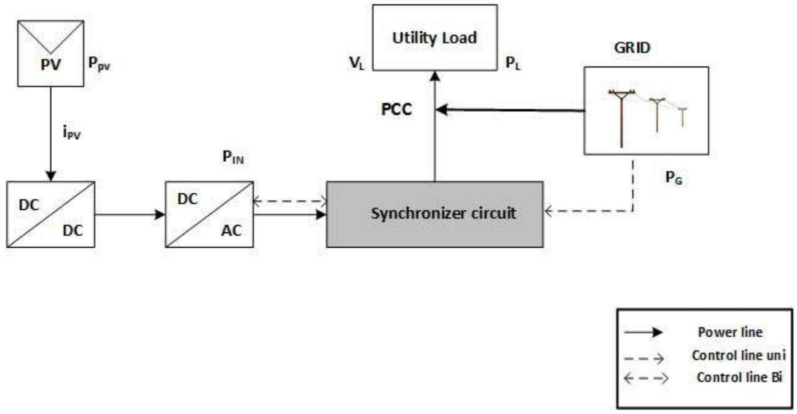

Figure 2: General schematic of synchronizer circuit.

3.1 Phase detector

A single phase power provides two zero crossing per cycle. For simplification one cycle is removed through half bridge rectifier. The detector verifies the phase once per complete cycle and feed back this information to PV inverter. The inverter starts its signal by the same time when the detector detects the starting point of grid power. The below Figure 3 (a) shows phase detector circuit while 3 (b) shows the output.

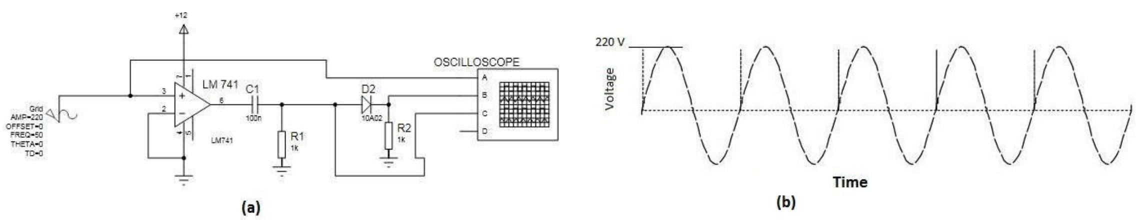

Figure 3: (a) Phase detector circuit and its (b) Output waveform.

3.2 Frequency calculator

Frequency, a time derivative of phase, is calculated using the same circuit shown in Fig 2(a). The proposed circuit generates a pulse after each complete cycle. The time required for one complete cycle shows the time- period of a signal while its reciprocal give us frequency. This information is feedback to the inverter for the desired frequency generation. The switching of MOSFETs in power stage of PV inverter can be controlled using these pulses, getting the desired frequency as mentioned in Fig. 4.

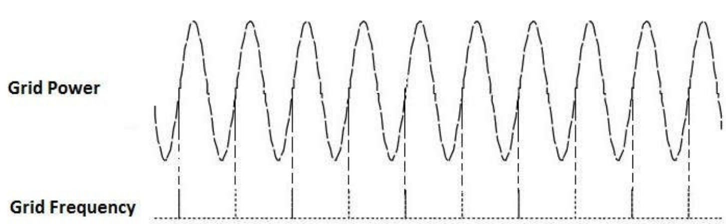

Figure 4: Calculated frequency of grid line using zero crossing detector.

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3.3 Voltage comparator

This circuit compares both voltages of PV inverter and grid line, a gain factor is obtained by dividing the grid voltage value over inverter voltage value in arithmetic logic unite (ALU). Furthermore, the quotient acts as amplifier gain for inverter voltage amplifier as shown in Figure 5.

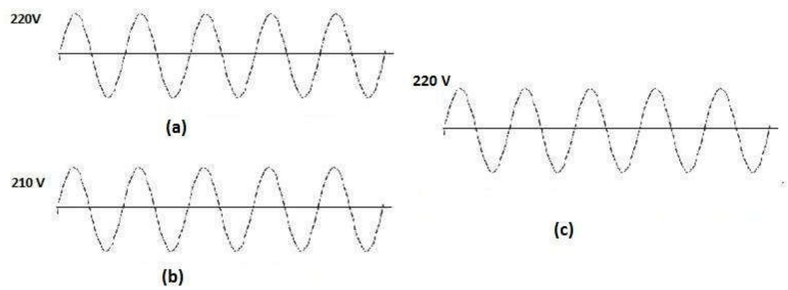

Figure 5: Comparator circuit output waveform: **(a)** Grid **(b)** PV inverter **(c)** resultant value waveform.

A complete synchronization circuit is mentioned in Figure 6. Each block performs special function, mentioned by its label. Further, every block consists of complex circuit internally which performs the desired function. The experimentations were performed in Matlab/Simulink, Labview and Proteus. The Simulation shows the possibility of mixing PV and grid power using the proposed strategy.

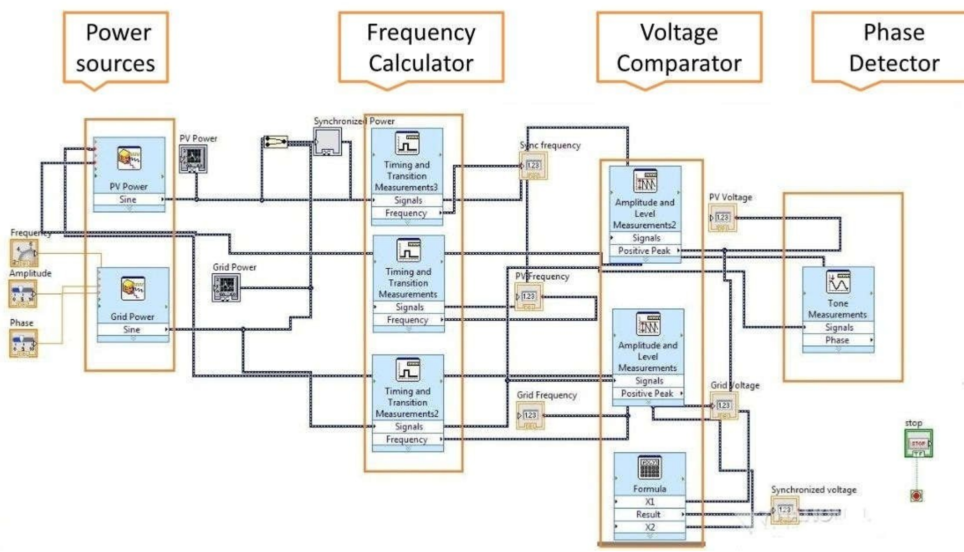

Figure 6: Internal circuit diagram of synchronizing system.

The control algorithm is shown in figure 7. The proposed control strategy auto-synchronize the PV inverter output with grid effectively. Simple algorithm is used which make the system simpler and faster to manipulate the data.

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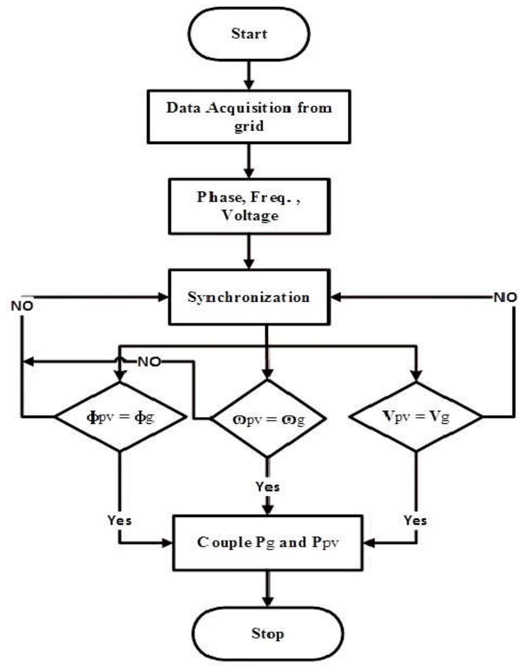

Figure 7: Control algorithm for auto-synchronization process.

4. RESULTS AND DISCUSSION

The process of synchronization can be defined as matching the voltage, frequency, phase angle and sequence of two AC power sources and running them in parallel. If two unsynchronized power sources are mixed together they will cause serious disturbance like current surge and sage problems etc. Therefore, synchronization is the key issue in mixing two alternating current sources. It becomes difficult at remotes areas where grid power quality is bad. Synchronizer circuit was designed, simulated and various experiments were conducted. The output power wave form of both PV and grid are illustrated in Figure 8.

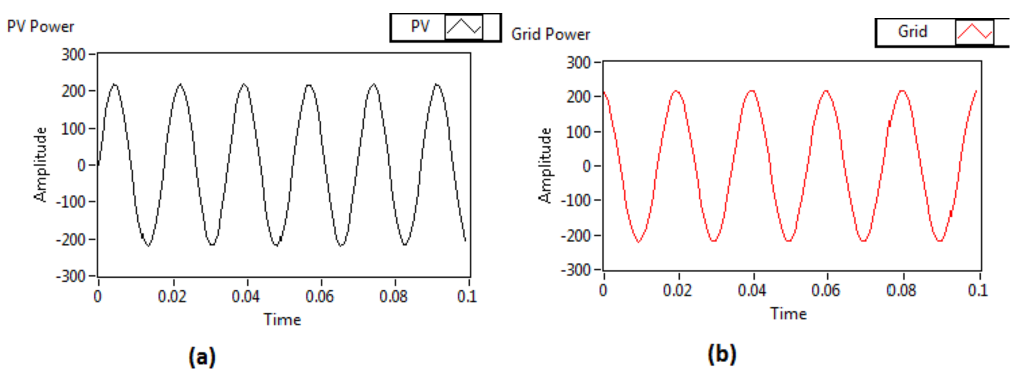

Figure 8: (a) PV inverter waveform and (b) Grid power waveform.

It is evident from the following figure that these two sources (PV and grid) are out-of-phase, frequencies and voltages are different. If these two were combined on single line, the result would be same as cleared in Figure 9. As already discussed that these power sources are unsynchronized therefore, it could not be used for domestic appliances.

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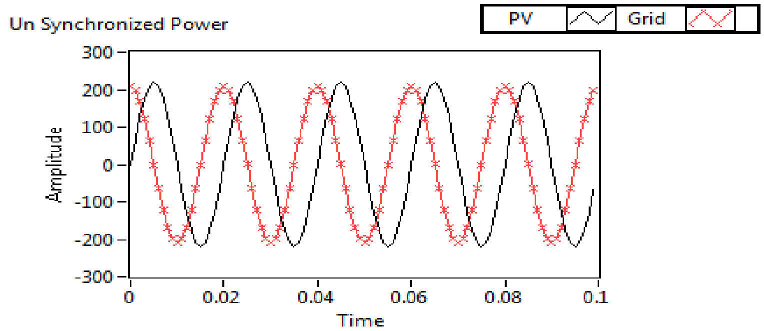

Figure 9: un-synchronized power sources mixed over single line.

During this study, zero crossing detection method is adopted to synchronize the PV power with grid line. When these two sources (PV and grid) were combined using the proposed synchronization technique, the phase difference becomes zero, the frequencies matched with each other and the resultant voltage raised to the desired range. Now mixing is possible and the results are shown in Figure 10.

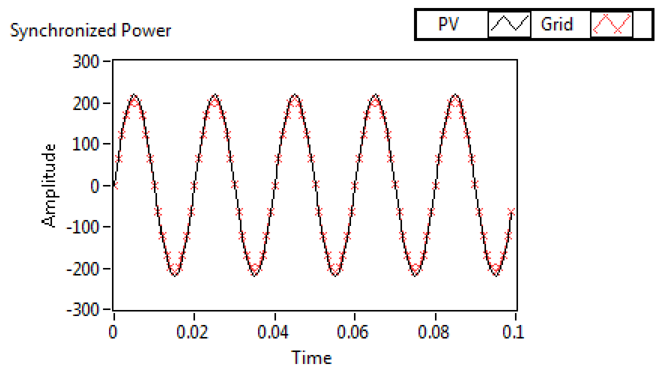

Figure 10: synchronized power sources mixed over single line.

Practical implementation of the proposed system in rural and urban areas will maximize the utilization of PV energy and will reduce power short-fall; hence living standards of people could be improved. The proposed system is an effort to make possible optimum harvesting of an everlasting, environment friendly and free source of energy. Harvesting green energy (solar energy) will reduce CO_2 emission resulting decrease in green house effects, ozone depletion, global warming and pollution etc.

5. CONCLUSION

In this research work, a system was designed that synchronize PV power to grid line effectively. A ZCD technique with a novel approach for voltage stabilization is adopted. The proposed technique is relatively less complicated, reliable and user friendly in implementation. Hence, it has an advantage over other PLL techniques which are complex in nature. However, they are robust and have minimum chance to fail. Moreover, the literature study shows that ZCD technique has good performance over single phase stable grid conditions. The author has considered the same conditions for simulation. Hence the results obtained are satisfactory and show that the proposed technique has the capability to synchronize any two alternating power sources.

In future it would be interesting to experiment the possibilities of integrating two or more renewable energy sources (such as Wind and Solar) with grid power.

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FAILURE ANALYSIS OF A PRODUCTION TUBING IN A GAS CONDENSATE WELL

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ABSTRACT

Production tubing is a critical component in oil and gas production. A case-study is presented on the failure analysis of production tubing in a gas condensate well. A puncture, occurred in a tubing of a production string in a high temperature and high pressure (HTHP) gas well, detected by slickline camera. The case was undertaken for failure investigation. After visual inspection it is found that there was hole in a tubing in production string. Various analytical techniques including elemental analysis of tubing material, hardness testing, tensile testing, microscopic analysis, and compositional analysis of well water, and produced gas were carried out to determine if the failure occurred due to selection of non-suitable tubing material. The analysis results showed that the tubing material was of API 5CT grade L80 type 1 (1% Cr). The well fluid analysis confirmed the presence of water moisture, CO2 and low amounts of H2S. In these conditions the use of tubing of API 5CT L80 grade type 1 is highly vulnerable to uniform corrosion as well as pitting corrosion in the absence of a suitable corrosion inhibitor. For the same reason the tubing failed due to formation of hole in tubing body caused by pitting corrosion.

Index Terms— Production Tubing, Pitting, Corrosion, Gas Condensate well, Failure Analysis

1. INTRODUCTION

Energy is considered to be the backbone for the development of a nation. Nowadays the quality of life of nations are measured by amount of energy they used. Research is being carried to harvest and utilize different sources of energy including conventional and non-conventional sources. Hydrocarbons, that is, Oil and gas is the most important part of conventional sources of energy. Though it causes environmental issues yet there is no alternative source developed that may replace it completely in near future. As the demand of the energy is increasing day by day, more oil gas fields are explored to fulfil this demand. Now the oil and gas producers are also producing gas from those wells which are ignored in the past due to harsh well environments. A major issue associated with these wells is the corrosion of the tubing and piping materials employed in their environments.

Corrosion costs world a lot of its resources. For the first time an accurate survey was conducted by Uhlig in 1949, reported that United states alone has corrosion costs of $5.5 billion which is equal to 2.1% of Gross National Product of U.S. at that time (Uhlig, 1949). In a relatively recent 3-years study (from 1999 to 2001) conducted by C.C. Technologies Laboratories Inc. with the support of Office of the Infrastructure and Development, Federal Highway Administration and National Association of Corrosion Engineers, it is reported that the corrosion costs are approximately $276 billion equal to 3.1 percent of 1998 GDP of the United States of America only (CC Technologies, 2001, FHWA, 2001, NACE, 2002). These studies only considered the direct costs of corrosion. Generally, corrosion costs the industrial nations on an average of 3.5% to 4.5% of their gross national products (Uhlig, 1985).

Although Corrosion is a natural thermodynamically favored phenomenon which adversely affects all the oil and gas production and transportation facilities, but those having harsh environments like having high contents of carbon dioxide (CO2) and hydrogen sulfide (H2S) and high temperature and pressure. These gases called acid gases and are highly corrosive. On the other hand, low carbon or low alloy steel is widely used material for manufacturing piping and tubing employed in oil and gas production and transportation due to its low costs, wide availability, and high processing versatility. But they are easily corroded especially in oil and gas environments due to the presence of aqueous media containing oxygen, carbon dioxide (CO_2), hydrogen sulfide (H2S), and microbial activity in

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wells, and pipelines (Gupta et. al., 2008). These species acts in different ways in corrosion process. In some wells all these gases may exist while in others one or two of them may be present. Figure 1 shows an illustration of how these species acts during corrosion process (Brondel et. al., 1994). Although corrosion may be purely chemical in nature, yet mostly corrosion in industry occurs in electrochemical systems made of electrolyte, two electrodes, cathode and anode, and path for electronic movement. The absence of any of these components of the electrochemical cell will prevent the electrochemical reaction and so materials corrosion and degradation (Fontana, 1978).

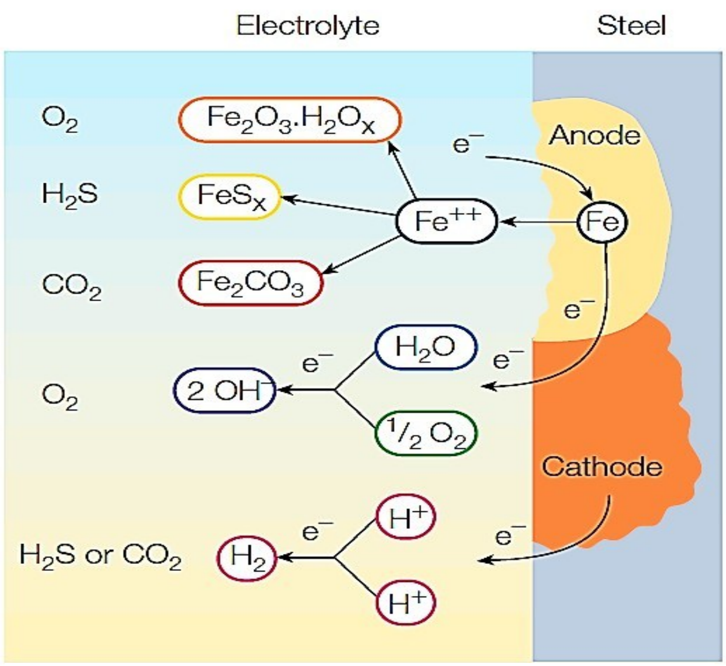

Figure 1 Corrosion due to various species on a steel surface

Like any other electrochemical cell, corrosion cell is also consisted of two half reactions, i.e. cathodic reaction and anodic reaction. In electrochemical cell anode is the metal which is more reactive, that is, at lower electronegative potential than the cathode. It loses the electrons which moves towards the cathode through the metallic path. In this way the metal or metal region acting as anode gets corroded. This process is called oxidation and can be expressed by following reaction (Davis, 2000):

$$\mathrm{M} \longrightarrow \mathrm{M}^{n+} + n\,\mathrm{e}^-$$

Where

M: metal acting as anode

n : number of lost electron

On the other hand, cathode is the metal which is less reactive and at higher electronegative potential. It consumes the electron which are ejected from the anode. These electrons then participate in the cathodic reaction, called reduction. This reduction reaction depends on the species available in electrolytes present in the cell. The two frequent reduction reactions are:

i. ***Hydrogen Evolution:***

$$2\,\mathrm{H}^+ + 2\,\mathrm{e}^- \longrightarrow \mathrm{H}_2$$

ii. ***Oxygen reduction:***

$$2\,\mathrm{H_2O} + \mathrm{O_2} + 2\,\mathrm{e}^- \longrightarrow 4\,\mathrm{OH}^-$$

This transfer of charges occurs through electrolyte, a conducting solution present in the cell. Without electrolyte the electrochemical cell is not complete and so corrosion reaction is not possible.

Gas condensate well environments are highly corrosive due to water condensation which dissolves oxygen, carbon dioxide (CO_2) and hydrogen sulphide (H_2S). Normally CO_2 and H_2S also called as acid gases are non-corrosive, but upon dissolution in water they form weak acids, and hence provide H^+ ions for corrosion reaction of tubing (Gaverick, 1994). Recently as the demand for oil and gas in increased many folds, the issue of corrosion is increased due to production of oil and gas from well having high contents of acid gases and other species like salts, and organic acids. Moreover, due to its great

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length (upto 5000 meters) beneath the earth surface, tubing is monitored by indirect methods like by placing corrosion coupons or measuring iron counts (Murthy, 2015) as these are relatively difficult to monitor directly for corrosion. Throughout this length it is exposed to harsh conditions like exposure to different chemical species and high temperature and high pressure.

The corrosivity of aqueous phase increases with concentration of dissolved gases, and salts like chlorides, sulphates and bicarbonates (Kermani *et. al.,* 1997). Over a long period, these factors contribute to reduction in thickness, loss of mechanical properties, formation of leakages, and in various cases sudden failure of the tubing. These types of failures are widely investigated to know the mode and cause of failure (Mowat et. al. 2011, Javidi et. al. 2012, Yang et. al. 2015, Zhu et. al. 2011, Al-Jaroudi et. al. 2014). These studies suggested that corrosion failures are mostly related the presence of high contents of CO_2, H_2S, chloride ions and organic acid with applied stresses. In the presence of these species different modes of failure are possible including extensive pitting, sulfide stress corrosion (SSC), stress corrosion cracking (SCC), erosion corrosion. The failure may occur due to any one phenomenon or a combination of them.

In current study, such a failure of tubing is investigated to find the underlying causes of failure. A hole was formed in one of the tubing body. Since every oil and gas field have unique well conditions and environment, the failure analysis of such failures may provide different findings specified for that field.

2. ANALYTICAL TECHNIQUES

Firstly, the failed tubing was visually inspected for perforations on outer and inner surfaces. The sections of the tubing which were heavily corroded were cut from the tubing. They were also cut across the length to inspect the tubing inner surface. Different types of samples were cut according to the test requirements specified by API 5CT. To investigate the failure following analyses where carried out:

(1) Visual inspection of inner and outer surfaces of the tubing
(2) Optical emission spectroscopy of tubing
(3) Metallography of tubing material
(4) Mechanical testing of tubing
(5) Evaluation of produced gas & formation water corrosivity

During visual inspection, photographs were taken of the corroded sections through NIKON S2800 camera. Corrosion deposit and product layers were then cleaned from the section surfaces to inspect the surface under the corrosion layer. After cleaning photographs were taken again.

Various cleaned un-corroded samples were obtained to carry out the chemical compositional analysis of the material used for manufacturing the production tubing. The optical emission spectroscopy was done through AMTEK spectrometer called as SPECTROCHECK.

For microscopy various samples were cut from cross section of the tubing adjacent to leaked area of the tubing section. They were grinded and polished. Firstly, they were studied under stereomicroscope to get magnified three-dimensional images showing the small pit on the inner surface of the tubing. They were then etched and studied under light microscope made by Olympus. Metallographic features were obtained and saved through built-in camera in microscope.

For hardness and tensile testing, sample were prepared from uncorroded sections of the tubing body. Tensile testing was carried out through Instron Universal Testing Machine (30 KN Load). For hardness measurements Rockwell instrument was used with C Scale employing 150 kg load. The corresponding API and ASTM standards were followed during preparation of the samples.

In last stage of research, chemical compositional analysis of produced gas and water was carried out to determine the present and concentration of corrosion agents in the produced gas and formation water. These species which included carbon dioxide, hydrogen sulfide, and other gases through gas chromatography. The concentration of chloride ions in formation water was also determined.

3. RESULTS AND DISCUSSIONS

3.1. Visual Examination:

From visual examination it was observed that the corrosion occurred in tubing bodies while the coupling was relatively less corroded. There was general or uniform corrosion as well as pitting corrosion. The outer layer of the corrosion deposit was loosely intact with the surface and was easily striped during preliminary cleaning. The holes or puncture formed in tubing were due to pitting corrosion. Figure 2 and Figure 3 shows the photographs taken of the inner side and outer side of the surface of tubing near the punctures. The photographs show the punctures caused by pitting corrosion in the tubing body.

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Figure 2 Puncture observed from outside of tubing

Figure 3 Inner side surface of tubing near to puncture

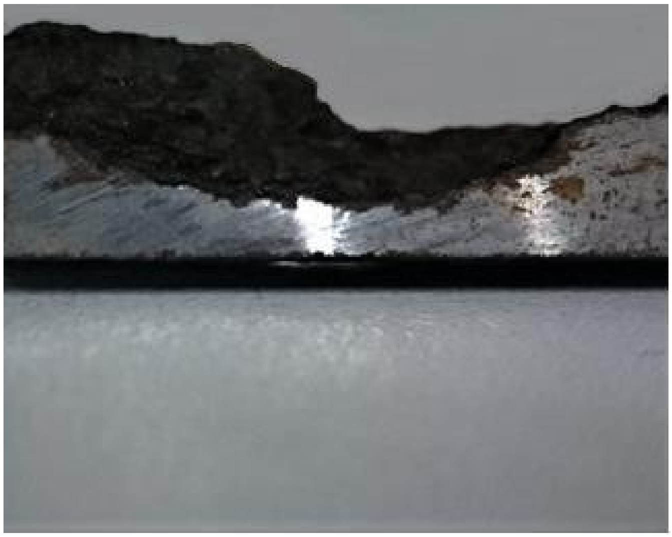

Figure 4 Cross section of the pipe showing Corrosion of the tubing

Figure 5 Inner surface of tubing after cleaning of corrosion products and deposits

Figure 3 shows the extensive pitting corrosion in the close regions of punctures. The color of corrosion deposits is dark brown. Figure 4 shows the extensive penetration of the corrosion into the cross section of the tubing. Figure 5 is the photograph of the tubing surface after cleaning of corrosion layer. The pitting corrosion into the surface of tubing can be observed. These studies propose that the protectivity of the corrosion film was negligible.

3.2: Composition Analysis:
Table 1 shows the elemental analysis of the steel used for manufacturing of the tubing. The chemical composition of the material shows that it is a low alloy steel containing about 0.40 percent carbon and 1 percent Chromium (Cr).

Element	Fe	C	Mn	Mo	Cr	Ni	Cu	Si	S	P
Content (%)	97.0	0.40	0.79	0.19	1.01	0.07	0.09	0.27	<0.01	<0.01

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Table 1 Elemental Composition of steel used for Tubing

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3.3: Metallography:
Figure 4 shows the metallographic images of the tubing materials. It can be observed from the figure that steel has tempered martensite microstructure. There are martensite lathes or needles throughout the ferrite matrix. These observation shows that the steel has been quenched and then tempered. In figure 5 a small corrosion pit, that has penetrated in into tubing cross section, is visible.

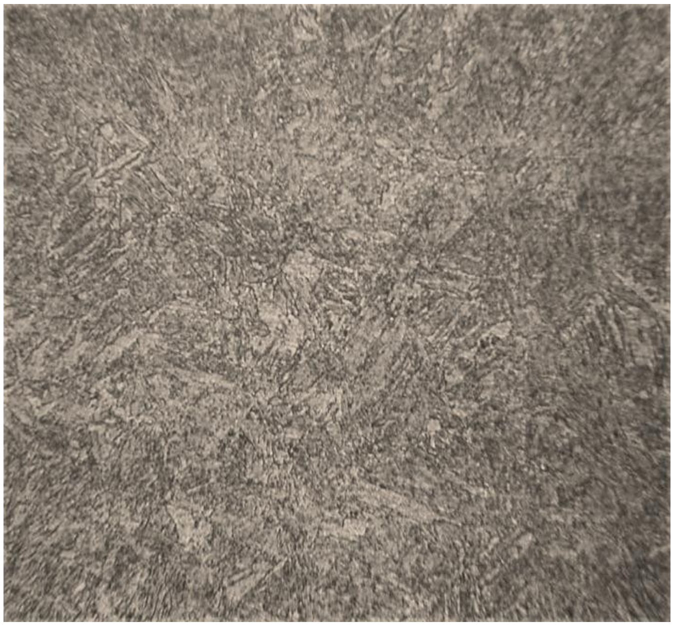

Figure 6 Microstructure of tubing cross section (Magnification x800)

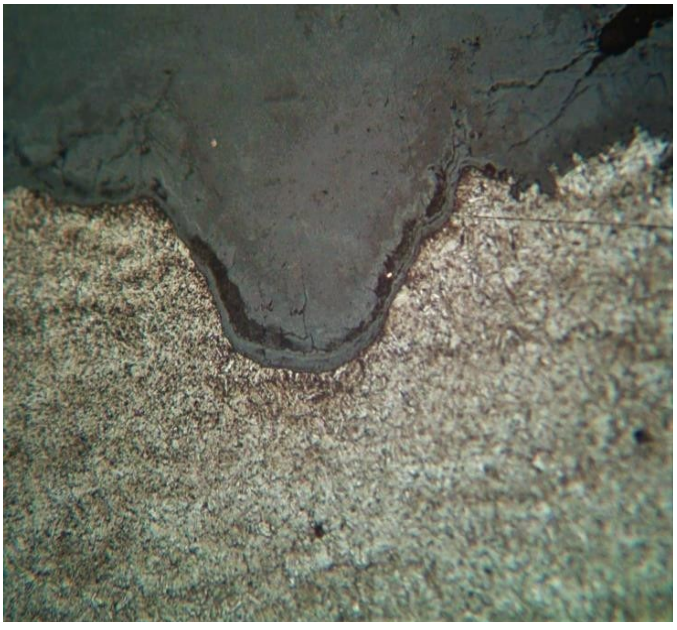

Figure 7 Microscopic images showing small pits in the tubing cross section (Magnification x200)

Hardness and tensile properties of the production tubing as measured from the tests are provided in table 2.

Species	**Hardness HRB (HB)**	**Yield Strength psi (MPA)**	**Tensile Strength psi (MPA)**	
Content	21 (229)	96,540 (665)	111,680 (770)	

Table 2 Mechanical Properties as measured of Tubing

Combining these information with the chemical composition, microstructure, and mechanical properties, and then comparing it with API 5CT standard (API, 2005), it is determined that the tubing was supplied against API 5CT L80 grade. As it contains 1 percent chromium so it is of type 1 of the L80 grade. It was also then confirmed by the company that was operating the gas well.

2.5: Composition of Produced Gas and Water
Produced gas was containing high carbon dioxide content while H2S is also present in considerable concentration. The content of these gases in produced gas is given in Table 3.

Species	**CO_2**	**H_2S**	**Water Cut**
Content	7 mole %	50 ppm	22%

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Table 3 The content of corrosive species present in produced gas

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The composition and other characteristics of well formation water is given in Table 4.

Species	**Chloride**	**Sodium**	**Sulphate**	**pH**
Content	52g/L	19	32 mg/L	4.9

Table 4 pH and selective composition of formation water

4. CONCLUSION & RECOMMENDATIONS

To API 5CT L80 tubing grade is used in wells producing sour gas. The type 1 belonging to this grade is the least corrosive resistant as it contains 1 percent chromium. Therefore, these types of tubing are employed in low corrosive environments with or without corrosion inhibitor. The well in this study has a high amount of corrodants. There is great amount of water, which upon condensation in well cause corrosion. Moreover, the composition of the gas and water is highly suitable to promote corrosion. Carbon dioxide is available in high amount alongside hydrogen sulphide. The present of high amounts of chloride ions, and high pH is also promoting the corrosion, as it decreases the possibility of the formation of protective corrosion film. On the other hand, the corrosion inhibitor is not used which may mitigate or prevent the corrosion process. Concluding the discussion, everything is in favor of corrosion process especially pitting process. It is evident from the visual inspection that general as well as pitting corrosion is seen throughout the tubing length. The pitting continued throughout the thickness without any hindrance due to the unavailability of protective film or corrosion inhibitor.

Based on the current study, it is recommended to use a suitable tubing grade in the wells in the particular gas field. In this regard, type 13Cr which has 13% chromium is proposed. If the economics of the production is not favorable for using that type then type 1 or type 9Cr may be used along with a suitable corrosion inhibitor. Also, corrosion monitoring techniques should be carried out on regular basis to avoid such failures in future.

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DESIGN AND FABRICAION OF AUTOMATIC WHEELCHAIR

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Abstract.

It is inevitable for any country to have people with disabilities or have difficulty with standing up. In this world there are over 100 million people with disabilities. The most common used accessory for disabled and physically challenged people is wheelchairs. The researchers predict that demand of wheelchair will increase by 22 percent over next 10 years. A wheelchair is a wheeled mobility device that will reduce the physical, perceptual, and cognitive skills of physically challenged persons. As disable people of our society find it problematic to use a typical manual wheelchair. The goal is to come up with an automatic wheelchair which gives comfort to the paralyzed person. In this we have done designing & analysis of the wheelchair by using hydraulic system which empowers the challenged people to lift up. The use of hydraulics will provide comfort and make paralyzed person to do his own work without any dependence of normal person by providing them with some sort of mobility. Designing, simulation, analysis, fabrication has been implement in this whole project. Our proposed project will have the strength to provide privilege to a considerable consumer base.

Keywords: New mechanical Structure, Automatic wheelchair, lifting features, designing and simulation.

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1. INTRODUCTION.

Disability is a state of human body in which a person is unable to do certain tasks or unable to work according to his will. Lack of community living and inadequate services and reliance on institutional solutions leave people with disabilities isolated and dependent on others. Residential institutions are reported to be responsible for lack of autonomy, segregation of people with disabilities from the wilder community and other human rights violations. Most support comes from family members or from social network but reliance on this informal support can have adverse consequences for caregivers Main problems that physical disabled person faces every day is that they cannot move freely according to their will and as physical disabled persons faces bad health issues. [1].

Wheelchairs may have many mechanical structures and operating functions such as through voice controlled, through hand gestures, through joystick, through buttons or can be operated manually. They have variety range of styles in structure. The proposed wheelchair is operated through joystick microcontroller, so disable person will not move the wheelchair manually or through someone help. As physically disabled and challenged person faces health issues so they cannot move freely according to their will so powered system is propose that enables them to move easily and freely.

A new kind of wheelchair is lifting wheelchair which helps disable person and facilitate them to some extent. By lifting the disabled persons he or she will be enable to achieve his goal which might be that he or she wants to pick something up from shelves and to make an eye level with things or it might be that he or she wants to deliver a speech at podium [2].

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While performing daily life activities improper structure can impact the safety and functions of wheelchairs users. There is lot of medical conditions

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which become a reason requiring a wheelchair. Most of powered wheelchair does not have a feature of lifting disable person automatically, so for this they require some arm force to lift up. So that's why we have recommend power system in lifting disable person. We have done mechanical research and use electrical components to make our wheelchair safer, easily control, comfortable, saving more energy and economical.

During research work the feasibility has been taken into account of the proposed design. Research work includes calculations for the system used to enable physically challenged person for lifting. To check safety factor, displacement and Mises factor, stress analysis has been done on simulation software on the proposed system to make sure that wheelchair will bear properly.

Research also includes study on different types of conventional wheelchair such as they can be automatically operated or they can be standard manual wheelchairs. Both kinds of wheelchair have its own features and functionality in it. There are also transport wheelchairs, heavy duty and bariatric wheelchairs, light and Ultralight weight wheelchairs, sports wheelchairs and hemi weight wheelchairs [3].

2. RELATED WORK SURVEY.

Brief research on wheelchairs automation and lifting mechanism has been done for disable person. After getting data from survey it states that these functions have become an aid for challenged person and a lot of organization is working on it for physically challenged person.

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Kyoto International Conference Center has done work on automation of wheelchairs [4]. They published their paper in 2009 on automation of wheelchair by joystick. They have used a very strong and unique mechanical structure to aid disable persons but the structure they have used is complex and a bit difficult to use. see figure 1.

Figure 1: Automation of Wheelchair

Secondly in 2013, IJARECE published a **paper** in which they have done automation using voice controlled [5], see figure 2. In their project voice system and infrared and ultrasonic sensors have been integrated. There main focus is that if a person limbs are not working than it will be grateful to them. They have also use an aid for those persons whose limbs are working and can easily move his/her hands. They have considered mechanical model, electronic system, voice

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recognition and other control.

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Figure 2: Automation using Voice Controlled

Related work survey also includes brief research on lifting mechanism. The first edition of lifting and standing wheelchair, published in 2005 [6], see figure 3. The lifting mechanism they have use is done through manually which requires a lot of human force to lift or stand a disable person. They have used mechanical method to do the task but if a person is weak or have problems with his arm so he/she will not be able to use this kind of wheelchair.

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Figure 3: Manually lifting of Wheelchair

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Georgia institute of Technology by August 2011 done work on height adjustable wheelchair. They have done similar research and proposed different solution for lifting of wheelchair. They can raise and lower the wheelchair to only 4’’ range. They have fulfilled their design needs from different stakeholder groups.

3. PROBLEM STATEMENT, OBJECTIVES AND MAIN CONTRIBUTION.

Due to the no. of increasing accidents and disabilities in the world, wheelchairs have become an aid for physically challenged persons. This paper proposed a system which will help the needy persons and fulfill their will and will face the day to day life problems and to make challenged person to live a comfortable life.

This research work includes a lot of objectives taken into account the feasibility and comfort level of persons. First objective indicates the designing and fabrication of wheelchair. The design wheelchair will be automatic by means of some controlling system. Second objective is to design the controlling system regarding wheelchair movement and lifting. A strong mechanism is used to make our seat to lift up to some height. While doing the project some important aspects is considered that are, our system will be simple in structure, easy to use and it should be economical.

Main contribution of this research work and project will be designing and automation part. Designing a new mechanical structure which will be simple in

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structure and easier in use. Fabrication of new mechanical structure is the main

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part of proposed project. Power consumption should be less so that travel distance of wheelchair will be more and easy.

4. SOLUTION FOR AUTOMATION AND LIFTING.

There are many solutions regarding automation and lifting of wheelchair. Some of them are discussed below.

4.1 Different Solutions of Automation:

4.1.1 Automatic Motion of Wheelchair using Hand Gestures:

Hand gesture is based on curvature of hand shapes contour. Highly sensitive sensor is used for the motion of wheelchair. MEMS (Micro-Electro-Mechanical Sensors) accelerometer sensor is capable of detecting the tilt motion of gloves. This sensor finds the tilt and moves the wheelchair using accelerometer. The motion of wheelchair using hand gestures is totally wireless.

The sensor is connected to the gloves. Due to the movement and tilting of hand, sensor send a signal which is receive by receiver and generate the analog values using MEMS accelerometer. By tilting the hand, serials values are generated which are than transmitted to motor driver circuit which than results in motion of wheelchair.

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The overall mechanism is that accelerometer send signal to microcontroller which is than transmitted to receiver than receiver send signal to

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motor drivers which are connected to DC motors. Using the hand gestures we can control five possible movement of wheelchair i.e. forward, backward, right, left and stop.

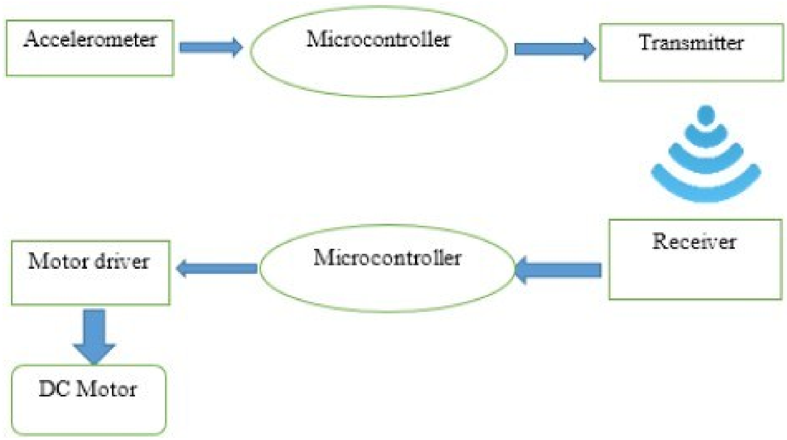

Figure 4: Flow diagram for hand Gesture control

4.1.2 Automatic Motion of Wheelchair using Joystick Micro-controller:

This is another solution for the locomotion of wheelchair. Joystick is used to move disable persons from one place to another place. Joystick is nothing but a lever which acts as an input device which consists of stick and controls the angle or direction in which it is rotate by the users. It consists of a plastic base with a

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flexible rubber sheath. There is an indicator light in it that represents the battery power.

Joystick is directly connected to DC motors. When joystick moves, the signal is send to front casters which changes its direction quickly and move the chair in given command position. Charger is required to charge the joystick. Speed can be adjusted in joystick. When there is no command from joystick motors automatically turns off and stops the motion of wheelchair. We can control all the possible movement of wheelchair using the joystick.

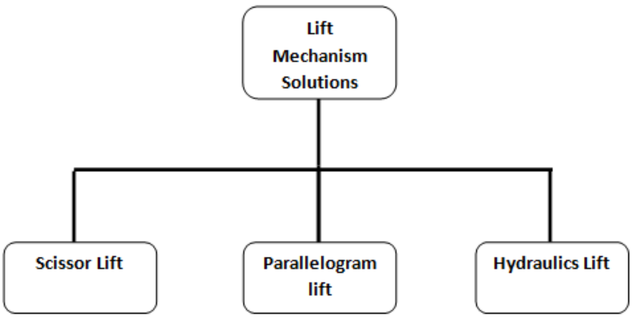

Figure 5: Solutions for Wheelchair lifting

4.2 Solutions for Lifting:

4.2.1 Lifting the Wheelchair Using the principle of Scissors frame:

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Lifting mechanism will provide an elevation to the person and make things at an eye level when it lifts. The solution which we are going to discuss is based upon the scissors frame. The scissor frame is connecting upper part of wheelchair i.e. the seat and the lower part of body including complete base structure. When the scissor frame is at rest, there is no vertical displacement in the upper portion of wheelchair but as the scissor frame is in working condition it will move the upper part in vertical direction.

Scissors frame consist of several cross bar linkages which plays its role when it is required. It produces a vertical displacement and increase the factor of mechanical advantage. An Actuator is required to move the bar linkages for the displacement of upper body. One thing in this case is very important regarding the actuator point on which it is applying force, if it is not in the right position than it acts as a mechanical disadvantage but even for a light weight a very large force is required for displacement which results in an energy loss [7]. See figure 6.

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Figure 6: Scissors Frame Lifting Mechanism

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4.2.2 Lifting the Wheelchair Using the principle of Parallelogram Structure:

In this kind of mechanism instead of normal seat we have a parallelogram structure. Parallelogram is a complex structure regarding to achieve the objective because the seat use in this kind of structure is very thin. We can also make seat parts separately and can use in parallelogram structure and use in normal standard wheelchair.

In this process parallelogram seat itself lift up when we are dealing with the lifting of human body. In this hinged are use at each vertex. Springs are installed at the opposite side of frame which helps in lifting the wheelchair and the front side is fixed with frame. A large amount of force needed in this case as compared to the previous principle. Springs are installed between non-adjacent vertices to provide compression power. We can install strong springs having large force so that no more external support is required for both the human body and structure [8].

4.2.3 Lifting the Wheelchair using Hydraulics:

Another research based upon our objective can be achieved using Hydraulics system. We have done calculations regarding the length of cylinder, the diameter of cylinder, and the rate at which the vertical displacement will occur. Hydraulic pump is required for the displacement of the cylinder.

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Comparing with the previous one, in this we have to only lift up the human body and seat weight. When the person reached his or her target than center of gravity plays its role which is very important in this kind of mechanism used. We have to control the rate of wheelchair when it is reaching down because we have to avoid damping because our main target is safety. The main advantage of using this kind of wheelchair is that the angle between the upper body and lower body is 90 degree because we are just having a vertical displacement if a person having a backbone problem he or she will be comfortable in using this.

5. DECISION MATRIX.

5.1 Decision Matrix for Automation:

	Less Complexity 0.05	Easy to use 0.1	Applicability 0.05	Economy 0.3	Safety 0.5	Total 1
Hand Gestures	**60/3**	**30/3**	**50/2.5**	**60/18**	**40/20**	**46.5**
Joystick Controller	**50/2.5**	**50/5**	**70/3.5**	**75/22.5**	**85/42.5**	**76**

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5.2 Decision Matrix for lifting Solution:

	Less Complexity 0.05	**Less Power Consumption 0.05**	**Applicability 0.1**	**Economy 0.3**	**Safety 0.5**	**Total 1**
Scissors Frame	40/2	80/4	50/5	90/27	15/7.5	45.5
Parallelogram.	10/0.5	40/2	90/9	20/6	40//20	37.5
Hydraulics system	80/4	10/0.5	70/7	60/18	95/47.5	77

From the above related work survey and solutions, the best and easy to use mechanism has been selected. Decision matrix includes different parameters having different priority values based on ease of disabled person. Joystick is used for the movement of wheelchair and hydraulics mechanism is used for the vertical displacement of wheelchair.

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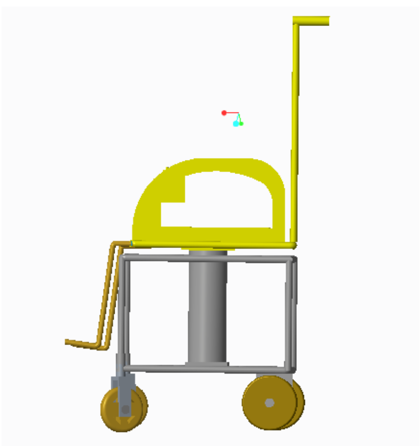
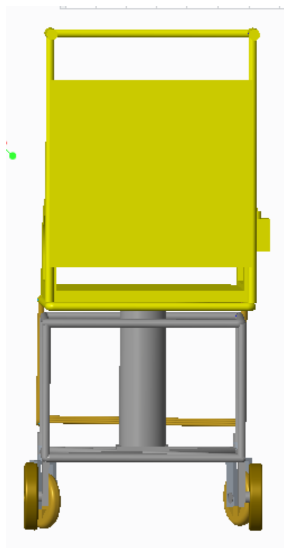
6. PROPOSED MODEL AND STRESS ANALYSIS.

The proposed model consists of three part top (including backrest), base and hydraulics cylinder. The research work includes the design, a 3D model of the project using creo 3.0. To bring most comfortable movement and lifting displacement for the person a research was conducted to find out accurate dimensions. Following are the different views of the proposed project.





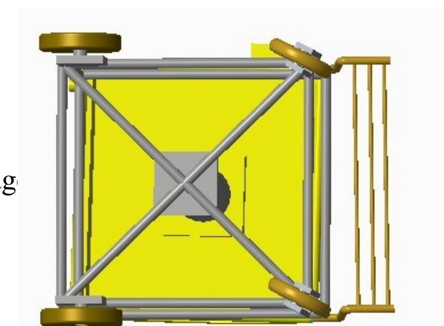


Figure 7: CAD model

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Stress Analysis:

This research includes the stress analysis on our project to get the result of safety factor, displacement and Mises. Analysis is done on simulation software. For stability test seating part of model is carried out of assembly. A weight of 80kg is applied on two different thickness of seat for the results. Hydraulic cylinder is also an important part to considered because during lifting a huge amount of tension will be acting on cylinder circumference. Results drawn from simulations are as follow.

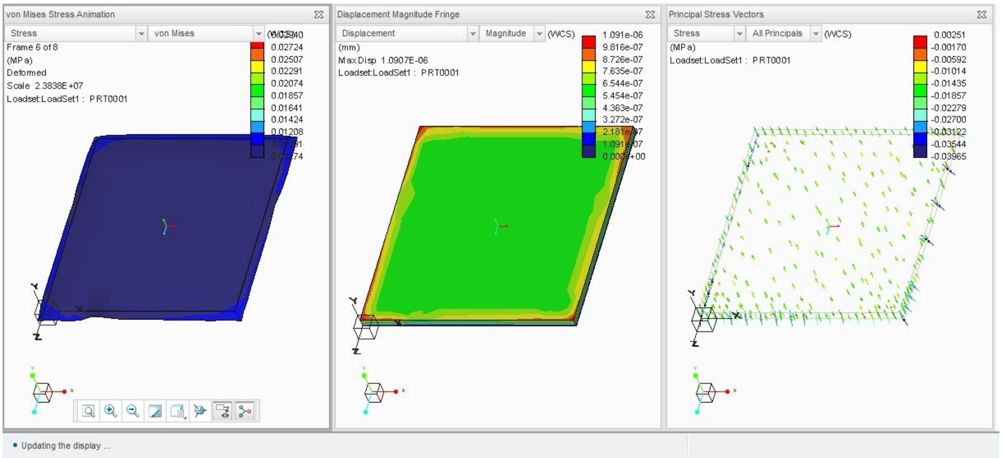

Figure 8: Stress Analysis using 10mm thickness

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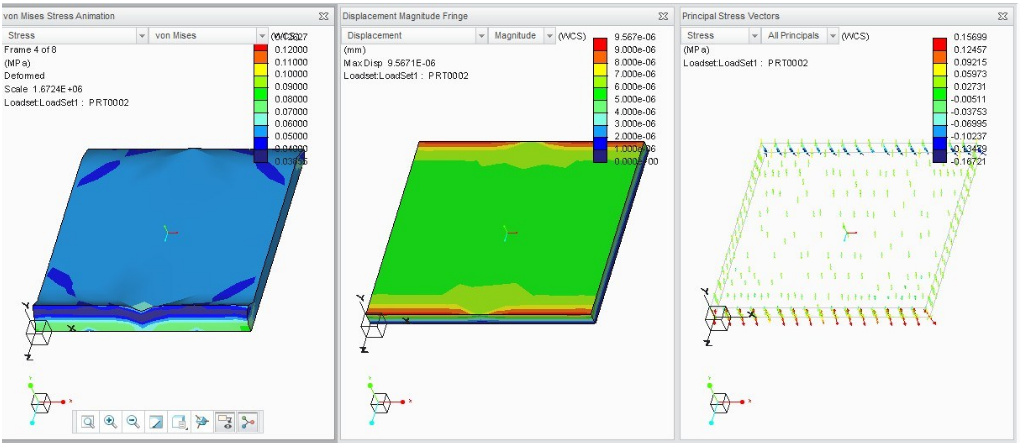

Figure 9: Stress Analysis using 15mm thickness

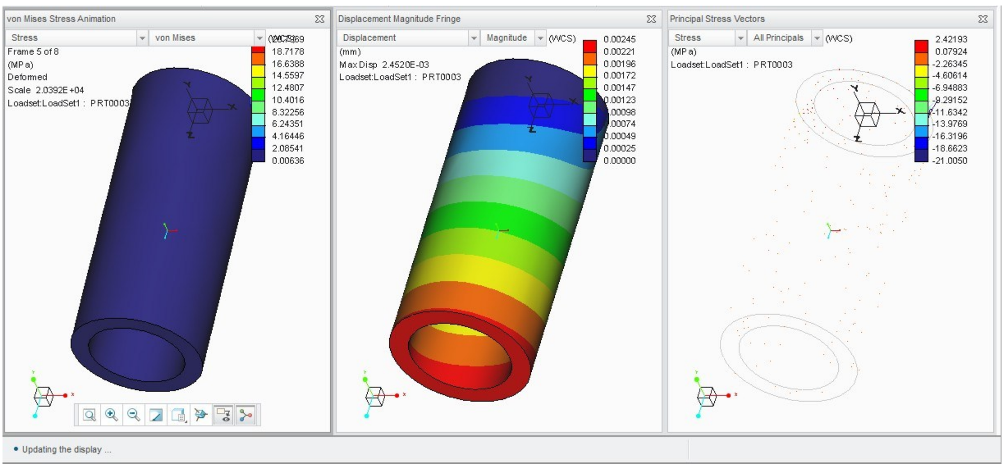

Figure 10: Stress Analysis on Hydraulic Cylinder

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7. CALCULATIONS.

7.1 Hydraulics Calculation:

$A= \Pi(D^2 /4)$

$A=\Pi(0.1)^2 /4$

$A=0.007854 \text{ m}^2$

W=100 kg

F=100*9.8

F=980 N

P=F/A

P=980/0.007854

$P=1.2478 \text{ Bar} = 18.0978 \text{ lb/m}^2$

7.2 Center of Gravity:

$\sum Fy = 0$

$Rr + Rf – W = 0$

$W = Rr + Rf$

$W = 70+30$

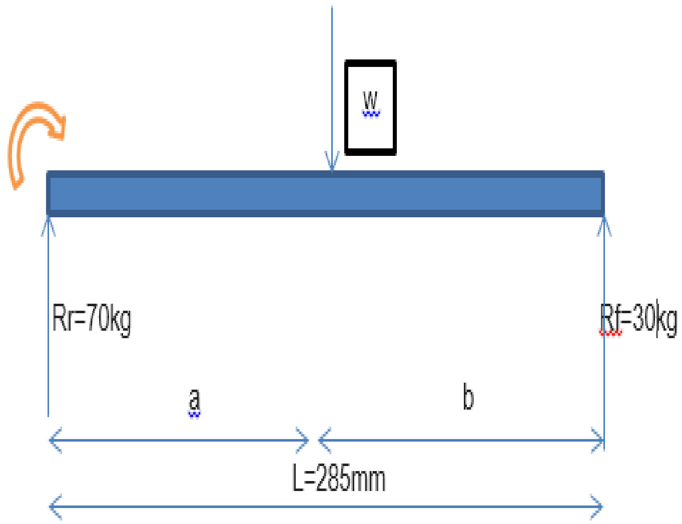

Figure 11: Center of Gravity

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W = 100 kg

$\sum Mr = 0$

100*a – 30*285 = 0

a = 85.5mm

b = L-a

b = 199.5mm

Location of C.O.G for rear wheel is at 85.5mm.

FRONT C.O.G CALCULATIONS

$\sum Ml = 0$

0 + 100*x -390*R = 0

X= 195mm

Y = L-195mm

Y = 195m

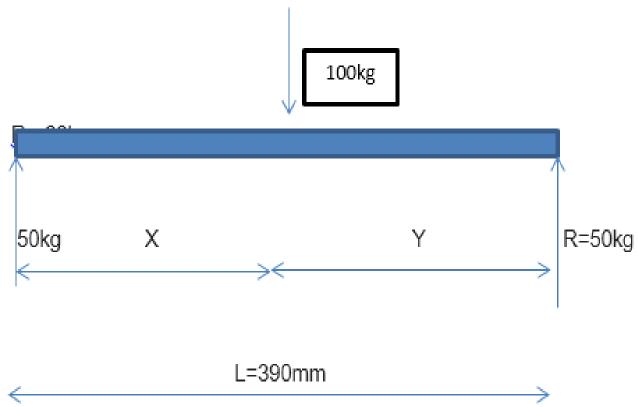

Figure 12: Front C.O.G

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8. CONCLUSION.

In presently world there are a lot of Disable people living. There disability is due to the no. of accidents increasing day by day. It is very difficult to face day to day life problems in a computation world. There should be some remedial action to be taken to encounter their problems.

This proposed wheelchair enhances the capability of the existing wheelchairs. The purpose of this research work is to propose for an automatic wheelchair system that would facilitate a paralyzed person. An Automatic wheel chair aims to provide aid to those physically challenged persons by providing them with some sort of mobility which would greatly help them. By introducing lifting mechanism in it, it will make an eye contact with objects a person wants to get.

The elderly and disabled use of power wheelchairs has increased dramatically. The greatest advantage of a power wheelchair is the ease and convenience it supplies.

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EXPERIMENTAL STUDY OF A FREE VIBRATION ANALYSIS OF A COLUMN STRUCTURE

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ABSTRACT

The current paper is the experimental study of a column structure subjected to free vibrations. The experimental comparison is drawn by exhibiting the vibration replication of a damaged and undamaged column structure. First vibration patterns of an undamaged column are recorded and analyzed. Then vibration pattern of a damaged structure is recorded, both patterns are compared to ascertain the intensity of damage caused by free vibration. Three depth cases i.e. crack depths of 03mm, 06mm and 08mm are considered at a single location near the fixed end of the column. Transducers (accelerometers) record the data of the vibrating column. The free vibration is given to the structure by striking the column structure with a hammer to record the data. The natural frequency inclines to get reduced as the crack grows. The frequency of a damaged column structure is lowered by reduction of stiffness and material degradation. With the avail of vibration patterns and transmute in natural frequencies, it is facile to monitor the health of the structure and to detect the damage at the right time, to take safety precautions afore the structure goes to failure.

Keywords: Column Structure, free vibrations, Natural frequencies, Accelerometers.

1. INTRODUCTION

The first natural frequency is extracted from the uncracked and cracked column structure using free vibration analysis. (Gounaris, 1988) discussed that vibration amplitude are greatly affected by the crack. The harmed structure yields high amplitude of vibration than the unharmed structure. He added that if the crack position is known the damage level can be estimated using vibration amplitude. (Sathe, 2016) showed that the natural frequency changes significantly due to the existence of cracks. The change in the frequency depends on the size and position of the crack. (Gillich, 2014) proposed a method that is applicated to beams having open cracks is based on the dynamic characteristics of the beam. The changes in natural frequencies of beams, when damage is formed, are significantly influenced by the damage's position, while the crack's depth just intensifies this effect. (Jt Kim, 2003) presented the method to detect and estimate the size of crack by frequency-based damage detection method and mode shapes based damaged detection method for the first modal frequency of a structure. He added that the damage in the structure can be located quite easily with a very small error by two mentioned techniques. (Furukawa, 2004) provided information about the position of crack and severity of damage caused by a change in structural parameters. Damage detection equations were derived from the equations of motion of a structure before and after damage. This identification method has a benefit that data is obtained by excitation frequency. (M. Yu, 2018) analyzed the effects of natural frequency for a single crack on the fan blade. Also, the vibration parameters are delicate to the crack position, size and number of modes. Numerical simulation based on finite element analysis method was used for the detection of a damage to the fan blade. He measured the frequency of the blade by using accelerometers and this method provided a useful tool for diagnosing the damage in the blade.

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(T.Y Kam, 1992) quantified modal parameters and vibration frequencies that are utilized in a damage level assessment procedure to define damage position and extent. The use and the accuracy of the planned techniques are established for finding a crack in a cantilever beam.

(S Sekhar, 2004) identified that the equivalent loads and faulty parameters should be compared from quantified vibrations and mathematical model. The data would match precisely when no noise and faults are existing in computing the data due to the modal expansion of the damaged model. (Ruotolo, 1997) addressed the techniques for structural damage identification like damage detection, and damage sizing. He applied the damage identification technique both on numerical and experimental data. The cracks were introduced in the form of cuts at identified location, depths and dynamic characteristics were measured for both harmed and unharmed specimen.

(Gudmundson, 1982) presented that the variations in the frequencies give evidence about the size of flaws in a structure.

Precedent studies were only limited to the analysis on a

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cantilever beam or structures, but very limited amount of study is done in the field of column structures. In this study, the experimental study of a column structure is presented utilizing the experimental data collected from transducers for the damaged and undamaged column structure when the structure is subjected to free vibration.

2. METHODOLOGY

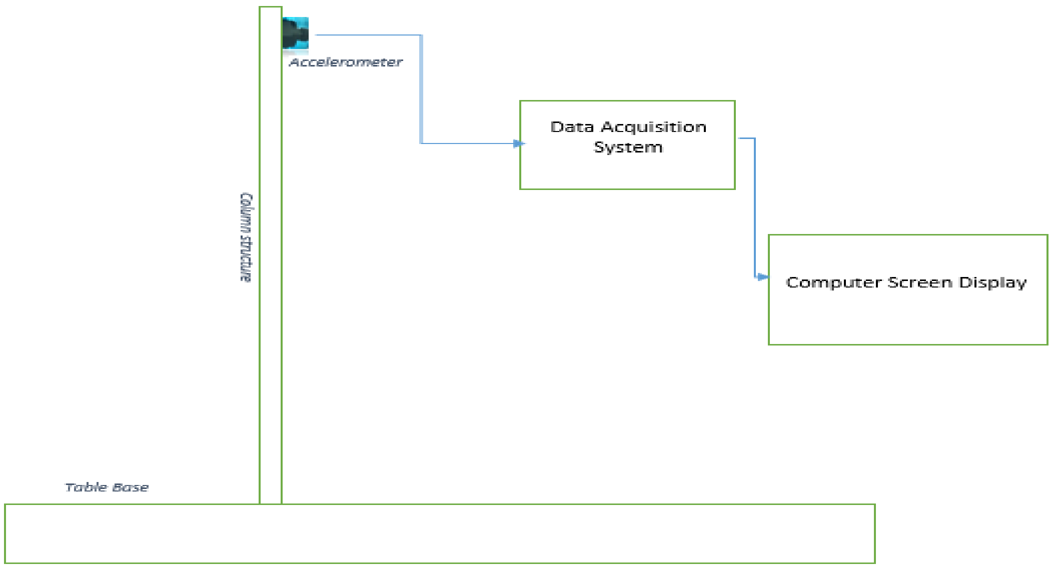

Figure No. 1 Experimental setup for column structure

The cast iron column structure is a 1000mm long column, while the cross-section area of the column is 12.5mm. The model is welded to the flat plate to make it a column structure for which one location is restrained and another location free. The entire model is bolted to the shake table. The column structure resists axial loading however, it vibrates for transverse loading and cracks are more sensitive to the transverse loading.
The structure is instrumented with an accelerometer which is screwed to the top end of the column structure. The accelerometer is a sensor that converts vibration signal to the acceleration signal. This acceleration signal is further transferred to the Data Acquisition System which acts as a device to convert analog signal to digital signal. This signal is filtered to remove unwanted noise and other unwanted signals. The column structure is given free vibration by striking it with the help of a hammer. Free vibration of an undamaged column structure is carried out and first three undamaged natural frequencies of the column are extracted. The structure is damaged at three different crack depths near the fixed end of the column. The structure is damaged at 250mm from the restrained end. The modal parameters and modal frequencies of the damaged and undamaged column are compared together to show the response of the column for different crack depths. This research deals with the experimental vibration analysis of a column structure and to find the response of the structure for different crack depths when the damage is induced adjacent to the secure end of the column structure.

3. RESULTS

3.1 Undamaged column structure response

The siesmo-signal software was used to manage the data extracted from the column structure. The undamaged response of the column structure is plotted in Figure 2 and Figure 3.

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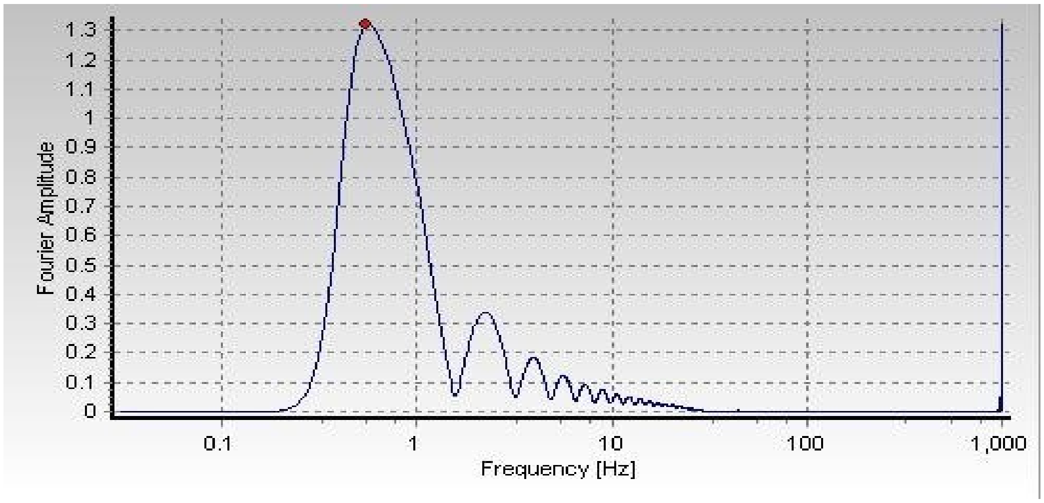

Figure No. 2 Undamaged column data showing Fourier Amplitude Vs Frequency

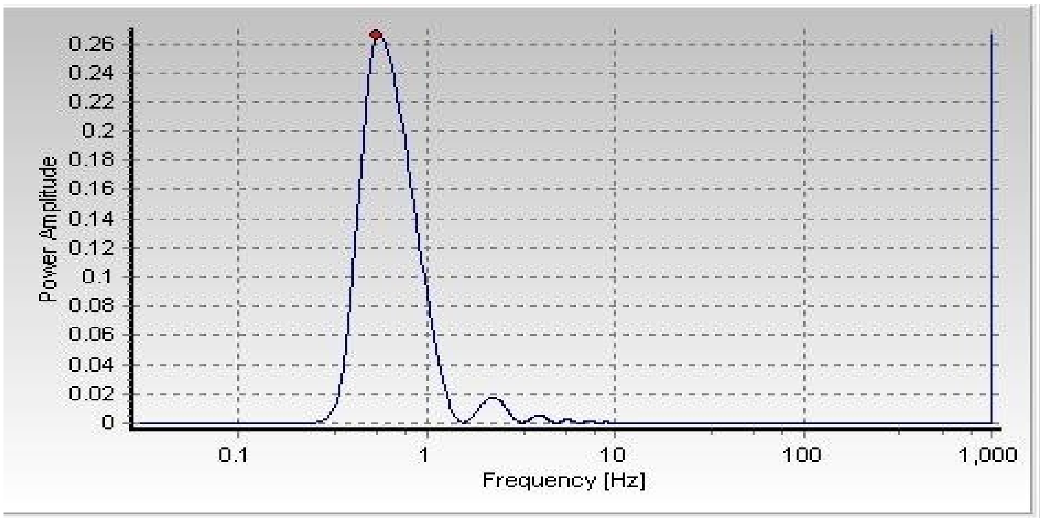

Figure No. 3 Undamaged Column structure showing Power Amplitude vs Frequency

The peaks on both figures represent natural frequency. The first natural frequency for the undamaged column structure appears at 0.54932 Hz.

3.2 Damaged Column response

The column structure is damaged at three different damage levels ranging from 03mm to 08mm in depth. The position of the damage is kept constant which is at the distance of 250mm from the fine-tuned end. The first mode for the 03mm depth and the data from the accelerometer is depicted in Figure 4 and Figure 5.

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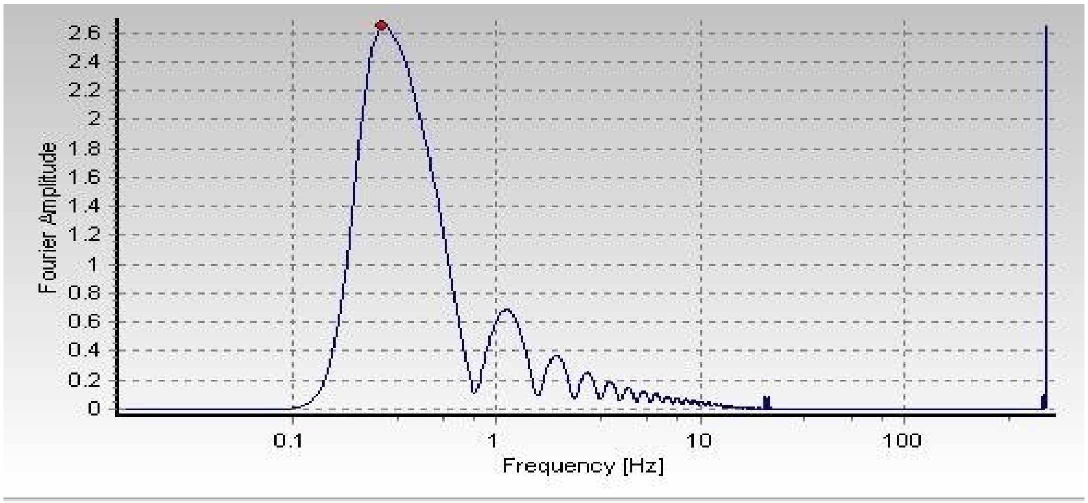

Figure No. 4 Damaged column structure showing Fourier amplitude vs Frequency for 03mm crack depth

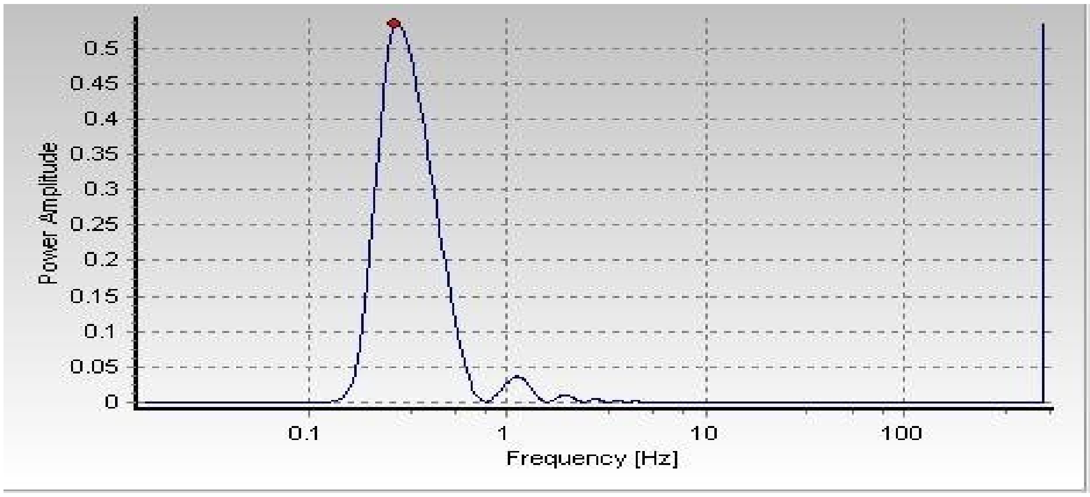

Figure No. 5 Damaged column structure showing Power amplitude vs Frequency at 03mm crack depth

The column was damaged near the fixed end at 03mm crack depth with the help of a hand saw. The first natural frequency for the column with the crack depth of 03mm comes out to be 0.27466 Hz. the natural frequency gets lowered when the crack is initiated in the column. As it is decreased from 0.54932 Hz to 0,27466 Hz. This reduction in the natural frequency established that damage appears in the column.

The damage level further amplified with the aid of a handsaw at the same location. The structure is now at the 06mm damage. The plots showing Fourier and power amplitude vs frequency is depicted in the Figures 6 and 7.

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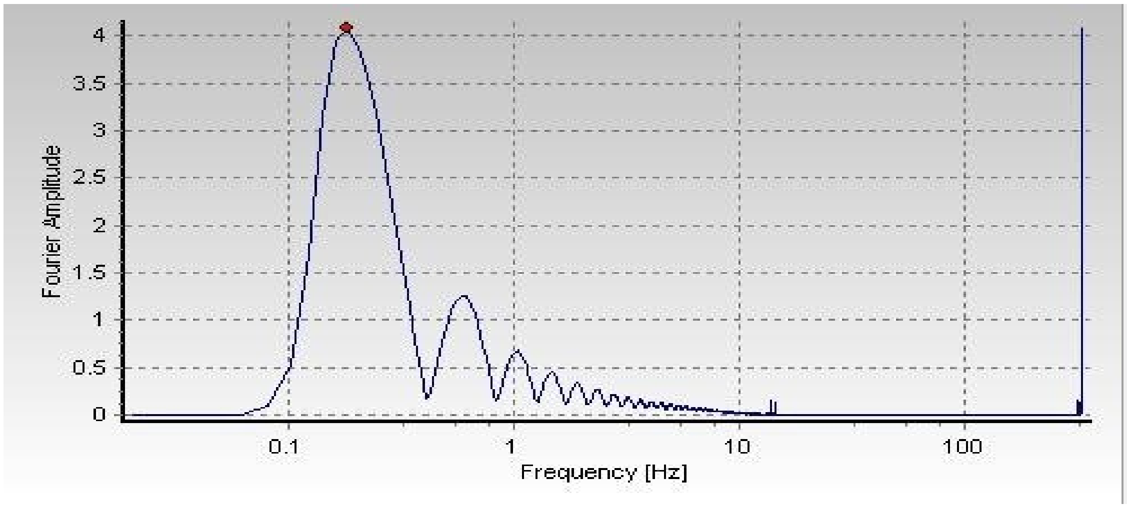

Figure No. 6 Damaged column structure showing Fourier amplitude vs Frequency at 06mm crack depth

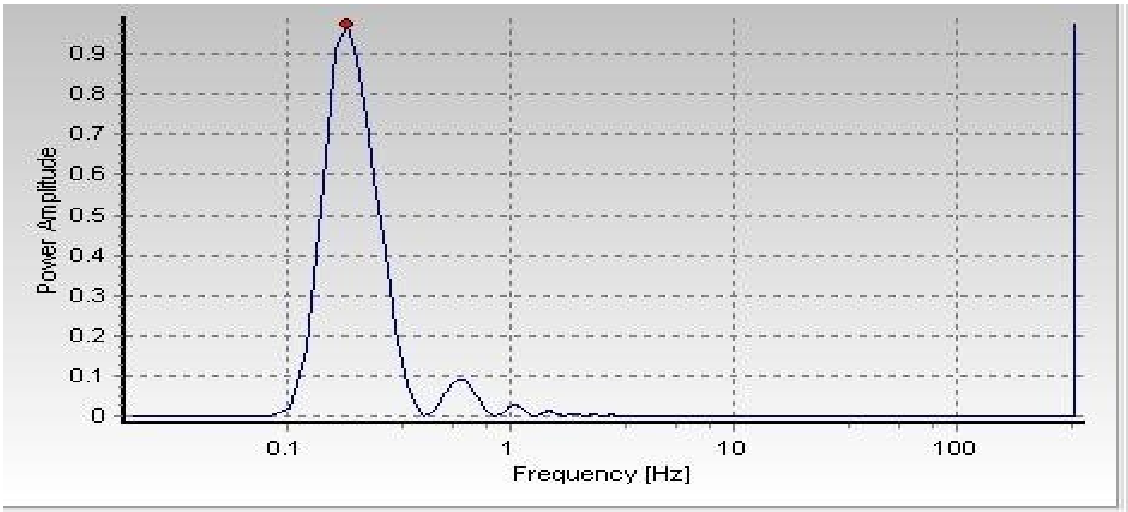

Figure No. 7 Damaged structure showing Power amplitude vs Frequency at 06mm crack depth

The natural frequency is reduced from 0.27466 Hz to 0.18311 Hz when the crack depth is increased from 03mm to 06mm.

The column structure crack depth is increased from 06mm to 08mm for the same location that is near the fixed end. The data from the transducer is plotted in Figure 8 and 9.

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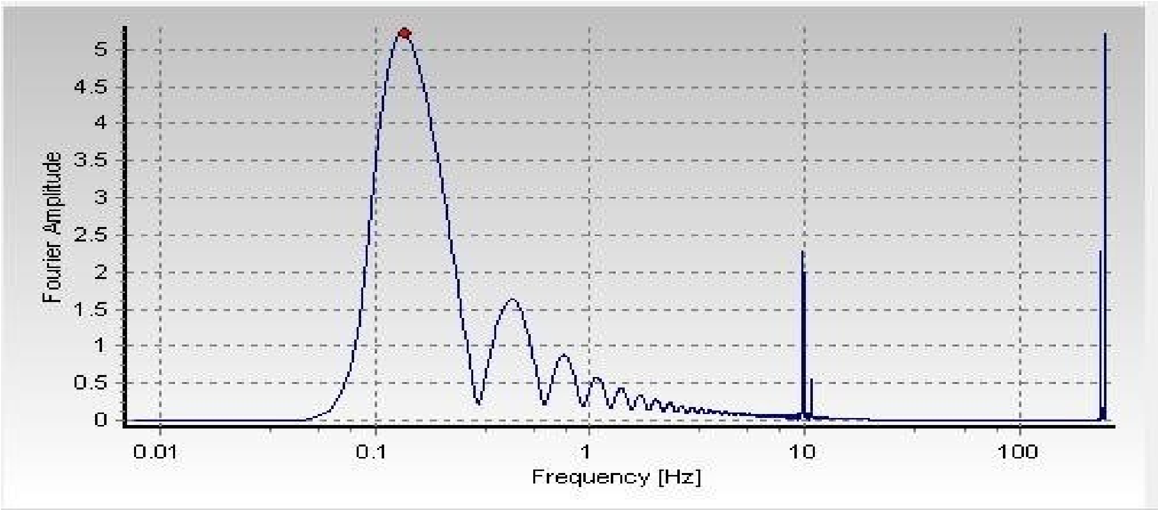

Figure No. 8 Damaged column structure showing Fourier Amplitude vs Frequency for 08mm crack depth

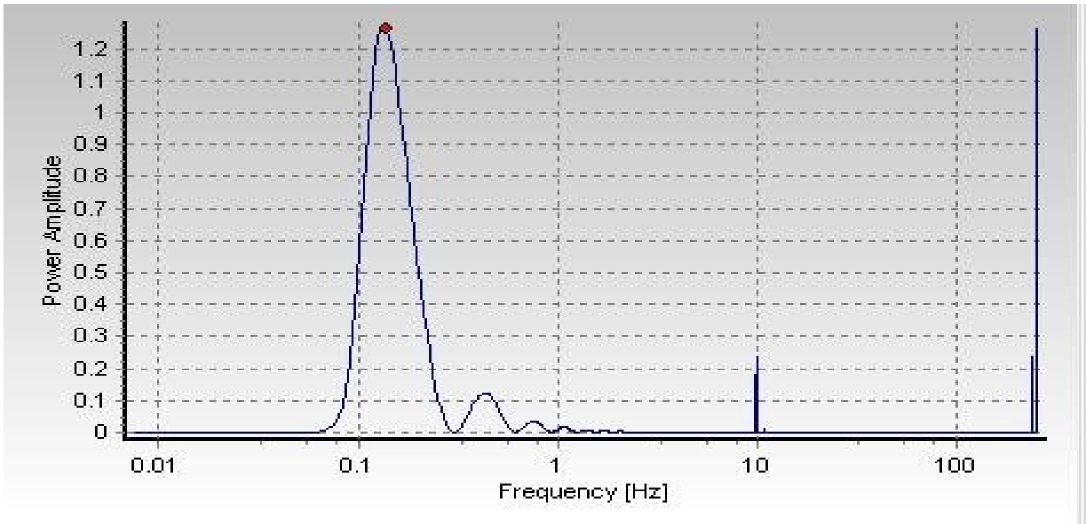

Figure 9 Damaged column structure showing Power amplitude vs frequency for 08mm crack depth

The natural frequency for 08mm crack profundity when the damage is positioned near the secured location is reduced from 0.18311 Hz to 0.13733 Hz. This decrease in the natural frequency corresponds to the reduction in stiffness and material degradation.

4. DISCUSSION

A squared cross-section area column structure is taken to carry out the free vibration analysis of a damaged and undamaged column structure. hammer has used a tool to strike the structure for free vibration analysis. The sensor (accelerometer) pick up the vibration signal and transform it to the acceleration signal. The output of the accelerometer is subjected to data acquisition system where signal conditioning is done to filter out the unwanted noise and other signals. After signal conditioning, the signal is imported into the software in the form of a text file. The frequency is intrigued on X-axis; the Fourier amplitude is plotted on the Y-axis for undamaged column structure.

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The peak in the results indicated the natural frequencies. Free vibration analysis is done for the column structure to extract the natural frequencies. In this analysis, the only first natural frequency is taken into the account for the damaged and undamaged column structure. The structure is damaged adjacent to the welded end of the column with crack depth ranging from 03mm to 08mm. The same analysis is repeated for the damaged structure for each depth case. The first natural frequency is taken from the results for every crack depth i.e. 03mm, 06mm and 08mm. these natural frequencies are plotted for the different damaged scenarios.
The normal frequency of the column depreciates as the damage in the structure advances. The frequency and crack depth are in the inverse relation with each other. from the outcome of the results for cracked and uncracked column structure we notice a decline in the modal frequencies. For the undamaged column, the first natural frequency was 0.54932 Hz. When the damage of 03mm was introduced the first modal frequency dropped to 0.27466 Hz. this drop in the natural frequency specifies that the damage has arisen in the structure. The crack depth is increased from 03mm to 06mm and again the first natural frequency decrease to 0.18311 Hz. Similarly, for the 08mm damage, the first natural frequency again dipped to 0.13733 Hz.
It is observed that when the damage in the column structure advances decreases in the natural frequencies is noticed. If we keep on increasing the damage level the frequency will drop and a time will come when the structure will undergo failure. The summary of the first natural frequency for different damage cases is mentioned in Table 1.

Table No 1. Summary for First Natural Frequency for different damage levels.

Damage Level	Natural Frequencies
Undamaged column structure	0.54932 Hz
03mm damaged column structure	0.27466 Hz
06mm damaged column structure	0.18311 Hz
08mm damaged column structure	0.13733 Hz

5. CONCLUSION

Experimental free vibration analysis of a column structure is presented in the paper. The free vibration is subjected to the undamaged and damaged column structure to extract the first modal frequencies. The response of the uncracked and cracked structure is noted. It is observed that the frequency tends to drop as the crack in the structure increments. The natural frequency is reduced when the crack in the structure grow bigger in depth. The natural frequency and crack depth share an inverse relation with each other. The frequency decreases due to increase in damage levels, reduction in stiffness and material degradation. If the damage level in the structure increments, then a time will come when a permanent failure in the structure will occur.

ACKNOWLEDGMENT

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SELECTION OF COMPOSITE MATERIAL USING ONE WAY ANOVA FOR FRICTION STIR WELDING

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ABSTRACT

The paper focused on the selection of composite material using One-way ANOVA based on the tensile shear strength of weld joint produce by Friction Stir Welding process. The FSW was carried out on industrial grade locally available customized polycarbonate (PC). The fibre glass (FG) used as composite material in this research is arranged from local market. One-Way ANOVA is used to find the significance difference in the mean shear strength of material and Fisher's Least Significant Difference Test are employed to compare mean shear strength of welds produced by FSW among different composition materials having composite material (FG) by weight. The composition of fibre glass is 5%, 10%, 15% and 20% under same machine parameters i.e., feed rate and rotation speed. The selection of fixed parameters is; 12 mm/sec for feed, 1250 RPM for tool rotation and conical threaded probe tool. The experiments suggested that PC with 15% FG produce highest mean strength under same process parameters and also exhibit the highest mean shear strength to base material. The materials have shown significant difference in their mean shear strength after analysis through Fisher's LSD method.

Index Terms— Single factor ANOVA, One-way ANOVA, FSW, Friction stir welding, Composite material, Polycarbonate

INTRODUCTION

The process of FSW is defined as, it is a process in which a rotation tool having probe and a shoulder plug into the welding specimen causing the friction that result in heat generation which lead to plasticize the material around the tool probe and it is forged together behind the probe under adequate pressure exert by the shoulder in the direction of tool travel (Ahmadi, Arab et al. 2014, Gibson, Lammlein et al. 2014).

Thomas et al (Thomas and Nicholas 1997) advised this method of welding during his investigation for non-conventional method of welding. He was researching for "The Welding Institute" (TWI) located in Cambridge of United Kingdom and was patent of TWI. The objective of this method was to obtain a high strength weld joint with improved mechanical characteristic, while keeping in view the cost effectiveness of the method. From 1991 till this date different materials were welded through FSW process that include light metals like copper, aluminium brass, magnesium etc. beside these light metals plastic was also welded through this process (Sahu and Pal 2015). This process has been researched by different researchers and its benefits were harnessed in their publications. The research studies showed that the process produce significantly low distortion in joining process when compare to other fusion type welding. Also, not using the filler and low energy for welding make this process more cost-effective compare to other fusion processes (Unnikrishnan and Raja 2017).

This welding process is influence by its parameters and its proper selection are key for process performance for suitability with the purpose (Ahmadi, Arab et al. 2012). It also influences the microstructure of the weld (Liu, Murr et al. 1997, Buffa, Campanile et al. 2009, Vagh and Pandya 2012). One of very bright aspect of this welding method is the joining of two dissimilar material which is not possible through conventional fusion method (Koilraj, Sundareswaran et al. 2012, Gao, Li et al. 2016). The world is striving for green method of processes and are encourage the researcher to work for development of process that add little hazard to the environment. FSW is advancement towards green environment as it lacks the fumes, arc flash, spatter, and pollution associated with most fusion welding techniques (Akinlabi and Akinlabi 2012). For these and many other reasons, FSW has expanded quickly and has found applications in a wide variety of industries, including aerospace, automotive, railway, and maritime (Boulahem, Salem et al. 2015). The FSW is yet to be implemented in industries, but the researchers are investigating this process for different applications and for that reason they are studying its parameters. However, they can be applied to several applications that includes the heat sinks welded laminations cabinets and enclosures for electrical applications, in Shipping industry pallets boats and ship Building, golf cars, snow mobiles suspensions, tanks, cylinders for seam welding replacement, in aerospace industry floors, wing and fuselage. In automotive industry wheel rims and suspension arms while in locomotive industries Rail car body, window, side wall and coupling gears (Akinlabi and Akinlabi 2012).

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LITERATURE REVIEW

FSW process was initially developed for aluminium but later with the advantages and benefits of its process the application has been extended to polymers and a number of studies were conducted to verify its applicability in polymers family (Bagheri, Azdast et al. 2013, Ahmadi, Arab et al. 2014, Panaskar and Terkar 2016).

The important parameters that effect the FSW process are the rotation of tool, the feed rate or also known as the welding peed, tool probe profile design, tilt angle and plunge depth (Koilraj, Sundareswaran et al. 2012). These parameters need to be verified for different materials as their behaviour varies with the material and especially in case of polymers. Varying the parameter will produce different result in term of weld efficiency, strength and quality of weld (Bozkurt 2012). In this context, researchers have studied the parameters and published their work.

Tool rotation

The Tool rotation an important parameter and is controlled by the spindle of machine. The literature review suggest that the high rotation speed of tool favour the weld strength produce as result of FSW (Bagheri, Azdast et al. 2013). Rotation is source of heat generation in this process and high rotation will result in availability of more friction and hence easy heat the material for welding (Gao, Shen et al. 2015, Gao, Li et al. 2016). But with the high rotation speed of tool the studies suggested that adequate feed rate is necessary. In metal FSW the relatively high feed rate is favoured the finish and quality of the weld with combination of high tool rotation. The grain size of the metal in stir zone decreases while the yield strength increases and the weld produce is having slightly higher hardness at weld zone however the tensile strength increases.

Feed rate

Fast feed drops the strength and quality of the weld (Barcellona, Buffa et al. 2006, Buffa, Campanile et al. 2009, KS, Karur et al. 2015). However, in case of polymers the studies suggest that the feed rate should be minimal in order to produce a quality weld with high shear strength. However again this feed rate varies with the material as every material in polymers have different melting point and their mechanical characteristics are sensitive towards the temperature
.

Tool probe design

Tool probe design is important parameter of FSW and studies suggest that it has significant influence on the weld quality and strength (Amirizad, Kokabi et al. 2006). Different type of prob designs were tested on different material and their results indicated that the threaded pin probe threaded conical (Panneerselvam and Lenin 2014), cylindrical threaded (Watanabe, Kagiya et al. 2006), frustum-shaped rounded-end and cylindrical flat-end (Kumar, Kailas et al. 2008) fillet and cavity influence more than flat and smooth probe design without a feature (Scialpi, De Filippis et al. 2007). These design also has influence on the microstructure of weld (Zhao, Lin et al. 2005).

Most of the research is on Aluminium, however, now the thermoplastics are also tested for this welding method. The literature review indicates that different material has been experimented for FSW, however no evidence has been found that has testified Polycarbonate having composite material for FSW**.** This research is intended to determine which material composition is more favouring the FSW process. The material is polycarbonate (PC) having composite material as Fibre glass (FG) 5%, 10% 15% and 20% that has been arranged from local market.

METHODOLOGY

The research approach is illustrated in flow chart as in **Figure-1**. The One-way ANOVA approach (Alo, Atanda et al. 2017) of design of experiment has been used along with Fisher's Least Significant Difference (Krishnaiah and Shahabudeen 2012) for pair comparison.

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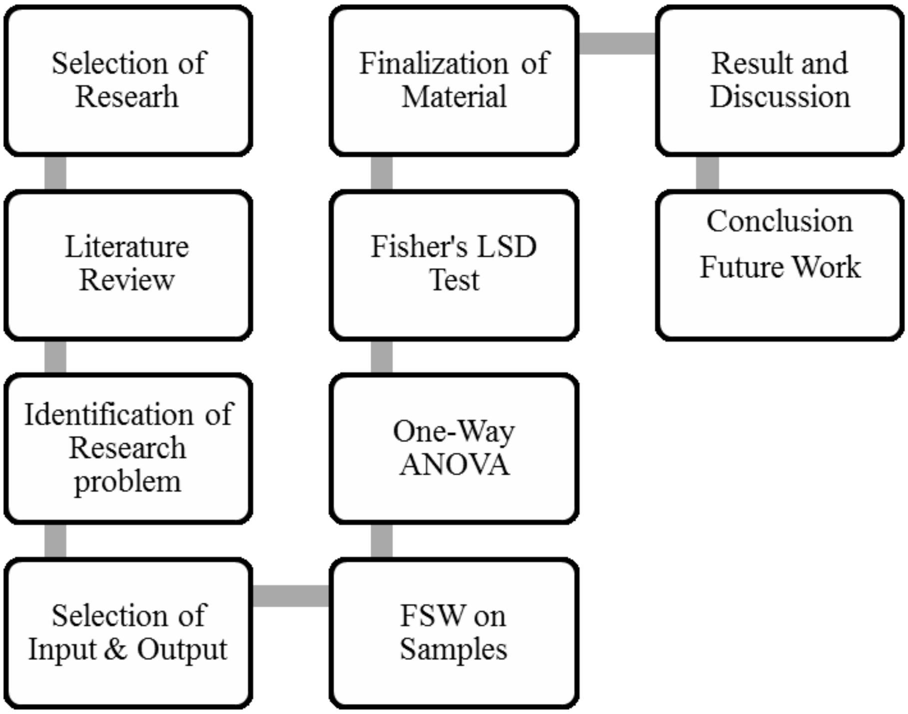

Figure-1, Flow Chart of Methodology

EXPERIMENTATION

The specimens are moulded using injection moulding machine (JSW JD 220 AD as shown in **Figure-2**) according to their compistions. The mould were design using CAD/CAM software and the model design and mould is shown in the **Figure-3.** ASTM D5868 standard is followed for specimen sizes that are 101mm × 50mm × 4mm and having thickness of 4mm shown in **Figure-4**. A CNC machining centre (Lilian VMC 1100) as shown in **Figure-5** and a clamping arrangement as shown in **Figure-6** are used for FSW process.

Figure-2: Injection Melding Machine

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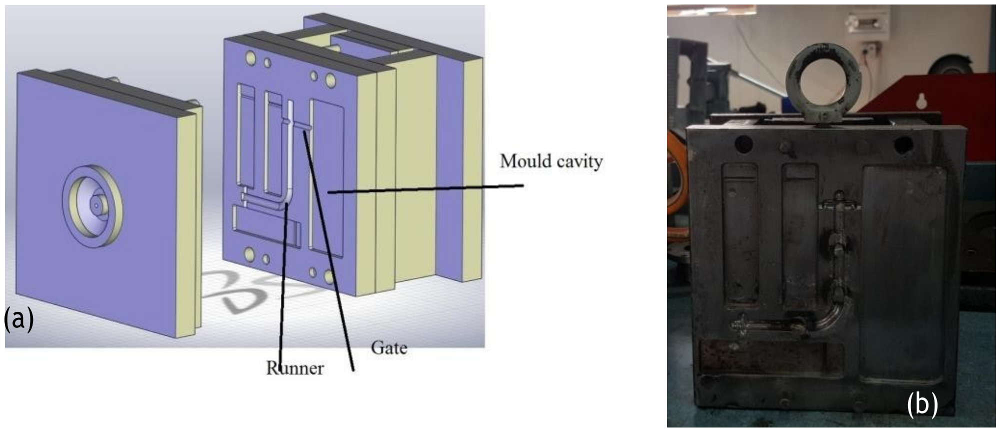

Figure-3: (a) Mould Assembly Model (b) Mould cavity and runner

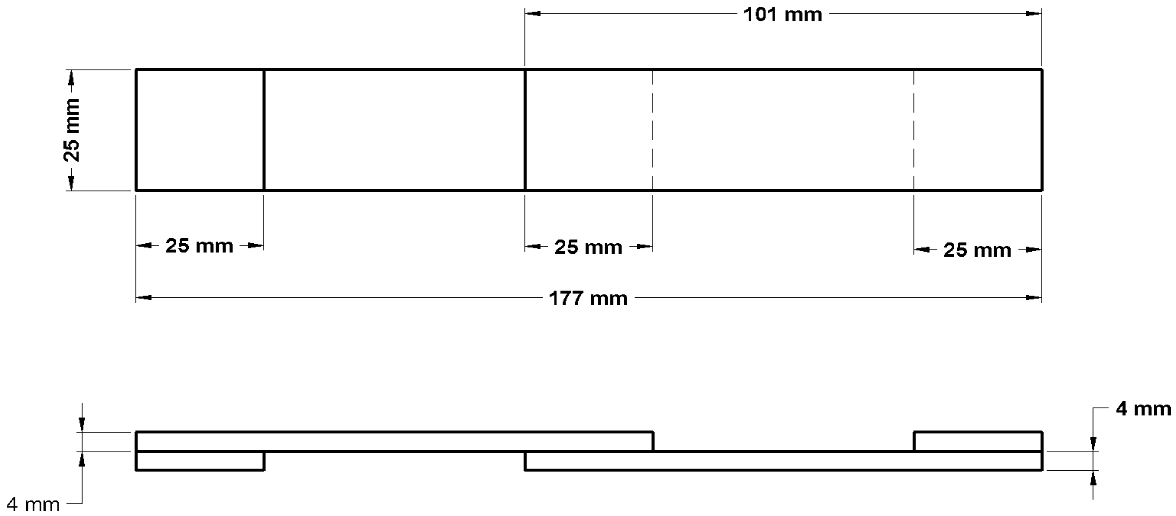

Figure-4: ASTM D5868

Figure-5: CNC Machining Centre VMC1100

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Figure-6 Fixture and specimen setup

The tool has threaded conical probe design and having shoulder diameters 12mm. the description of tool is given in the **Table-1** and the pictorial illustration is given in **Figure-7**.The H13 material is used for manufacturing of tool.

Tool No	Description of the pin	Length of the pin (mm)	Diameter of the pin (mm)	Diameter of the shoulder (mm)
4	Threaded Conical	7	4	12

Table-1: Tool Pin Geometry

Figure-7: Tool and its Geometry

Tensile shear strength tests have conducted using a Universal Testing Machine (UTM). Figure-4 illustrates the tensile test setup.

PROCESS PARAMETERS

In first phase working material based on composition of FG in PC (i.e., 5% 10% 15% and 20%) is selected using One-way ANOVA and the fixed input parameters were selected as 1250 RPM for tool rotation and 12MM/sec feed rate and tool selected were conical threaded. These fixed parameters were selected based on literature review and test runs before conducting the research to check the performance. The shear strength of weld is selected to be the response and is given in **Table- 2**

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Material (Factor)	Rotation (RPM)	Feed Rate mm/sec	Tool Design	R1 (MPa)	R2 (MPa)	R3 (MPa)	R4 (MPa)	R5 (MPa)
5%	1250	12	Conical Threaded	4.92799	7.32567	4.78087	7.4102	5.15535
10%				5.81663	4.2105	7.10926	16.8965	4.80507
15%				8.56025	9.7476	12.3143	13.3126	8.55958
20%				7.46291	7.46291	6.3004	7.84926	5.8543

Table-2: Input Output Parameters

RESULTS AND DISCUSSIONS

Before ANOVA analysis the data was tested for assumption and test of equal variance was carried out. Leven test has been performed which has clear the health of data. (R stands for response and F stand for factor which is the material). The Levene p-value is more than $\alpha = 0.05$ then it means the hypothesis is accepted and there is equal variance in the data. The test is shown in the **Figure-8**

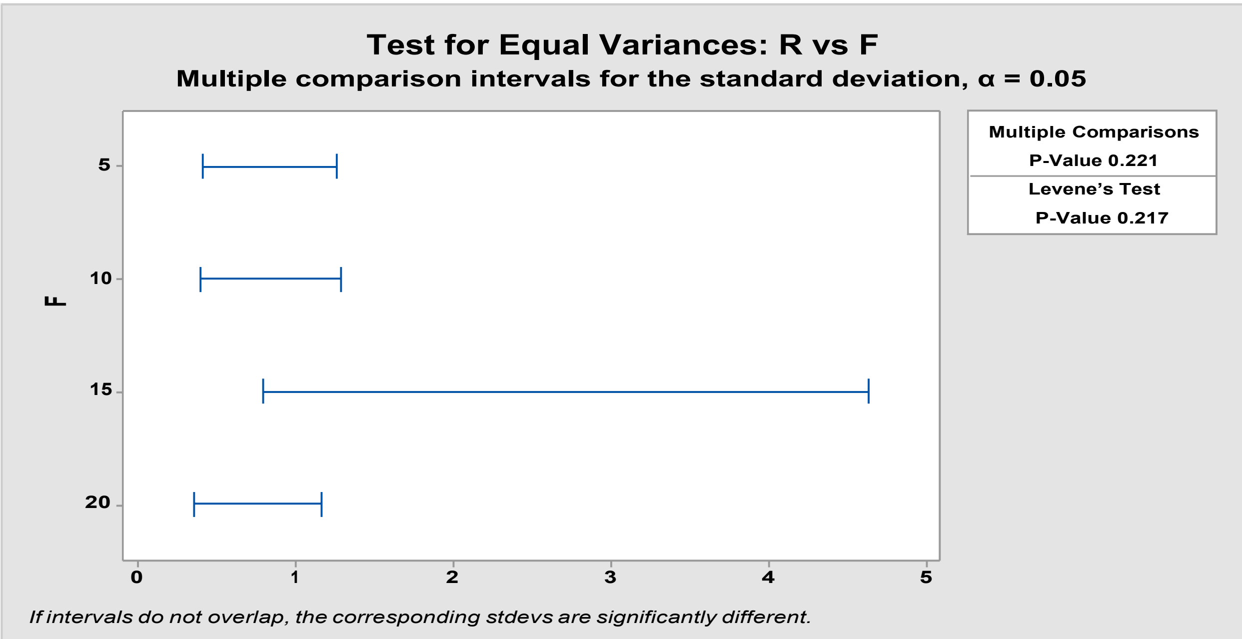

Figure-8: Test for equal variances

Analysis of variance has been carried out for the material as factor. The difference in mean of material has been studies. The factor (material) has significant effect on the shear strength of FSW. The probability value (P-value) at 0.05 CI the value is less than 0.05 which indicate that all means are significantly different.

Source	DF	SS	Contribution	MS	F-Value	P-Value
Factor	3	72.649	87.98%	24.216	39.05	0.001
Error	16	9.922	12.02%	0.6201		
Total	19	82.57	100%			

Table-3, One-way Analysis of Variance

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Grouping Information after application of Fisher's LSD Method at 95% Confidence is given in **Table-4**. In these results, the table shows that group A contains PC with 15% FG and group B contain PC with material 10% FG and 20%FG while group C contain PC with 5% FG. This means that all the means are different while the PC 10% FG and PC 20%FG has minimum difference in their mean and are placed in same B group. This table shows that all the means do not share the groups so they are statistically significant.

Factors	Number of experiments	Mean	Grouping		
15%	5	12	A		
10%	5	8.7		B	
20%	5	8.678		B	
5%	5	6.678			C

Table-4, Respective shear strength of each material

Table-12 illustrates Fisher's individual test comparisons. It shows a set of CI for difference between means of comparing pairs. From **Table-5** and **Figure-9**, the Cl for the difference between the means of Factor 10%FG and 5%FG spreads from 1.044 to 3.156 which does not contain zero. This shows statistical significant difference between two comparing means. Same is case for 15% FG and 5%FG that has range from 4.264 to 6.376, 20%FG and 5%FG has mean spread from 0.942 to 3.054, 15% and 10% has spread from 2164 and 4276 and 20% and 15% has spread from -4.378 to -2.266. All these CIs do not include the zero and hence all of them have significantly different means. However, the CI 20% and 10% pairs has upper and lower limits from -1.158 to 0.954 and spread of mean covers zero, this mean that there is no statistical difference between their means.

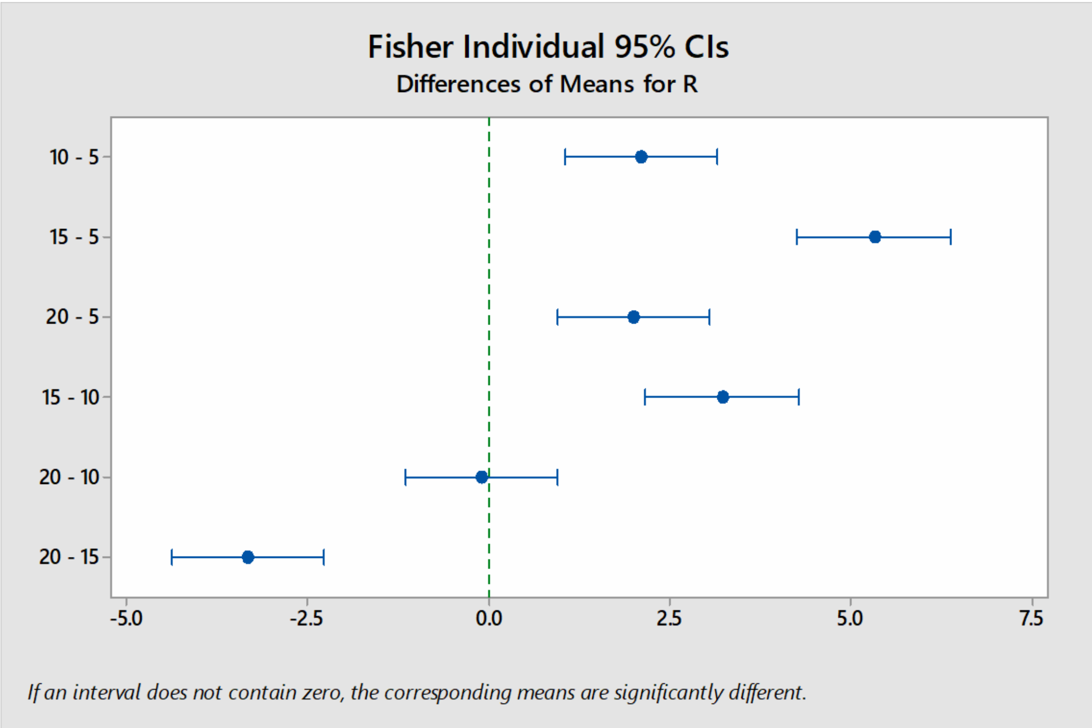

Figure- 9, Fisher "Individual" 95% CIs difference of Mean for R

The **Table-5** shows that all the p-values for comparing pairs are less than alpha level (α) that is 0.05, except for the pairs 20 and 10 that is 0.84. The p-value is higher than designated the significance level. This indicates that the only

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non-significance pair means difference is of PC 20% FG and PC 10% FG.

Difference of level	Difference of Means	SE of Difference	95% CI	Adj. T-Value	P-Value
10 and 5	2.1	0.498	(1.044 , 3.156)	4.22	0.001
15 and 5	5.32	0.498	(4.264 , 6.376)	10.68	0
20 and 5	1.998	0.498	(0.942 , 3.054)	4.01	0.001
15 and 10	3.22	0.498	(2.164 , 4.276)	6.47	0
20 and 10	-0.102	0.498	(-1.158 , 0.954)	-0.2	0.84
20 and 15	-3.322	0.498	(-4.378 , -2.266)	-6.67	0

Table-5, "Fisher Individual Tests for Differences of Means"

The results of F-Test indicate that all the groups' means are significantly difference as all the pairs does not contain zero as shown in Figure-5 and has P-Value less than 0.05. However, only the material with 10% and 20% FG are insignificantly different and contain zero with P-value 0.840 which is greater than 0.05. From Table-5, material (PC) with 15% FG shows the highest mean shear strength among all the other materials and also has significant difference of mean when compare to other materials. Based on its strength and study above material PC 15%FG is selected for further studies as result of one-way ANOVA.

Based on above analysis, it has been determined that the material with 15% FG has significantly different mean and has the highest mean for tensile shear strength among all the other materials under same conditions as show in the Figure-10. Therefore, we conclude that the PC with 15% FG by weight will produce optimal tensile shear strength during FSW compare to other competing materials.

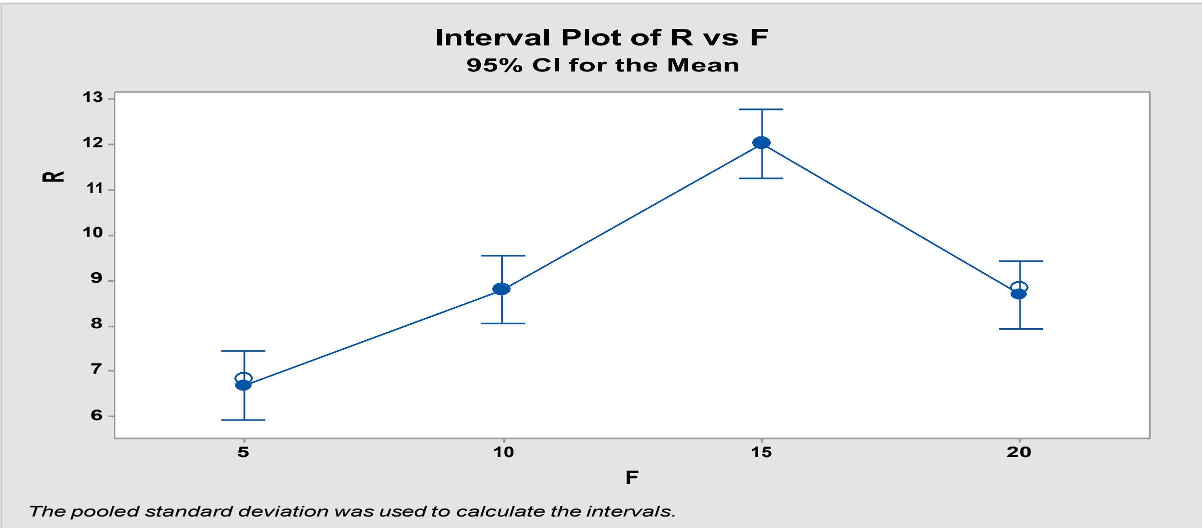

Figure-10, Interval Plot of R Vs F

CONCLUSION

Material was selected among four options based on strength of joint and later own the selected material confirmed for having highest weld to base strength. Experimentation was carried out for each material and 20 samples were prepared. The data was validated for ANOVA assumptions through variance equality tests. After fulfilling the assumptions One- way ANOVA was carried out and in the result the material it is concluded that all the mean are significantly different from each other. One-way ANOVA also confirmed that the process has significant effect on the material variability. The LSD test concluded that the material having 15% has significantly different mean shear strength from other comparing competitors. Based on highest mean strength of weld that is 12 MPa, it is concluded that the PC having 15% FG is more suitable for FSW process.

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FUTURE WORK

A Taguchi design of experiment may be carried out to find the parameters effects on the weld joint shear strength. Multiple levels of parameters may be selected based on the literature review and their effect and process variance may be determined. A confirmation test may be carried out to confirm the resulted strength and compare it with the model predicted shear strength.

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AUTOMATIC STAIR CLIMBING WHEELCHAIR

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Abstract

Since the beginning, human has been striving to excel in science and technology to overcome the limitation and enjoy a comfortable life. More than A billion people (approximatly15% of the world's population) over the globe have one or another form of disability constituting. Mobility is the most common problem of disabled peoples and to facilitate in stairs climbing or tackling barrier without assistance, automatic wheelchairs are becoming a necessity. This study is the design of a compact and economical wheelchair with stair climbing ability to make disable people independent. The method is to employ a joystick controlled stair-climbing wheelchair operation beyond institutional settings (outdoor), moving in structured and unstructured environments. Our proposed proto type wheelchair model can easily adjust with surfaces such as, flat, bumpy, and moving up/down stairs.

Keywords: Automation; power electronics; dynamics.

1. INTRODUCTION

Since the beginning man has been striving to excel in science and technology to overcome the difficulties and provide for himself a comfortable life. Unfortunately, not all people enjoy the same level of comfort especially the disabled. They face countless number of obstacles and hardships in their life. More than 1 billion people over the globe have one or another form of disability constituting about 15% of the world's population[1]. Over the last few years, the disable people got more attention of the society. The most common problem of disabled people is mobility, an issue that the introduction of power wheelchairs has done much to diminish. However, a power wheelchair is useless when tackle it to architectural barrier as it limits the mobility and access [2][3]. To overcome this reason, various number of wheelchairs having the ability of stair-climbing have been introduced[4].

In Pakistan there is no as such facility for disable people to climb the stairs or tackle any barrier without any assistance. So for this purpose a compact and economical wheelchair with stair climbing ability is designed to make disable people independent.

2. LITERATURE REVIEW

For the betterment of lifestyle of disable people up to a great extent, a lot of work is done in the order to provide a better way for mobility without any assistance[5]. In present times a wide range of assistive and guidance systems are available in wheelchair to make their life more comfortable [6][7][8][9]. In present-day times various control systems have been developing specialized for people with various disabilities. The old traditional systems are less competitive to the systems that are developed now a days[10][11][12][13][14][15].

The research and analysis of motorized wheelchairs dates back in time with several researchers and scientists assessing the mechanism of stair climbing. Ghani et al[16] investigate the control of a wheelchair with stair climbing ability used for indoor objective.

This paper appraises different mechanisms having ability of stair climbing i.e. leg type, crawler type, Ibot, hybrid type, and wheeled type[17][18][19][20].

This research is to design a wheelchair which can step and stair controlled by joystick. This stair climbing wheelchair helps the user to move in surrounding by overcoming obstacles and doorway. This wheelchairs must be highly interactive to enable the system to work most efficiently based on previous research[21][22][16].

2.1. Comparison of different mechanism

As previously mentioned 15% of world population is suffering from different type of disabilities. And a courteous society must make sure equitable living condition of its member counting disable people. Therefore, for this purpose, different wheelchairs are designed which are discussed in table 1. Various mechanisms are discussed in the following table in which the advantages and drawbacks of each mechanism are discussed in detail.

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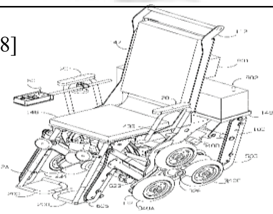
Table 1. Comparison of various wheelchair mechanism

S.No	Mechanism name	Advantages	Limitations
1	Platform Stair lift mechanism[23] 	1. Carries wheelchair directly Compact form (when not in use). 2. Need no assistance.	1. Require open and wide stair way. 2. Expensive. 3. High Power consumption. 4. Mechanism dedicated to single Stair way.
2	Light weight wheelchair climbing attachment[24]. 	1. Stair climbing facility. 2. Compact. 3. Light weight. 4. Suitable for all type of stairs. 5. Use extensive wheelchair.	1. Required assistance in stairs and sloppy areas. 2. Required special instruction regarding usage. 3. No auto Break Mechanism. Can cause wear and tear of stairs. 4. Orbital motion may be uncomfortable for Passengers.
3	Dual wheel Cluster Stair climbing [25] 	1.Works as a general purpose wheelchair. 2. Automatic stair climbing ability. 3. Appropriatefor most standard stairs.	1 Large 2.Heavy 3. Orbital motion tends to be unbearable for Passengers. 4. Must climb stairs Backward.
4	IBOT wheelchair[26] 	1. High stability. 2. Automatic break system. 3. High speed. Comfortable. 4. Compact.	1. High Cost 2700$. 2. Complex Design 3. Maintenance and repair problem.
5	Planetary wheel stair climbing wheelchair.[27][28] 	1.Light weight Economical 2. Movement Efficiency. Suitable for all type of Stairs. 3. Convenient operation. 4. Compact. 5. Stair climbing Ability.	1. Must climb Stairs backward. 2. Require assistance. 3. Orbital motion may cause disturbance for Passengers.
6	Tracked wheel Mechanism[10]. 	1..Good Adhesion 2.Simple control 3.Not easily slip Good pass ability 4.High Transmission efficiency 5. Strong ability to adopt the terrain.	1. Heavy and large size structure. 2. Must climb stair backward. 3. Difficult to turn especially in narrow and small places. 4. High Pressure exerted on edge of stairs resulting in wear and tear. 5. Crawler drive with lower energy efficiency and moving slowly. 6. Noisy. 7. High Cost. 8. Low efficiency.
7	Leg type stair Climbing wheelchair 	1. Strong adoptability to terrain. Mechanism 2. Move Flexible.	1.Complex control 2.Complex Structure 3. Low carrying capability. 4. Low efficiency. 5.Low automation

3. MATERIAL AND METHOD

An economical and compact automatic stair climbing wheelchair is to be designed and demonstrated for disable people.

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One of the principal aim of this study is to analyze and prototype an automatic wheelchair having stair climbing facility based on large-scale establishment of facts and research on already exist models, used technology , market outline, and customer needs. One aim is to provide increased freedom in terms of mobility for the disabled. One of the main reasons to conduct this study was to provide an extra ordinary life for the disabled and make them independent in order to reduce the load on assistance. First stage of the research was literature review and market survey to build a theoretically sound foundation for the research. Second stage of the research is modeling and simulation that includes finding customer needs, plotting specifications, and producing conceptual ideas. Product architecture is also defined in this phase and parts are modeled in Solid works. We focus on design assembling, and simulation in effective environment. In the final phase, we advance towards prototype to run various tests.

3.1 Modeling and design

This phase include two steps shown in figure 1.

1. Design of wheelchair
2. Optimization design

In this step we start with outlining specifications, and generating concept designs shown in figure 3. Product architecture is also defined in this phase and parts are modeled in Solid works. The final phase we focus on design assembling, and simulation in effective environment. In the final phase, we advance towards prototype to run various tests

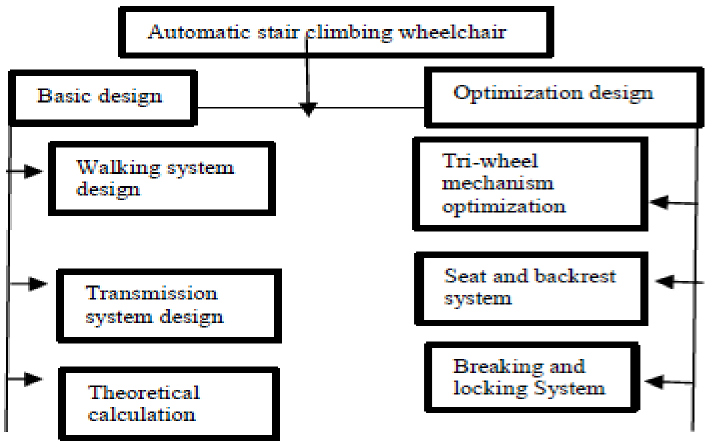

Figure1. Modeling and design

After analyzing and research on currently existing designs, used technology, market survey, and customer needs, we design an economical and compatible wheelchair having ability of step and stair using Tri-wheel mechanism as shown in figure 3 with an additional facility of uplifting a patient up to one feet by introducing linear actuators (Jack system) which can also help in stability of wheelchair as shown in figure 4. A gyro sensor was used for stability which is linked to the linear actuators. The Automatic Stair climbing wheelchair is controlled by Joy stick, thus making disable independent.
The design of an automatic wheelchair with "Tri-wheel mechanism" (Shown in Figure 2). In this mechanism three wheels are fixed in a standard triangle with two on the ground and one on the top of them. If any of the wheels in contact with the ground gets stuck with an obstacle, the entire system (principal axis) rotates over the barrier.

- The three wheels are 120 degree apart from each other
- The entire mechanism can rotate about a fixed axis passing through its center
- Each wheel can act as free wheel as it can also rotate freely on its own axis.

Figure2. Tri-wheel mechanism for automatic stair climbing wheelchair.

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Tri-Wheel mechanism (Also called Tri-star wheel) is introduced as a front wheeler while there is one wheel mechanism in rare side having 50cm diameter.

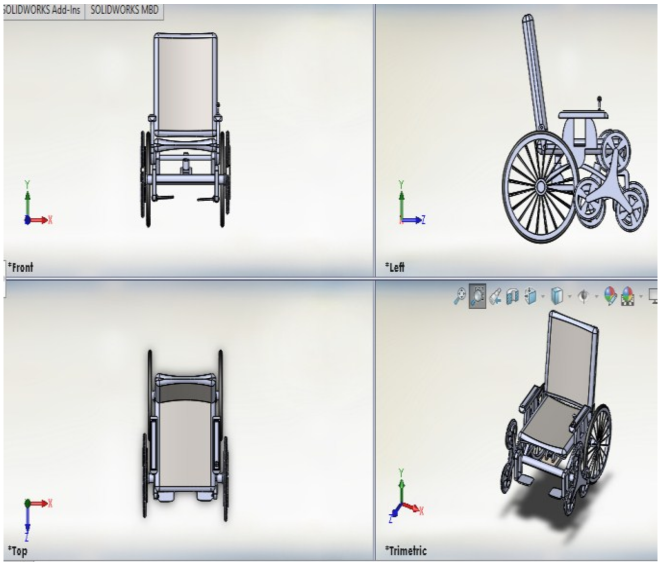

Figure3. Different views of design Automatic stair climbing Wheelchair Model using solid works.

There are three motors (each 120 W), one is connected to the shaft of rare wheel and two motors are connected to the shaft of tri-wheel mechanism. In normal condition (straight plane), only motor connected to the shaft at back side will be operating and tri-wheel mechanism will act as free wheel. When there is any stair or any obstacle comes automatically motors connected to the tri-wheel mechanism and back shaft will be turned on, thus the principal axis of tri-wheel mechanism will start rotating in order to stair up or down according to the conditions.

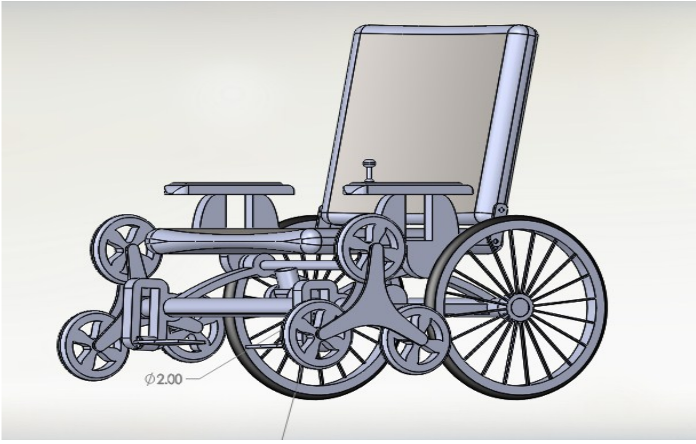

Figure4. Design of an automatic stair climbing wheelchair using solid works.

3.2 Stair step dimensions and observations

Basically there are three types of stairs which are mentioned below as shown in figure 5.

- The width is greater than the height.
- The width is lesser then the height.
- The width in equal to the height.

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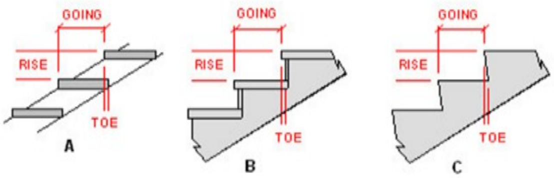

Figure5. Stairs dimension (a) width is greater then the height. (b) The width is lesser then the height. (c) The width is equal to the height

We had done some calculations of stairs in our department. We had find slope relationship for Rise and Going of stairs which is shown in Table 2.

Table 2. Stair Calculation

S. No	RISE (R)	GOING (G)	Slope Relationship= Rise + Going= 2R+G
1	15	35	65
2	18	39	75

3.3 Design Dimensions

In the design phase the dimension varies in proportion to scaling, depend upon requirement and need arises. While implementing on subjective case dimensions of some features of automatic stair climbing wheelchair may vary in some percentile after performing subjective analysis keeping in view the subjective perceptions. As this prototype is made for domestic use so variation in the size of stair will cause change in the dimension of wheels and wheel carrier. Dimensions of different parts of the proposed automatic stair climbing wheelchair are shown in Table 3.

Table 3. Design dimension

S.No	Parts	Length/depth	Width
1	Backrest	70 cm	49 cm
2	Base	10 cm	49 cm
3	Arnset	26 cm	7 cm
4	Frame diminsion	43 cm	45 cm
5	Battery	18.5 cm	12.5 cm
6	Gear box	10 cm	49 cm
7	Dc motor	26 cm	7 cm
8	Center to Center distance	20 cm	
9	Diameter of Wheel	20 cm	
10	Jack System	6 cm	
11	Thickness of wheelchair	5 cm	

It is favorable to empower disable people to lead their life independently and play as much productive role in our society as other normal people. The proposed and designed prototype has capability to uplift disable people's lives. The proposed wheelchair provides independent mobility as well as has any intelligent feature which help patient.

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4. CONCLUSION AND FUTURE WORKS

This study was the design of a compact and economical wheelchair with stair climbing ability to make disable people independent. The method is to employ a joystick controlled stair-climbing wheelchair operation beyond institutional settings (outdoor), moving in outdoor and indoor environments. The design has auto adaptive locomotion units, so it can move in structured and unstructured surroundings, can surpass obstacle and can stairs up and down easily. Keeping capacity of motors, it can be used for various weighted patient. Our proposed proto type wheelchair model can easily adjust with surfaces such as, flat, bumpy, and moving up/down stairs. Special attention was paid to the significant cost reduction cost versus accuracy to make it available for lower and middle class disable peoples.
In future, it would be interesting to observe how fuzzy logic could further enhance its accuracy, is currently under investigation.

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