Conference Proceedings

FACTURA '19

5TH NATIONAL CONFERENCE ON 'EMERGING TRENDS IN MANUFACTURING'

12th & 13th JULY 2019

DEPARTMENT OF MECHANICAL ENGINEERING
NSS COLLEGE OF ENGINEERING
PALAKKAD, KERALA

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FOREWORD

Dear Guests,

FACTURA'19 is an annual National level Conference organized by the Department of Mechanical Engineering of NSS College of Engineering. FACTURA'19 is a notable event which brings together academia, researchers, engineers and students to develop and showcase their technical prowess. There has been rapid development in technology related to these areas during the past few years and has resulted in change in techniques adopted in various applications. The scope of further development always exists and the conference would provide the opportunity to discuss the state of the art and to explore the avenues for future work. The activities were conducted as technical events in a two day programme at NSSCE campus. These conferences are now well-known national academic events and the number of paper submissions and attendees increase every year. This year, FACTURA'19 is funded by AICTE. This Conference has received almost 50 applications. The Conference Academic Advisory Board has accepted approximately 27 papers to be presented in the Conference.

We would like to thank Dr. A Surendran, Senior manager HRD,SIFL,Thrissur for the supports of organizing these Conferences.

We also would like to thank all participants who will present their academic works in FACTURA'19 and especially to our distinguished guests and keynote speakers for their collaboration and contribution for the success of FACTURA'19.

We wish you a successful conference and good time in NSSCE, Palakkad.

Dr. Rajeev N

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Effect of femtosecond laser-induced periodic structures on hydrophilicity and osseointegration in bioimplants

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Abstract: Titanium alloys (Ti6Al4V) are extensively used as implant material because of their good mechanical property and biocompatibility. However, the needs for better quality and longevity of implants have demanded even higher levels of biocompatibility of implants with human tissues. Inadequate osseointegration is the most distinguished motives for implant failure. In this study, Laser-induced micro features were created on the implant surface and Osteoblasts cells were seeded on the implant surface to measure the cells viability. The surface characterizations of the surfaces were evaluated by 3D confocal microscopy. The hydrophilicity of samples were assessed by measuring water contact angles through sessile drop method. The reaction of osteoblasts cells put into contact with the laser treated surfaces in controlled conditions was explored by fluorescence microscopy 48 h after cell seeding. The results show that the presence of micro periodic features enhanced the cell adhesion and surface wettability.

Keywords: Micro Texturing, Bio implants, Osseointegration, Wettability

I. Introduction

Titanium (Ti) and titanium alloys (especially Ti-6Al-4V) are widely used as hard tissue implant materials because of their excellent properties including low cytotoxicity and biocompatibility, corrosion resistance, wear resistance and fatigue resistance. Titanium is preferred over SS further due to its MRI compatibility [1]. Widespread use of Ti and its alloy in orthopedic and dental implants has resulted in considerable research in improving the biocompatibility of such implants. When the implant is permanently kept in a body, the integration between bone and implant is a great concern because better osseointegration can facilitate the early healing and relieve patients' pain[2]. Various surface modifications techniques of dental implants made up of Ti has also been reviewed [3]. With the advancements in laser micro machining, it is possible to create micro/nano level features on Ti substrates with the help of ultra short pulsed lasers [4-6]. A hierarchical micro-pattern covered with calcium phosphate (Ca/P phase) obtained on titanium implant surface by a femtosecond pulsed lasers irradiation in hydroxyapatite suspension has also been reported to improve osseointegration [7]. Chemical methods also have been adopted for creating surface modifications on Ti implants for enhancing interaction with bone cavity [8]. Surface characterization of laser textured implants has also been reported in literature [9]. Periodic structures have been fabricated using laser surface texturing (LST) enhanced hydrophilicity and the surface free energy of the material [10]. LST is found to have significantly increases the bone integration rate. It is reported to be a promising and simple technique of endowing implants with better osteogenic properties. In this study, the effects of laser surface treatment on enhancing the osseointegration properties of Ti6Al4V (Grade 5) have been evaluated and compared. Beneficial properties due to laser texturing are attributed to the combined effects of reduced hydrophobicity, thicker and stable oxide films and presence of laser-induced micro-features. It has been observed that most of the research works are on going to enhance the bone integration, wear and corrosion resistance of implant materials. The world wide uses of prosthetic implants are increasing due to the increase in aging population and also due to the increased availability of medical care.

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II. OBJECTIVE

The objective of this research is to:

1. Laser micro-fabrication of surface features on polished and laser textured titanium Grade-5.
2. Surface characterizations of samples by Confocal-microscopy and surface wettability analysis through Goniometer.
3. In vitro analysis of osteoblasts cell behavior on polished and textured titanium grades
4. Analyzing the adherence rate, viability of cells using fluorescent imaging.
5. Analyzing the influence of wettability, surface chemistry and surface topography on osseointegration.

III.EXPERIMENTAL DETAILS

A. Specimen preparation

The experiments were performed on two types of medical grade titanium, namely Grade-2 (99% pure Ti) and Grade-5 (Ti6Al4V, Alloy). The samples were sourced from KELTRAC Ernakulum and cut into square pieces using a Wire cut EDM machine (Electronica Ultracut S1).The final Titanium sheets having dimensions of 10mm ×10mm length, breadth and a thickness of 1mm.In order to get surface homogeneity samples were sequentially polished with SiC paper having grits size of 120-1200. The laser surface texturing were performed using an pulsed Nd-YAG laser system. The Wave length of the laser was 1064 nm. The laser track were covered the entire area of $10 \times 10 mm^2$.

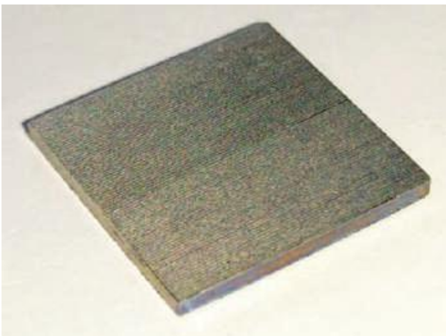

Fig.1 Laser textured Titanium grade-5.

B.Surface topography and roughness analysis

The surface topography of the laser polished and textured surface were analysed by Olympus LEXT OLS 4000 Confocal Laser Microscope.2D and 3D surface images were captured using laser imaging mode. The scanned area was $256 \times 256 \mu m^2$. Images were recorded under various magnification scale using a 405nm Laser and Photomultiplier Detector. The Minimum Z-Resolution was 10 nm and Minimum XY-Resolution was 120 nm. Micro scale 2D surface roughness profile was also generated using the confocal microscope by laser scanning. The surface parameter include R_a (Arithmetic mean height), R_{sk} (Skewness of surface), R_{ku} (Kurtosis of surface) were recorded randomly from the polished and laser textured surfaces.

C. Surface Wettability Analysis

Sessile drop method was used to measure the surface wettability by dropping micro-litre droplets on the surface. Deionized water was used as the testing liquid in order to avoid the chemical reaction with the surface. The contact angle values were analysed using a multifunctional video based camera system -KRUSS Drop Shape Analyzer - DSA25. The image capture and data analysis were made by ADVANCE Software. The volume of droplets to be injected on the surface was controlled by a micro-litre syringe and allowing to spread over the surface for 60s.

D.Invitro analysis

Osteoblast cells were procured from National Center for Cell Sciences, Pune. An in vitro cell adhesion test was performed with test materials Grade-2 and Grade-5. HOS cells were trypsinised, seeded on test materials and control glass cover slip at density of 1×10^4 cells/cm^2 and incubated for 48 h at 37±1ºC under humidified atmosphere containing 5% CO_2. After 48h, cell seeded test materials

IV.RESULTS & DISCUSSION

A.Surface topography

Images obtained by confocal microscopy showed neat parallel microgrooves on the surface of titanium grade 5 (Fig.2b). The reference state of the grade 5 titanium surfaces was shown in Fig.2a. From the surface parameters (Table.1), surface roughness of both the titanium grades increased after laser texturing. The Fig.2c shows 3D topography of the surface and the parallel micro grooves can be clearly visible.

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Table.I Surface roughness parameters

Samples	Roughness Parameters		
	R_a	R_{sk}	R_{ku}
Grade 5 Polished	0.035	0.425	2.837
Grade 5 Textured	1.602	-1.574	2.975

The groove having a width of 18.12µm and a depth of 3.12µm formed as a result of laser scanning. The polished samples follow R_a values in the range of 0.035µm.

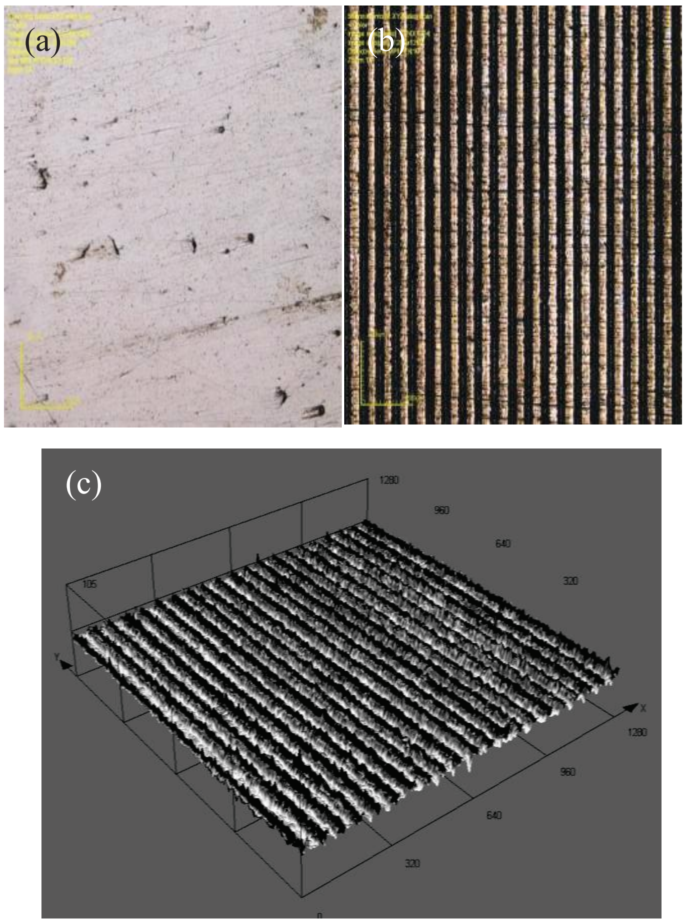

Fig.2 Confocal microscopy images of: (a) Polished and (b,c) Textured Titanium grade-5.

The R_a value of laser textured samples increased to 1.602µm. R_{sk} and R_{ku} is the direct measure of sharpness or skewness of the profile. Higher the kurtosis value (R_{ku} >3) the surface will be spiky and negative skewness (R_{sk} < 0) indicates eminence of troughs. From Table.1 we can see that the laser textured samples show negative kurtosis value and positive skewness. From surface roughness parameters laser treated titanium grade 5 has more troughs than peaks.

B. Surface wettability analysis

The contact angle values of the polished and laser textured samples are show in Fig.3.The hydrophilicity of the surface is enhanced after laser texturing. It has been reported that a hydrophobic surface have a contact angle greater than 90^0 and a hydrophilic surface have less than 90^0. Laser textured samples have contact angle less than 90^0, it’s a hydrophilic surface. The results show that the surface wettability increased after laser texturing. The microgrooves act as a reservoir for enhancing the surface wettability. The contact angle of laser textured titanium grade-5 deceased to 63^0

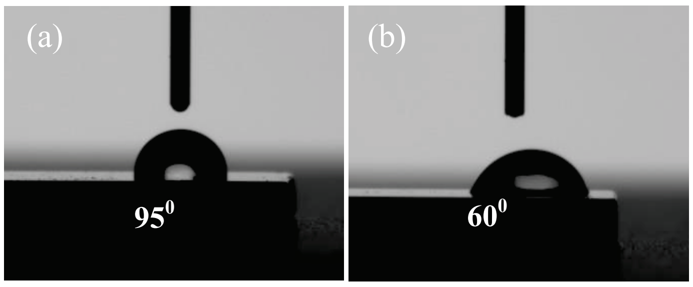

Fig.3Wetting of water in (a) Polished and (b) Textured Titanium grade-5

C. In Vitro analysis

Cell adhesion is the first reaction when cells contact with the biomaterials, which mediate subsequent cellular behaviours, such as proliferation, mobility, and differentiation. To investigate cell adhesion, the morphologies of osteoblasts cultured on the polished, and laser textured titanium substrates were observed via fluorescent microscopy. Osteoblasts adhered on polished titanium substrates displayed less spreading morphologies By contrast, osteoblasts adhered to laser textured titanium substrates showed well-spreading morphologies (Fig.4). A large amount of spreading structure was noticed in this study, which indicates the preferable, strong interactions between cells and laser textured surfaces. The cells were oriented along the direction of grooves. The cell density was much more on the groove width and they integrate rapidly on the laser textured samples due to increased wettability, surface roughness.

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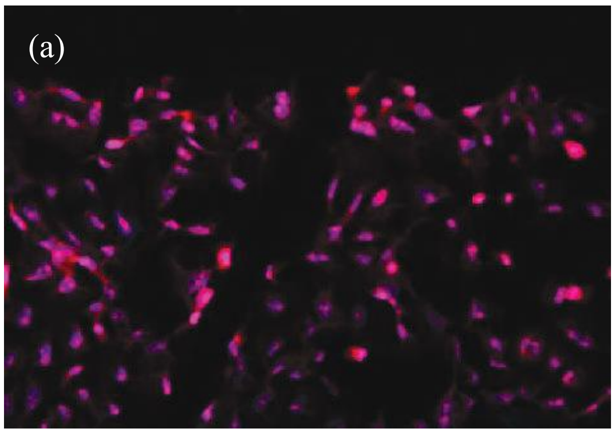

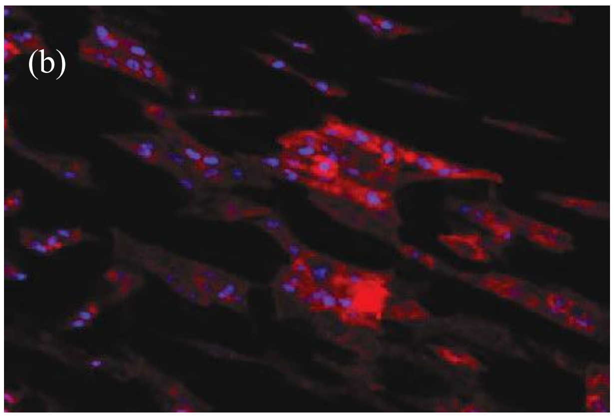

Fig.4 Fluorescent microscopy images of titanium Grade-5 (a) Polished (b) Laser textured

V. CONCLUSIONS

This work is focused on the study of osteogenic behavior of two different grades of titanium surfaces, and aims at improving the cell adhesion rate of the laser textured implant surfaces. The conclusions of the study are as follows:

- ❖ The surface roughness of the specimen surfaces increased significantly after laser texturing.
- ❖ The hydrophilicity of Ti Grade -5 was greatly increased by laser texturing.
- ❖ Osteoblasts adhesion rate is greatly increased in laser textured titanium substrates.

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Optimization of Assembly Sequence for Process Improvement Using A Hybrid Ant Colony Optimization Approach

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Abstract: An optimal assembly sequence enables the manufacturing industry to produce their product at optimal cost with quick delivery time to meet their demands. T K Machineries is acknowledged as the leading manufacturer and supplier of Automatic Multi Mill. But although they have modernized manufacturing units and adequate resources, they find themselves lacking when it comes to keeping up with the demand. This project focuses on Assembly Sequence Optimization by employing a Hybrid Optimization inspired from Ant Colony Optimization (ACO) Algorithm for a traditional manufacturing product. This method has been applied to a "Single Head Rice Pulverizer".

Keywords: T K Machineries, Production Rate, Assembly Sequence, Ant Colony Optimization

IV. Introduction

T K Machineries is the original designers and manufacturers of Double Stage and Triple Stage Automatic Multi Mill in India since 1984. They are guided by the vision to be "The best in the manner in which we operate, best in the products we deliver and best in our value system and ethics". T K Machineries is acknowledged as the leading manufacturer and supplier of Automatic Multi Mill. At their modernized manufacturing units, machines are designed and developed with high precision and quality material that is durable and sturdy enough to make the mill long lasting in performance. But although they have updated machineries and adequate resources, they find themselves lacking when it comes to keeping up with the demand. The results were recorded and standardised for use by the company.

This paper focuses on the possible causes for the same and their practical solutions keeping in mind the requirements of the enterprise. Total Quality Management principles were used to carefully study and analyse their current hindrances. The possible causes were deduced and practical solutions were suggested and implemented to a certain extent. The most substantial among the possible solutions being optimization of assembly sequences for process improvement using ant colony optimization algorithm. Assembly is the process of joining separate components together to form a single final assembled unit (e.g. mechanism, device, building etc.). In many cases, the order in which these tasks are performed is an important consideration. Manufacturing and engineering design in industry require specialized knowledge and problem-solving techniques. Emerging soft- computing technique can facilitate part design, process planning, scheduling, understanding and diagnosis and effective sequence determination to assemble a product. Assembly plays an important role in the design and manufacturing stages or integration of both. A wrong selection of sequence may lead to either a wrong product or halting of the process from moving towards next stage. The results were recorded and standardised for use by the company.

V. Objectives

The objective of this research is to

1. To understand various products and the needs of the company.
2. To identify the various causes for the reduced rate of production of the company.
3. To rate each cause based on the degree of control upon their occurrence and prevention.
4. To derive a standardized assembly sequence using Ant Colony Optimization (ACO) Algorithm keeping in mind the constraints put forward by the company
5. Identify the gaps existing and suggest suitable measures to bridge the gap and enhance organizational performance
6. To apply the theoretical sequence in a practical situation and record the obtained results for future reference.

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VI. T K Machineries

T K Machineries is a small-scale enterprise which specializes in the design and manufacture of pulverizers. They are the original designers and manufacturers of Double Stage and Triple Stage Automatic Multi Mill in India since 1984. They are guided by the vision to be "We offer the pure taste of India. The best in the manner in which we operate, best in the products we deliver and best in our value system and ethics". Deep understanding of the industry and requirement of the customers coupled with sound technological expertise and experience, topped with a penchant for giving the best of products to the customers, have led them to today's leading position and a worldwide reputation as a trustworthy company for the finest quality machineries. The enterprise was established in 1984. Apart from pulverizers, the company also manufacture grain hullers, dryers and roasters.

VII. Problem Definition

A. Market Position

From Fig 1, it can be inferred all five external forces (Bargaining Power of Suppliers, Bargaining Power of Buyers, Threat of Entry, Threat of Substitutes and Industrial Rivalry) affecting the competitive position of T K Machineries are favourable for market growth. So, it is safe to understand that the low rate of production is due to internal factors.

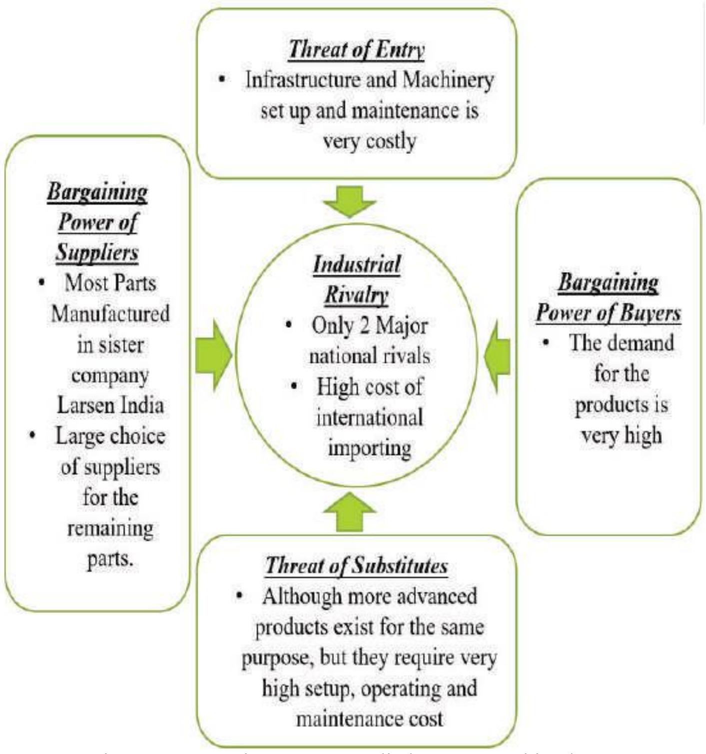

Fig. 1 Porter's Five Forces Applied to T K Machineries.

B. Internal Causes

The following Cause and Effect Diagram (Fishbone Diagram) has been devised by carefully studying the on-goings of T K Machineries. The secondary causes pertaining to Machine, Material and Environment are non-detectable as well as non-preventable. Hence, they are termed as Noise.

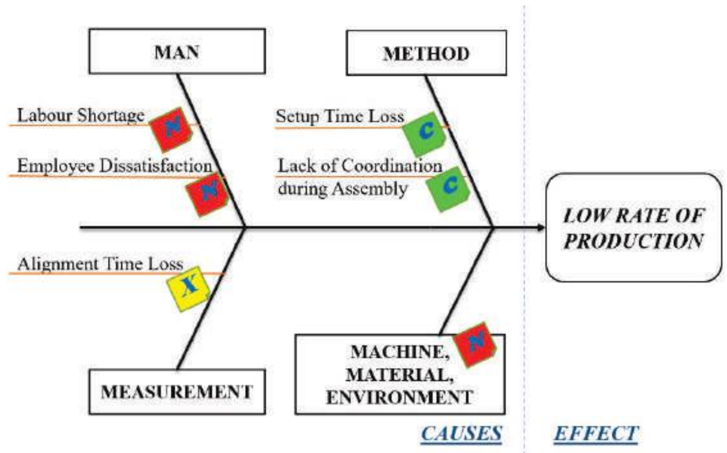

Fig. 2 Fishbone Diagram for Low Rate of Production

- *C: Controllable*: Preventable causes which requires new standard work procedure
- *X: Experimental*: Possibly Preventable which requires Trial and Error
- *N: Noise*: Non-preventable causes which requires Protection.

VIII. Root Causes

A. Man

The issues concerning the man force were as follows:

- Shortage of labor
- General dissatisfaction among the employees

Most of the labour force discontinues their service after a year leading to time being wasted for recruiting new personnel constantly. But due to reservations of the directors of T K Machineries, we were asked not to involve in the matters of the man force. So, the pertaining issues were cordially conveyed to the factory management to tackle at their own convenience.

B. Measurement

Another major cause of the low rate of production is the loss as alignment time. The alignment time lost for even the most basic machine built by the company can range from 5 to 6

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hours. But due to a variety of possible solutions for the same, none of them being a decisive one, a method of trial error needs to be applied for the same. Possible solutions for the same could be as follows:

- Use of standardized patterns and stencils for marking rather than trial and error
- Proper timing and organization of tasks
- Implementation of 5S principles (Sort-Set-Shine-Standardize-Sustain) in the enterprise.

C. *Method*

Absence of a standard assembly sequence has cost a lot of time for figuring out the next step during the assembly process. So, Assembly Sequence Optimization Procedure needs to be applied to create a standard Assembly Sequence for each product. T K Machineries is a perfect example for Mass Customization that is the difference between the products may only vary by a few parts. So, Assembly Sequence Optimization could be applied to any one product and the sequence could be modified for another product as well. The product selected is Single Head Rice Pulverizer being one of the most basic of their products. The Algorithm selected for the Assembly Sequence optimization is Ant Colony Optimization (ACO).

IX. ANT COLONY OPTIMIZATION

Ant Colony Optimization (ACO) was proposed by Marco Dorigo in 1992 in his PhD Thesis. The basic idea of an ant algorithm is to imitate the cooperative manner of an ant colony to solve combinatorial optimization problems within a reasonable amount of time. While building their path from nest to food source, ants can deposit and sniff a chemical substance called pheromone, which provides them with the ability to communicate with each other. An ant lays some pheromone on the ground to mark the path it follows by a trail of this substance. Ants essentially move at random, but when they encounter a pheromone trail, they decide whether or not to follow it. If they do so, they deposit their own pheromone on the path, which reinforces the trail. The probability that an ant chooses one path over others is determined by the amount of pheromone on the potential path of interest. With the continuous action of the colony, the shorter paths are more frequently visited and become more attractive for the subsequent ants. By contrast, the longer paths are less attractive because the pheromone trail will evaporate with the passing of time. Finally, the shortest way from the nest to the source of foods is found.

Although ant colony Optimization is generally applied to obtain the shortest lead time, it could be modified to apply various constraints needed to be included into the same. The main characteristics of ant algorithms are positive feedback, distributed computation, and the use of a constructive greedy heuristic search. ACO algorithm basically consists of two procedures:

- Construct Ants Solutions
- Update Pheromones, by which the pheromone trails are modified
- Daemon Actions (optional), is used to implement centralized actions which cannot be performed by single ants.

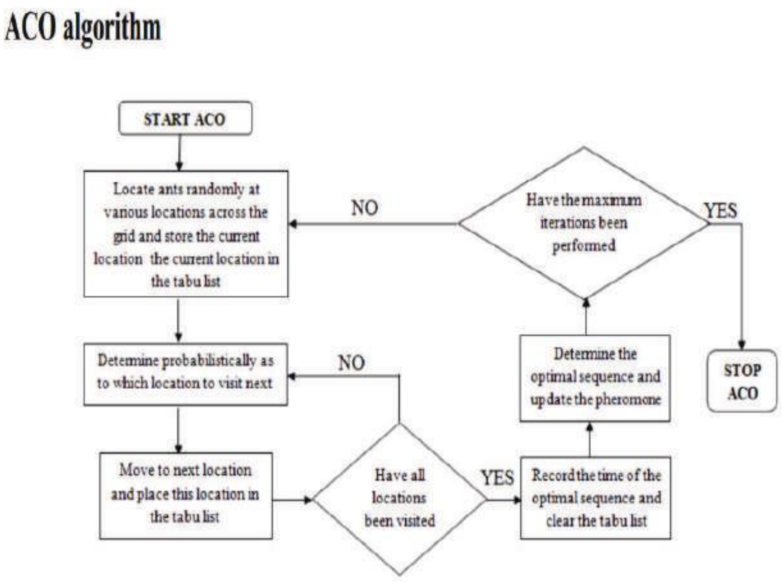

Fig. 2 Flowchart of Ant Colony Optimization Algorithm

X. ASSEMBLY PROCESS

In order to work on the proposed method, the product (Single Head Rice Pulverizer) is considered as the case study. The pulverizer was selected because it can act as the base product since most pulverizer designs follow the same set of parts and assembly process. The single head rice pulverizer has 33 parts.

1. Table 1 represents the Parts List of a single head rice pulverizer.
2. Table 2 represents the individual work elements. It shows the work element description.

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3. Table 3 represents Connectivity of the parts with each other that is the precedence of each work element in the assembly process

TABLE I
LIST OF PARTS

Part number	Part Name
1	Bracket
2	Bearing Housing
3	Grease Cap
4, 5	Cotton Oil Seal
6, 7	Teflon Bush
8	Shaft
9, 10, 11	Keys
12	Chopper Casing
13	Chopping Blade Rack
14	Pulverizer Drum
15	Pulverizer Blade Rack
16	Chopper Hammer
17	Pulverizer Hammer
18	Filter Bracket
19	Filter Sieve
20	Pulley
21, 22	Filter Gates
23, 24	Fly Nuts
25	Collector Tray
26, 27	Collector Gate
28	Support Beams
29	Drum Cap
30	Door Filter
31	Filter Cap
32	Right Hinge
33	Left Lock Hinge

TABLE II
WORK ELEMENTS DESCRIPTION

Code	Work Element Name	Components	Assembly Time (minutes)
A	Bracket	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11	600
B	Chopper Housing	12, 13	30
C	Pulverizer Housing	14, 15	30
D	Chopper Hammer	16	-
E	Pulverizer Hammer	17	30

Code	Work Element Name	Components	Assembly Time (minutes)
F	Pulley	20	-
G	Coarse Filter	21, 22, 23, 24	-
H	Fine Filter	18, 19	20
I	Collector	25, 26, 27, 28	30
J	Drum Door	29, 30, 31, 32, 33	15

TABLE IIII
PRECEDENCE TABLE FOR WORK ELEMENT

Sl no	Work Element	Preceding Work Element(s)	Assembly Time (minutes)
1.	A	-	-
2.	B	A	40
3.	C	A, B	40
4.	D	A	20
5.	E	A, B, C, D	20
6.	F	A	15
7.	G	A, B, C, D	20
8.	H	C	20
9.	I	A, B	35
10.	J	C, H	25

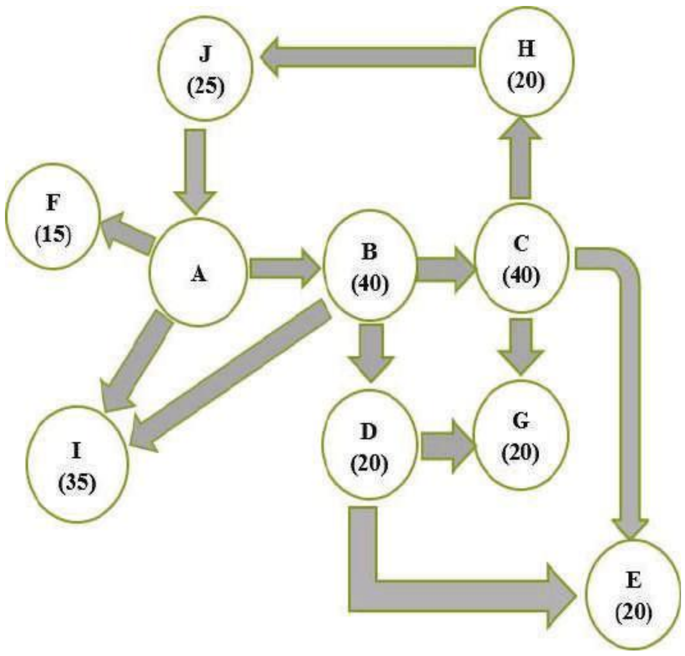

Fig. 3 Precedence Diagram

XI. Results

TABLE IV
List of Feasible Assembly Sequences

Sl no	Feasible Assembly Sequence
1	A B C D E F G H I J
2	A B C D E G H J F I
3	A B C D E G H J I F
4	A B C D G E H J I F
5	A B C D G E H J F I
6	A F B C D G E H J I
7	A F B C D E G H J I
8	A B F C D E G H J I
9	A B C F D E G H J I
10	A B C D F E G H J I
11	A B C D E F G H J I
12	A B C D E G F H J I
13	A B C D E G H F J I
14	A B C D E G H J F I
15	A B F C D G E H J I
16	A B C F D G E H J I
17	A B C D F G E H J I
18	A B C D G F E H J I
19	A B C D G E F H J I
20	A B C D G E H F J I
21	A B C D G E H J F I
22	A B C H J D E F G I
23	A B C H J D F E G I
24	A B C H J D E G F I
25	A B C H J D E G I F
26	A B C H J D G E I F
27	A B C H J D G E F I
28	A B C H J I D E G F
29	A B C H J D I E G F
30	A B C H J D E I G F
31	A B C H J I D G E F
32	A B C H J D I G E F
33	A B C H J D G I E F
34	A B C H J I F D E G
35	A B C H J I F D G E
36	A B C H J F I D E G
37	A B C H J F I D G E
38	A B I C D E F G H J
39	A B C I D E F G H J
40	A B C D I E F G H J
41	A B C D E I F G H J
42	A B C D E F I G H J
43	A B C D E F G I H J
44	A B C D E F G H I J
45	A B C D E F G H J I
46	A B I F C D E G H J
47	A B C I F D E G H J
48	A B C D I F E G H J
49	A B C D E I F G H J
50	A B C D E G I F H J
51	A B C D E G H I F J
52	A B C D G E H J I F
53	A B C D G E H J F I
54	A F B C D G E H J I
55	A B F I C D G E H J
56	A B C F I D G E H J
57	A B C D F I G E H J
58	A B C D G F I E H J
59	A B C D G E F I H J
60	A B C D G E H F I J
61	A B I C G E F G H J
62	A B C I D G F E H J
63	A B C D I G F E H J
64	A B C D G I F E H J
65	A B C D G F I E H J
66	A B C D G F E I H J
67	A B C D G F E H I J
68	A B C D G F E H J I
69	A B I F C D G E H J
70	A B C I F D G E H J
71	A B C D I F G E H J
72	A B C D G I F E H J
73	A B C D G E I F H J

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74	A B C D G E H I F J
75	A B F I C D G E H J
76	A B C F I D G E H J
77	A B C D F I G E H J
78	A B C D E F G E H J
79	A B C D G E F I H J
80	A B I D C G F E H J
81	A B I D C G E H F J

XII. CALCULATIONS

A. *Stage 1*

Since B is preceded by only A, the first stage could be theorized as:

'A > B'

B. *Stage 2*

Relation of B with C, D and I can be depicted as:

T(B>C) = 40 minutes
T(B>D) = 20 minutes
T(B>I) = 35 minutes
T_{BC}(B>D) = 35 minutes T_{BC}(B>I) = 45 minutes
T_{BD}(B>C) = 40 minutes T_{BD}(B>I) = 50 minutes
T_{BI}(B>C) = 40 minutes T_{BI}(B>D) = 20 minutes
T_{BCD}(B>I) = 60 minutes T_{BCI}(B>D) = 20 minutes
T_{BDC}(B>I) = 75 minutes T_{BDI}(B>C) = 40 minutes
T_{BIC}(B>D) = 35 minutes T_{BID}(B>C) = 40 minutes
T(B>C>D>I) = 40+35+60 = 135 minutes
T(B>C>I>D) = 40+45+20= 105 minutes
T(B>D>C>I) = 20+40+75= 135 minutes
T(B>D>I>C) = 20+50+40= 110 minutes
T(B>I>C>D) = 35+40+35= 110 minutes
T(B>I>D>C) = 35+20+40= 95 minutes

"A > B > I > D > C"

C. *Stage 3*

T_{DC}(D>C>G) = 20 minutes
T_{DC}(D>C>E) = 20 minutes
T_{DCG}(D>C>E) = 20 minutes
T_{DCE}(D>C>G) = 40 minutes
T(D>C>G>E) = 20+20= 40 minutes
T(D>C>E>G) = 20+40= 60 minutes

"A > B > I > D > C > G > E "

D. *Stage 4*

There are no branch Assembly steps for work elements H and J. Also, F, being an independent entity, can occur at any step after A. Hence optimized assembly sequence is

"A > B > I > D > C > G > E > H > F > J"

XIII. CONCLUSION

The Optimized Assembly Sequence was obtained to be:

"A B I D C G E H J F"

After careful calculations, based on the demands put forward by the company, the projected assembly time for the Single Head Rice Pulverizer was reduced from 16.5 hours to 14 hours. The obtained assembly sequence saves 15.15% assembly time. When the obtained results were applied to practical application, the assembly times is obtained as 14.75 hours saving 10.61% assembly time. All the results were carefully tabulated and conveyed to T K Machineries for implementation at their own convenience.

XIV. ACKNOWLEDGEMENT

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Analysis and experimental validation of heat dissipation in Inconel 718 plate during milling operation using MQL

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Abstract: Heat generated in the cutting zone during metal cutting has an undeniable controlling influence on the work piece and tool life. Inconel (a nickel alloy) have excellent mechanical strength, corrosion resistance and greater resistance to withstand in elevated temperatures. Thus this, low thermal conductivity leads to high temperature in the cutting zone while machining. This may lead for the initiation of cracks while machining as the heat dissipation to the work piece. In this project work, validation of heat dissipation in Inconel 718 plate using MQL with the cutting parameters such as Spindle speed, feed rate, depth of cut during end milling is carried out. Spindle speed, feed rate, depth of cut are chosen as input variables in the investigation of the heat dissipation, in which the pressure of the MQL, flowrate of the lubricant has been kept constant throughout the experiment. The experimental samples are to be run on a CNC milling machine for each condition and the heat dissipation is measured using Fluke thermal imager. The heat dissipation is further analysed in ANSYS and validated with the true value obtained.

Keywords: MQL (Minimal Quantity Lubrication), Inconel 718, Heat dissipation, Thermal imager.

XV. Introduction

In the present scenario it is been observed that the cutting fluids have a higher effect on the machinability of a material. Generally, flood coolants are being used, which have a numerous disadvantage like the maintenance of coolant systems, cleaning the work area of the machine tool and, the unpleasant of the coolant systems and the high running cost of coolant pumps. It also requires a high level of maintenance, not only in monitoring coolant condition but also clearing up spills from leaks that present a health and safety hazard in the workplace. Therefore, it would be ideal to implement a proper machining setup which could eliminate all these problems.

Minimum Quantity Lubrication (MQL) is a currently emerging technique of lubricating method where cutting fluid is supplied in mist form at a high pressure at the cutting zone. It consists of a mixture of pressurized air and oil micro droplets applied directly into the interface between the tool and the chip. In this cooling and lubrication technology, the lubricating function is ensured by the oil and the cooling function mainly accomplish by the compressed air [1]. The improved lubricant characteristics of the oil are responsible for reducing the friction and as consequence the heat generation.

Inconel 718 is a nickel alloy belonging to the class of heat-resistant super alloys, a group of materials with excellent mechanical strength properties at elevated temperatures and high corrosion resistance. It has also excellent creep and fatigue resistance at high temperatures, good corrosion resistance and ductility at cryogenic temperatures and good weldability.

When considering potential uses of Inconel 718, it is important to study the applicable manufacturing processes, such as machining by milling. Most of the mechanical energy used for machining becomes heat that generates high temperatures in the cutting zone, and a high tool temperature leads to faster wear. As Inconel 718 is a low-conductivity material, the location of the heat generated is highly influential on the results and can lead for the initiation of cracks, when the heat dissipation to the work piece. So its quite important to validate heat dissipation to the work peice. In this project the heat dissipation which is anayltical obtained using the ansys software is validated with experimental data by machining in vertical machining center and temperature measured using fluke thermal imager.

XVI. Literature Survey

In 2017 Alborz Shokrani, Vimal Dhokia, Stephen T Newman, investigated MQL, cryogenic cooling and a novel hybrid

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cryogenic and MQL (CryoMQL) cooling technique in CNC milling of age hardened Inconel 718. During the analysis of above technique it was found that using the proposed hybrid CryoMQL cooling/lubricating system can almost double the tool life and improves surface roughness by 18% resulting in significant improvement in machinability of Inconel 718 [3].

Gleiton de Paula Oliveira, Maria Cindra Fonseca and Anna Carla Araujo (2017) conducted a series of experiments to gather the optimum parameters for the milling operation of Inconel 718 using MQL and compared it with conventional flooded cooling. It was found that at higher cutting speed MQL gives more surface finish than the conventional cooling [4].

Sharaf Al Sofyani and Ioan D. Marinescu in 2017 formulated an analytical modeling of the thermal aspects of metalworking fluids in the milling process. The analytical models of the temperature change in the workpiece were experimentally validated against workpiece-embedded thermocouple measurements. It was found that the results of the models show good agreement with the experimental results [2]. The functions for the heat generation was formulated as shown below :

The total heat generated in the cutting zone is mainly in three zones as the primary, secondary, and the territory region shown in figure 1.1. In primary zone the heat generated as a result of the elasto-plastic deformation represents early 80% of the total heat generated in the cutting process. In the secondary deformation zone, the heat generated due to chip plastic deformation and friction between the removed chip and the rake surface of the tool accounts for 18% of the total heat generated in the cutting process. In tertiary deformation zone the smallest portion of heat is generated due to elastic deformation of the workpiece and friction between the flank face of the tool and the newly generated surface of the workpiece. Usually, the heat generated in the tertiary deformation zone is considered a less important source of heat and is often ignored because of its small contribution to the total generated heat (about 2%).

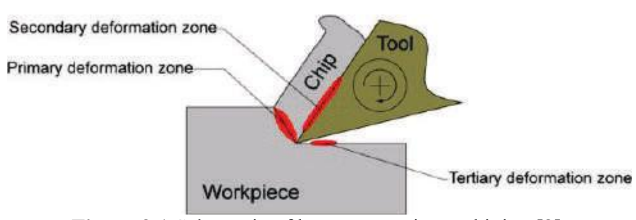

Figure 2.1 Schematic of heat sources in machining [2].

In this project the heat dissipation to the workpiece is been focused. So only primary and the tertiary deformation zones is been taken into consideration. The heat partition in the whole tool workpiece is shown in figure 1.2

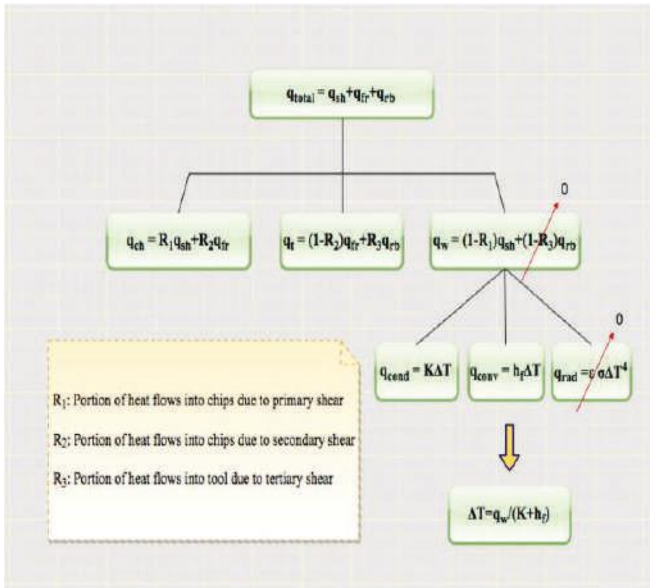

Figure 2.2 Schematic diagram of heat partitions during metal cutting [2].

Let, R_1 be the thermal energy dissipating with the removed chip as a result of the primary heat source and R_2 be the thermal energy dissipating with the removed chip as a result of the secondary heat source. Considering the primary zone $(1-R_1)$ will be the heat dissipated in the workpiece. Let q_{sh} be the heat generated due to the shear force then the total heat generated at the work surface will be:

$$Q_{gen} = \{(1-R_1) \text{ x } q_{sh}\} + 0$$

At teritary zone heat is generated due to the rubbing action, thus produces negligible amount of heat. So its can be assumed to be zero.

Total heat generated in the shear zone q_{sh} is given by:

$$q_{sh} = F_{sh} V_s$$

F_{sh} is the total shear force acting along the shear plane, and V_s is the relative speed of the chip to the tool. The relative speed of the chip to the tool can be calculated as follows:

$$V_s = V_c - V_{ch}$$

V_c is the cutting speed, and V_{ch} is the velocity of the chip. The chip velocity can be calculated using the following formula:

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$$V_{ch} = V_c \sin(ø) / \cos(ø-α)$$

The shear force F_{sh} can be calculated using the following equation:

$$F_{sh} = F_c \cos(ø) - F_{th} \sin(ø)$$

F_c is the cutting force, and F_{th} is the thrust force; F_c and F_{th} are the x and y components and ϕ is the shear angle. The shear angle can be calculated using the Merchant equation:

$$ø = 45 + \frac{\alpha}{2} - \frac{\beta}{2}$$

Where α is the rake angle of the tool, and β is the friction angle and can be calculated using the following equation:

$$\beta = \tan^{-1}\frac{Ffr}{N}$$

Ffr represents the friction force acting along the rake surface of the tool:

$$Ffr = Fc \sin(\alpha) + Fth \cos(\alpha)$$

N is the normal to chip force:

$$N = Fc \cos(\alpha) - Fth \sin(\alpha)$$

F_c is the cutting force is calculated by the formula:

$$F_c = (k_s\ a_p\ h)\ \check{n}$$

where
k_s is the specific cutting force.
a_p is the axial depth of cut.
h is the instant thickness of cut.
$\check{n}$ represents the unit vector in tangential direction.

$$ks = 13910 - 3.1\ (V_c) - 109900\ (f_z) - 0.0028\ (V_c)^2 + 23.9\ (V_c\ f_z) + 434500\ (f_z)^2$$

f_z represents the feed per cutting edge.

$$h = f_z \sin(\psi)$$

ψ function of the roating displacement (~ 90^0).

$$f_z = f / n_f$$

f represents the feed in radial direcion.
n_f is the number of flutes in cutting tool.

The thrust force F_{th} is usually presented as a ratio kr to the cutting force F_c.

$$F_{th} = F_c\ k_r$$

Based on the experimental data, k_r is around 0.3 for nickel alloys.

Thus the rate of heat consumed per unit area, or heat flux, in the shear zone is given by:

$$q_{sh} = \frac{\text{Fsh Vs}}{\text{ae ap csc}(ø)}$$

Assuming that the mean temperature at the shear plane is equal to the mean temperature of the chip near the shear plane R_1 is formulated as,

$$R_1 = \frac{1}{1 + 1.328\left(\frac{K\ Y}{\text{Vc ae}}\right)^{0.5}}$$

Where
K is the thermal diffusivity of the workpeice.
Y is the strain in the chip.

$$Y = \tan(ø-α) + \cot(ø)$$

In order to develop an idea about the convective heat transfer process during the application of a coolant jet parallel to flat surface thee are series of dimensionless correlations to describe the convection boundary layers. These dimensionless numbers are the Nusselt number (Nu), which is the ratio of convective to conductive heat transfer of the fluid across the boundary; the Reynolds number (Re), which is the ratio of inertial forces to viscous forces; and the Prandtl number (Pr), which is the ratio of momentum diffusivity to thermal diffusivity.

In order to quantify the quenching effect of the coolant, the heat transfer coefficient of the coolant must be estimated using the Nusselt number:

$$Nu = (h_f\ l_{ch}) / k_h$$

Where k_h is the thermal conductivity of the fluid (W/m K),and l_{ch} is the characteristic length (m), the diameter of the nozzle.

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The convective heat transfer across a flat plate is governed by the following empirical relationship:

$$Nu = 0.664\, (Re)^{1/2}\, (P_r)^{1/3}$$

The Reynolds number can be estimated using the following formula:

$$R_e = (V_f\, l_{ch}) / v_h$$

Where V_f is the velocity of the fluid jet (m/s), and ν_h is the kinematic viscosity of the fluid (m^2/s).

The Prandtl number can be determined as follows:

$$P_r = (C_p\, \mu) / k_h$$

C_p and μ are the specific heat (J/kg K) and the dynamic viscosity of the fluid (Pa s), respectively.
Fom the above equations the heat transfer coefficient of the fluid is obtained as:

$$h_f = \{0.664\, (Re)^{1/2}\, (P_r)^{1/3}\, k_h\} / l_{ch}$$

In MQL, a mixture of two fluid types, air and MWF, joins together to form a mist of single flow directed to the cutting zone. Creating a way in which one can accurately estimate the convective heat transfer coefficients of each fluid of the mixture is not a straightforward task. Therefore, it is reasonable to deal with the formed mixture of the two fluids as a homogeneous two-phase flow with averaged fluid properties. When using a homogeneous flow technique, it is assumed that the properties of the mixture are constant and that they possess the same temperatures and velocities.

The average weight of the mist can be expressed as follows:

$$w = \frac{\rho_a V_a}{\rho_f V_f + \rho_a V_a}$$

Where ρ_a is the density of the air, ρ_f is the density of the fluid, V_a is the volumetric flow rate of the air, and V_f is the volumetric flow rate of the fluid.

The volumetric flow rate of the air is expressed below:

$$V_a = u_a\, A_n$$

Where u_a is the velocity of the air, and A_n is the cross sectional area of the nozzle.

The velocity of the air can be calculated using the Bernoulli equation:

$$u_a = \sqrt{\frac{2P_a}{\rho_a}}$$

Where P_a is the air pressure, an ρ_a is the density of the air.

Similarly, the velocity of the fluid can be calculated using:

$$u_f = \sqrt{\frac{2P_a}{\rho_f}}$$

Where P_a is the air pressure, an ρ_f is the density of the air.

The density (ρ_h), dynamic viscosity (μ_h), kinematic viscosity (ν_h), thermal conductivity (k_h), and specific heat capacity (C_{ph}) of the mixture can be estimated as follows:

The density of the mist,

$$\rho_h = \left(\frac{w}{\rho_a} + \frac{1-w}{\rho_f}\right)^{-1}$$

The dynamic viscosity of the mist,

$$\mu_h = \left(\frac{w}{\mu_a} + \frac{1-w}{\mu_f}\right)^{-1}$$

The kinematic viscosity of the mist,

$$\nu_h = \left(\frac{w}{\nu_a} + \frac{1-w}{\nu_f}\right)^{-1}$$

The thermal conductivity of the mist,

$$K_h = \left(\frac{w}{K_a} + \frac{1-w}{K_f}\right)^{-1}$$

The specific heat capacity of the mist,

$$C_{ph} = \left(\frac{w}{C_{pa}} + \frac{1-w}{C_{pf}}\right)^{-1}$$

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Where

ρ_a is the density of the air (Kg/m^3)

ρ_f is the density of the fluid (Kg/m^3)

μ_a is the dynamic viscosity of the air (Pa s)

μ_f is the dynamic viscosity of the fluid (Pa s)

ν_a is the kinematic viscosity of the air (m^2/s)

ν_f is the kinematic viscosity of the fluid (m^2/s)

$$\nu_f = \frac{\mu_f}{\rho_f}$$

K_a is the thermal conductivity of the air (W/m K)

K_f is the thermal conductivity of the fluid (W/m K)

C_{pa} is the specific heat capacity of the air (J / Kg K)

C_{pf} is the specific heat capacity of the fluid (J / Kg K)

From these five equations given above, substituting to equations (21) and (22) can obtain the heat transfer coefficient of the homogeneous air -fluid during MQL:

$$h_f = \frac{0.664\,(R_e)^{1/2}\,(P_r)^{1/3}\,K_h}{l_{ch}}$$

Where

R_e is the Reynolds number of the mist

P_r is the Prandtl number of the mist

K_h is the thermal conductivity of the mist (W/m K)

l_{ch} is the characteristic length (m)

The heat dissipated into the Inconel while the milling operation can be considered as a case of three - dimensional heat conductivity through a flat plate. So in the actual scenario the heat dissipation takes places through all three dimensional planes with the governing differential equation for heat conduction as shown below:

Consider again the differential element of volume $\partial V = (\partial x\ \partial y\ \partial z)$ in cartesian coordinate system. So the mathematical form of the energy balance equation for the element,

$$(q_x - q_{x+\partial x}) + (q_y - q_{y+\partial y}) + (q_z - q_{z+\partial z}) + E_{gen} = \frac{dE}{dt}$$

where,

$$(q_x - q_{x+\partial x}) = -\frac{\delta}{\delta x}\left(-k(dy.dz)\frac{dT}{dx}\right).dx$$

$$(q_y - q_{y+\partial y}) = -\frac{\delta}{\delta y}\left(-k(dx.dz)\frac{dT}{dy}\right).dy$$

$$(q_z - q_{z+\partial z}) = -\frac{\delta}{\delta z}\left(-k(dy.dx)\frac{dT}{dz}\right).dz$$

In general, the heat conduction through a medium is multi-dimensional. That is, heat transfer by conduction happens in all three - x, y and z directions. In some cases, the heat conduction in one particular direction is much higher than that in other directions. In such cases, we approximate the heat transfer problems as being one-dimensional, neglecting heat conduction in other directions,

$$Q_{gen} = -K_w A \frac{dT}{dx}$$

Therefore,

$$dx = \frac{-K_w\,A\,dT}{Q_{gen}}$$

XVII. Experimentation and Analysis

A. Material and Method

The work piece material used for the study was a rectangular plate of Inconel 718 with 100 mm x 100 mm x 5 mm. Detailed information on chemical composition of the Inconel 718, is provided in Table 3.1 and the properties are listed in the table 3.2. Method used for the experimental investigations is explained thus:

1. Preparation of the vertical CNC milling machine system ready for performing the machining operation. A total of 27 pieces, of the Inconel plate were prepared for the milling operation and the temperature obtained in each 27 pieces were measured using a thermal imager.

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2. Fixing of the diamond coated carbide end milling cutter of 5 mm diameter on the spindle taper of the machine.

3. Mounting the work piece, clamped on a vice mounted on top of the table of the machine.

4. Creating CNC part programs on CNC professional software for tool paths, with specific commands using different factor levels of spindle speed, feed rate, axial depth of cut and radial depth of cut, taking reference for Y axis, and Z axis then performing end milling operation.

After each machining the temperature and the time taken for the machining is measured.

B. Machine and Specifications

MQL system

Figure 3.1 MQL device

The device for application of MQL is composed of air compressor, pressure regulator, flow rate meter and nozzle. This device provides oil and allows control of oil/air flow rates individually. A dial gauge is used to monitor the air flow rate in the compressor and MQL device. The MQL device consists of a solenoid valve which allow the compressed air to mix with the MQL lubricant only when the machining takes place. This further reduces the quantity of the MQL used.

Vertical Machining Center

- Make : Bharat Fritz Werner Ltd.
- Model : Agni BMV45 TC24 4 axis Vertical Machining Center.
- Three axes : XYZ travel(X – 600mm, Y – 450mm, Z – 500mm)
- Clamping area : 450 x 900 mm^2
- Number of tool : 24
- Position accuracy : +/- 0.005 mm
- Repeatability accuracy : +/- 0.003 mm
- Speed : 6000 rpm
- Feed rate : 1 to 10,000 mm/min
- Max. tool diameter : 75 mm
- Max. tool length : 250 mm
- Max. tool weight : 8 kg
- Control system : FANUC OiMC

Figure 3.2 Agni BMV45 TC24 4 axis Vertical Machining Center

Thermal imager

Figure 3.3 Thermal imager

- Capture a clear, accurate image focused throughout the field of view.
- Inspect high-temperature components, up to 1500 °C (2192 °F)

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- Monitor processes with video recording, live video streaming, remote control, or auto capture.
- Models : Ti 400 PRO
- Emissivity = 0.89

C. Design of Experiment

In this study, full factorial design is adopted as the experimental design. Full factorial is probably the most common and intuitive strategy of experimental design. In the simple form, the three-levels full factorial, there are 3 factors and L = 3 levels per factor. Generally, the sample size is $N = 3^k$ for k factors. Therefore, here $N = 3^3 = 27$. The two levels are called high ("h") and low ("l") or, "+1" and "−1". Starting from any sample within the full factorial scheme, the samples in which the factors are changed one at a time are still part of the sample space. This property allows for the effect of each factor over the response variable not to be confounded with the other factors. The central point of the design space is also added to the samples in which all the parameters have a value which is the average between their low and high level and in 3k full factorial tables can be individuated with "m" (mean value) or "0".

Variable	Levels		
	-1	0	1
Spindle speed [rpm]	1500	3000	4500
Feed rate [mm/min]	10	20	30
Depth of cut [mm]	0.3	0.6	0.9
Pressure of the lubricant [MPa]	0.7	0.7	0.7
Flowrate [l/min]	0.005	0.005	0.005

Here the Spindle speed (V_c), feed rate (f) and the depth of cut (a_e) are chosen as input variables in the investigation of the heat dissipation in which the pressure of the MQL (p), flowrate of the lubricant (f_r) has been kept constant throughout the experiment. Therefore, the factors are the Spindle speed (N_s), feed rate (f_s) and the depth of cut (d) are varied in 3 levels such as high, low and intermediate as shown in the table.

Table 3.1: Parameters used in the experimental design.

D. Tool Design and Modelling

Tool used is coated carbide tool with diameter of 5 mm and rake angle of -3.5 ^{0} . Tool was modelled in CATIA V5 software with the specification listed below :

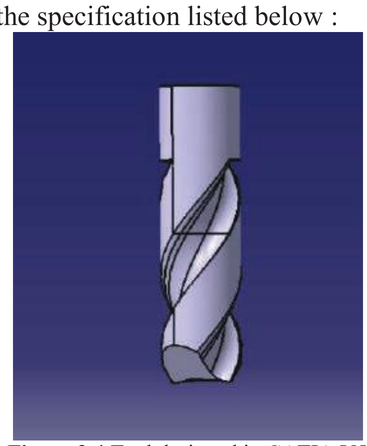

Figure 3.4 Tool designed in CATIA V5

E. Work Piece Selection and Design

Workpiece, Inconel 718 plate of dimension 100 x 25 x 5 mm is been used for study. The work piece was designed in CATIA V5 with the above specification

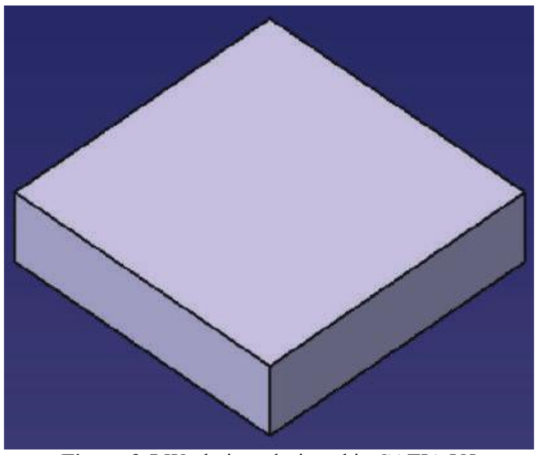

Figure 3.5 Workpiece designed in CATIA V5

F. Work piece preparations

- Inconel 718 - raw material – 2 plates (220 x 6 x 24 mm) & (320 x 7 x 24 mm)
- The material was cut into 5 piece of required dimension using a milling cutter.
- The workpiece was grinded of and made into 5 pieces of dimensions as 100 x 25 x 5 mm.
- CNC surface grinder was used for the material, which was clamped using an external chuck.

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Figure 3.6 Inconel 718 workpiece 100 x 27 x 5 mm (iso)

G. Tool specifications

- Ideal for: structural steel/ tool steel, grey cast iron.
- Also suitable for: stainless, acid rsistant steel, high-temperature material.
- Soft and hard machining uo to 48 HRC
- Coating: TiAlN
- Number of teeth: 2
- Shank: DIN 6535HA
- Diameter: 5mm

Figure 3.7 Milling cutter

For Hypothesis 4, the T test revealed a significance of 0.161, which is greater than 0.05. This is in favour of the null hypothesis. It suggests that there are no differences between motivational level of employees in large and medium scale organizations. This could be the direct effect of hypothesis 3 or could be the generalized mind set of the people.

XVIII. Results and Discussions

The validation tests were conducted on Vertical Machining Centre over a range of cutting speeds (1500, 3000, 4500 rpm) and at feed rate of (10, 20, 30mm/min). The radial a_e varies with (0.3, 0.6, 0.9) and axial ap depth of cuts were kept constant at 25 mm. a total of 27 experiment were conducted on the VMC and the temperature was measured using Fluke thermal imager.

Figure 4.1 Milling process

The machine was equipped with the MQL system consisting of the MQL device and the nozzle shown above. The nozzle was tilted with 30^0 to the horizontal and with a stand of distance of 70mm from base. The coolant used was the soluble cutting oil mixed with the air at a pressure of 0.7Mpa.

Table 4.1: Process Parameters.

SL NO.	Spindle Speed(rpm)	Feed Rate (mm/min)	Axial depth of Cut(mm)
	V_c	F	a_p
1	1500	10	0.3
2	1500	10	0.6
3	1500	10	0.9
4	1500	20	0.3
5	1500	20	0.6
6	1500	20	0.9
7	1500	30	0.3
8	1500	30	0.6
9	1500	30	0.9
10	3000	10	0.3
11	3000	10	0.6
12	3000	10	0.9
13	3000	20	0.3
14	3000	20	0.6
15	3000	20	0.9
16	3000	30	0.3
17	3000	30	0.6
18	3000	30	0.9
19	4500	10	0.3
20	4500	10	0.6
21	4500	10	0.9
22	4500	20	0.3
23	4500	20	0.6
24	4500	20	0.9
25	4500	30	0.3
26	4500	30	0.6
27	4500	30	0.9

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A. Thermal Image

For each run of experiment thermal image were taken. The imager uses the principle of radar and IR images are produce in the imager.

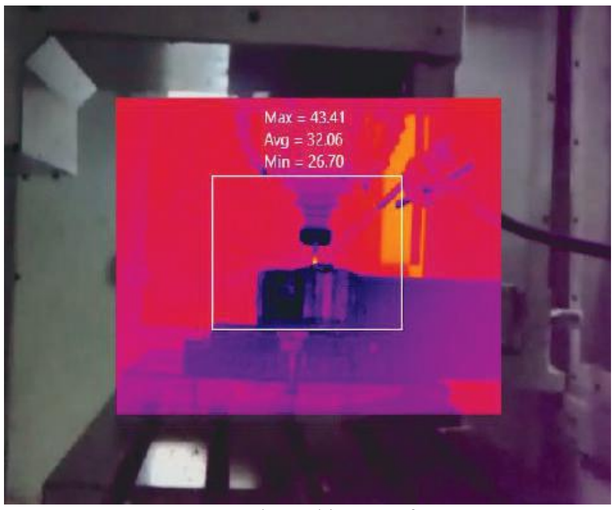

Figure 4.2 Thermal imager of set 14

B. Thermal Analysis

After experimental process the thermal deformation to the workpeice is analysed with the help of ANSYS. For each set the temperature obtained over the surface is validated with the true value obtained during the machining. Thus the thorectical model confines with the actul cases.

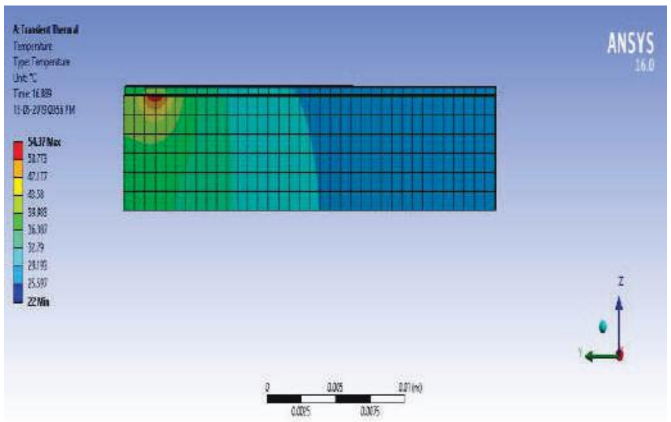

Figure 4.3 Thermal analysis of set 14

The below table shows the heat generated on the machined surface. The heat generated occurs maximum with the spindle speed, feed rate and depth of cut of 3000 rpm, 20 mm/min and 0.6 mm respectively and minimum occurs for the set with spindle speed, feed rate and depth of cut of 1500 rpm, 10 mm/min and 0.3mm respectively.

Table 4.2: Heat generated in the surface.

Sl No.	$1-R_1$	q_{sh}	Qgen
	W/m^2	W/m^2	W/m^2
1	0.198868	4025015.785	800445.61
2	0.198868	4830018.942	960534.74
3	0.198868	5232520.52	1040579.30
4	0.198868	4417120.783	878422.63
5	0.198868	5889494.377	1171230.18
6	0.198868	4490739.463	893063.01
7	0.198868	5026726.318	999653.48
8	0.198868	4524053.686	899688.13
9	0.198868	4322984.633	859701.99
10	0.149318	7951776.319	1187343.52
11	0.149318	6116751.014	913341.17
12	0.149318	5505075.913	822007.05
13	0.149318	6379916.519	952636.52
14	0.149318	8588349.16	1282395.32
15	0.149318	6257225.817	934316.59
16	0.149318	6459184.494	964472.66
17	0.149318	5997814.173	895581.75
18	0.149318	6828280.751	1019585.38
19	0.125352	7562523.613	947980.15
20	0.125352	8066691.854	1011178.83
21	0.125352	7814607.733	979579.49
22	0.125352	8066834.281	1011196.68
23	0.125352	8016416.567	1004876.70
24	0.125352	6806391.425	853197.20
25	0.125352	6806382.91	853196.13
26	0.125352	8318912.445	1042795.27
27	0.125352	7940780.061	995395.49

However, the theoretically obtained value of the maximum temperature differs from the practical within an average ratio of 0.782.

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This may due to the following reasons:

- Heat transfer between the tool and the machined surface constitutes 5-10% in actual case. This loses may lower the values of experimental set.
- It was assumed that the shear takes place due to cutting in the primary shear zone was uniform. The variation in the shear zone may lead to variation in results.
- The coolant used was soluble cutting oil along with air as in mist form. Analysis were done considering the mixtures to be homogenous. This may varies in actual case.
- The rays used in the thermal imager was IR rays which may get deflected by the coolant can cause the variation.
- The experimental surrounding differs with in the time can also cause the variation in results obtained.

Table 4.2: Temperature obtained

Sl No.	Exp. Tempt (^{0}C)		Theo. Tempt (^{0}C)		Exp/Theo
	MAX	MIN	MAX	MIN	
1	32.55	27.57	43.80	22.00	0.743
2	37.93	26.64	48.08	22.00	0.789
3	37.57	26.37	50.25	22.00	0.748
4	33.42	26.10	45.94	22.00	0.727
5	42.02	26.27	53.80	22.00	0.781
6	34.65	26.52	46.25	22.00	0.749
7	38.25	26.68	49.25	22.00	0.777
8	35.10	27.26	46.43	22.00	0.756
9	35.33	27.84	45.35	22.00	0.779
10	42.90	26.53	54.37	22.00	0.789
11	40.09	28.06	46.81	22.00	0.857
12	37.51	26.73	44.33	22.00	0.846
13	37.74	26.21	47.97	22.00	0.787
14	43.41	26.07	56.83	22.00	0.764
15	37.71	26.62	47.38	22.00	0.796
16	37.90	26.68	48.29	22.00	0.785
17	37.73	26.10	46.32	22.00	0.815
18	39.10	26.37	49.70	22.00	0.787
19	37.88	26.64	47.84	22.00	0.792
20	38.21	27.92	49.46	22.00	0.773
21	38.11	28.32	48.61	22.00	0.784
22	38.51	29.41	49.56	22.00	0.777
23	37.58	27.57	49.29	22.00	0.762
24	35.05	27.20	45.18	22.00	0.776
25	38.42	27.15	45.26	22.00	0.849
26	38.35	27.51	50.32	22.00	0.762
27	37.93	28.04	49.04	22.00	0.773
				AVG	0.782

The values thus obtained, validates with in a specific set of ranges by an average ratio of 0.782.

From the obtained set of values the maximum heat dissipation for a flat plate had formulated. The maximum deviation was observed for the set with the spindle speed, feed rate and depth of cut of 3000 rpm, 20 mm/min and 0.6 mm respectively in which the maximum heat generation occurred and minimum deviation occurs for the set with spindle speed, feed rate and depth of cut of 1500 rpm, 10 mm/min and 0.3mm respectively in which the minimum heat generation occurred.

Table 4.2: Length of heat dissipation from surface

Sl No.	Exp. Dissipation	Theo. Dissipation
	mm	mm
1	0.104	0.339
2	0.196	0.373
3	0.180	0.383
4	0.139	0.377
5	0.225	0.393
6	0.152	0.369
7	0.193	0.377
8	0.146	0.356
9	0.145	0.340
10	0.230	0.392

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11	0.220	0.343
12	0.219	0.358
13	0.202	0.381
14	0.226	0.401
15	0.198	0.371
16	0.194	0.374
17	0.217	0.377
18	0.209	0.382
19	0.198	0.373
20	0.170	0.356
21	0.167	0.346
22	0.150	0.333
23	0.166	0.361
24	0.154	0.352
25	0.221	0.354
26	0.174	0.365
27	0.166	0.352

Length of heat dissipation in both experimental and theoretical values were formulated and the average value for both was compared with the heat affecting zone obtained in ANSYS.

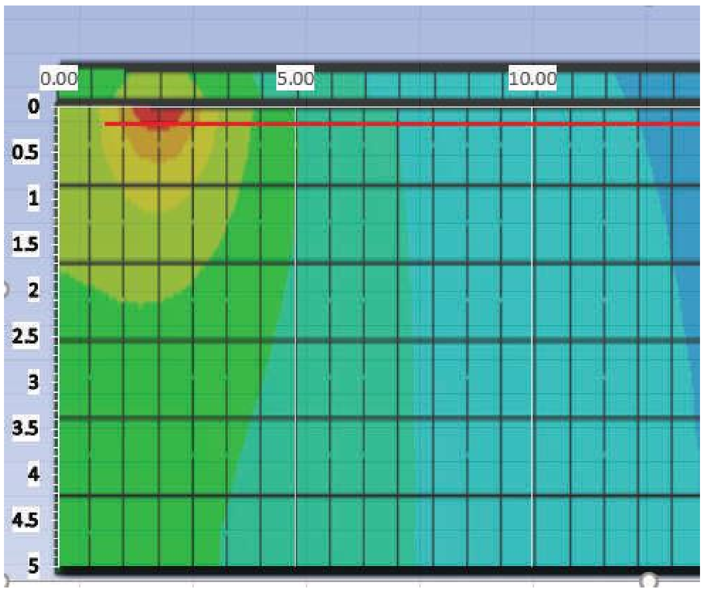

Figure 4.4 Dissipation length (experimental)

The figure represents the heat dissipation in the theoretical case with the dissipation length of 0.3658 mm, the mean value.

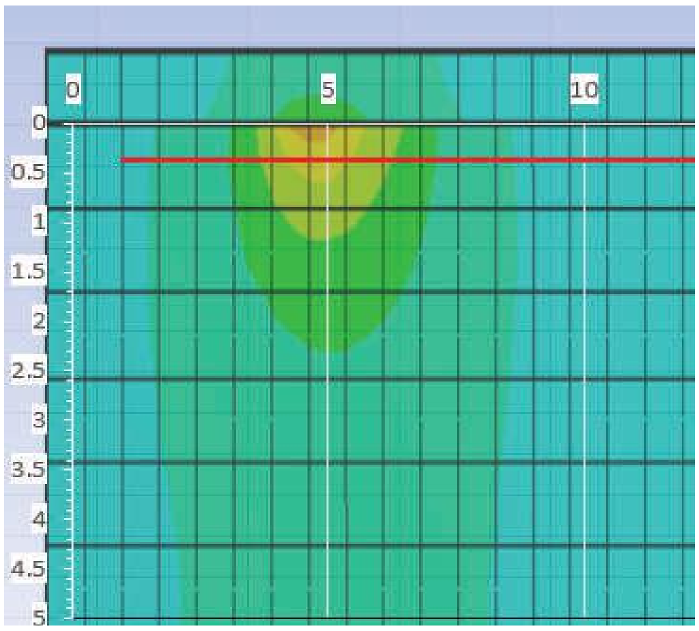

Figure 4.5 Dissipation length (theoretical)

The below figure shows the heat dissipation in the experimental set with a mean value of 0.1837mm.

XIX. CONCLUSIONS

The optimization effort of heat energy in the cutting zone should be tackled from two perspectives: first, by reducing the mechanical work spent during machining; and second, by increasing the heat flow out of the cutting zone. In the present work, an analytical approach was used to evaluate the temperature change in the workpiece due to heat generated in the primary shear zone. To achieve this end, three sub models were developed:

- Thermal analytical model to estimate the amount of heat generated in the shear zone.
- Heat partition model to estimate the percentage of thermal energy flow into the workpiece.

- With respect to MQL's heat transfer coefficient determination, a homogeneous single flow was assumed for the two mixtures of the mist.

Finally, experimental validations of the developed models were carried out, which showed that the models were able to simulate the behaviour of the temperature change in the workpiece with a ratio of 0.782. This indicates that the theoretical heat dissipation to the workpiece can be almost concluded same as the practical so an average of 0.315mm is the depth for which the heat is been dissipated to the workpiece.

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Design and Analysis of ABS Fender Fabricated Using Fused Deposition Modelling

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Abstract: Additive manufacturing (AM) technologies have been successfully applied in various applications. Fused deposition modelling (FDM), one of the most popular AM techniques, is the most widely used method for fabricating thermoplastic parts those are mainly used as rapid prototypes for functional testing with advantages of low cost, minimal wastage, and ease of material change. Due to the intrinsically limited mechanical properties of pure thermoplastic materials, there is a critical need to improve mechanical properties for FDM-fabricated thermoplastic parts for the fabrication of a customized product. This project is done to improve mechanical properties of thermoplastic material by changing the layer orientation, infill and angles of FDM-fabricated parts for the manufacturing of customized product. In this project automobile fenders are designed and fabricated using FDM and its analysis is done. For this first the Acrylonitrile Butadiene Styrene (ABS) is arranged in different combinations such as layer position, fibre orientation, volume of fibres etc. by using FDM machine and its mechanical properties are observed for each sample. Then the better combination with better mechanical property is taken for the manufacturing of fenders that are used in automotive (mainly bikes). By using design software fender design is made and then the design is taken into slicing software and arrangement of different layers is done and fabrication is done using FDM then its static analysis is done to stimulate its service conditions.

Keywords: Additive manufacturing, Fused deposition modelling, Acrylonitrile Butadiene Styrene

I. INTRODUCTION

Additive manufacturing (AM) is defined as "a process of joining materials to make objects from 3D model data, usually layer upon layer, as opposed to subtractive manufacturing methodologies". AM technologies make it possible to build a large range of prototypes or functional components with complex geometries those are unable or at least difficult to be manufactured by conventional methods. Compared with conventional methods, AM can shorten the design-manufacturing cycle and thus reduce the production cost and increase the competitiveness.

The first developed AM techniques are typically applied to fabricate pure plastic parts those are mainly used as rapid prototypes for functional testing. AM techniques include stereolithography apparatus (SLA) from photopolymer liquid, fused deposition modelling (FDM) from plastic filaments, laminated object manufacturing (LOM) from plastic laminations, and selective laser sintering (SLS) from plastic powders. However, FDM is the most widely used method among all the AM techniques for fabricating pure plastic parts with low cost, minimal wastage, and ease of material change. Before FDM-fabricating process, the STL file generated by the CAD software is sliced into horizontal layers and the thickness of each layer can be set depending on the demands of customers. As shown in Fig.1, Currently, only thermoplastic filaments are used as feedstock in FDM, including acrylonitrile butadiene styrene (ABS), polycarbonate (PC), polylactide (PLA), polyamide (PA), and the mixtures of any two types of thermoplastic materials. FDM of plastics are usually used to make conceptual prototypes with mature development stages, since the pure thermoplastic parts built by FDM are lack of strength as the fully functional and load-bearing parts. Such drawback restricts the wide applications of FDM technology. Therefore, there is a critical need to improve the strength of FDM-fabricated pure thermoplastic parts to overcome the limitations. One of the method suggested in this paper is to study the parameter of the FDM printing machine and optimising the better parameter from it samples with different lay ups are made. This samples change by its orientation,

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angle, layer fraction etc. and the better sample is optimized by testing its strength. This is a way to improve the strength of a functional product as now a day manufacturing is done using modern technologies like this kind of 3D printing. The designing a fender using this better optimized sample and fabrication is done using the same optimized sample properties to use this as a functional prototype with better strength and finish.

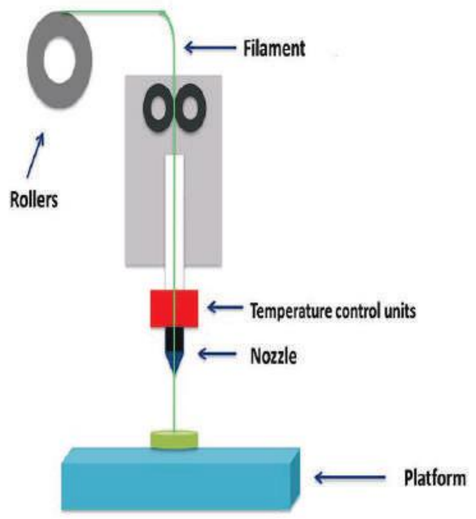

Figure 1. Fused deposition modeling

II. Literature Survey

Among reported literatures, there are limited numbers of studies on developing materials by layer by layer change in its parameters using FDM process.

Anna Bellini and Selcuk Guceri [1]presented a methodology to determine the stiffness matrix by conventional composite formulations. Due to the layered manufacture, the mechanical properties of FDM parts are orthotropic. Road shape, as well as the path, strongly affect the properties and performance of the finished product. The influence of deposition strategies on the mechanical behaviour of FDM has also been evaluated.

Sung-Hoon Ahn et al. [2] investigated the process parameters of FDM. Raster orientation and air gap were found to be the major influence on the tensile strengths. Bead width, model temperature, and colour have insignificant effects. Some design rules were also formulated based on experimental results

.

Ken-ichiro Mori et al. [3] compared two methods of fabricating composites by FDM. One is that carbon fibres are sandwiched by lower and upper plastic plates made by FDM then heated in an oven. Another method is to include carbon fibres in the molten plastics. The second method tends to have a better tensile strength and elongation rate. Some other fibre reinforcement materials such as glass fibres [4], wood fibre bio composites [5] and Hydrogel-Epoxy composite [6] have also been investigated.

Gujja Sunil Kumar , B. Naresh , Ch. Sunil [7] The product is successfully prepared and it is tested mechanically. And the results of the product are compared to that of the existing one and found to be more capable than the present one. The results indicate that due to increase in the layers of fibre the strength of the composite material increases

III. Sample Preparation and Testing

A. *Sample Preparation*

Here sample are prepared by taking various parameters such as layer orientations, angles, volume fraction, infill density etc. change in this parameters are made first by studying the machining parameters of FDM. Table.1, Shows the design parameters taken for sample preparation and Fig.2, Shows the illustration of the design parameters.

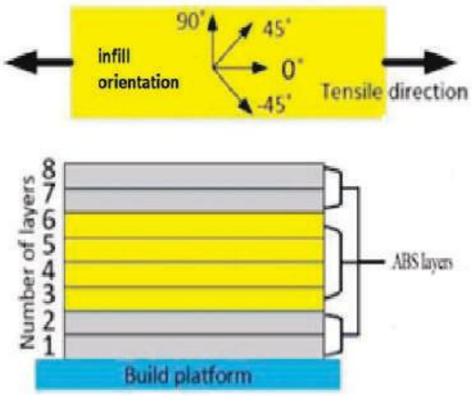

Figure 2. Illustration of the design parameters

ABS materials is used for the production of samples. Each sample having specified layer orientation, volume fraction, infill density and angles. This way samples are fabricated using FDM using Simplify3D software is used as slicing software in this software the layer formation, defining angles for each layers infill density and speed are set for printing shown in Fig.3

Table 1: design parameters

Sample No.	Total layers	Layers of ABS	Direction of ABS	Position of ABS layers
1	20	10	0	6-15
2	20	10	90	6-15
3	20	10	90	2-6, 15-19
4	20	18	90	2-19
5	20	10	0*5,90*5	6-15
6	20	10	45*5,-45*5	6-15

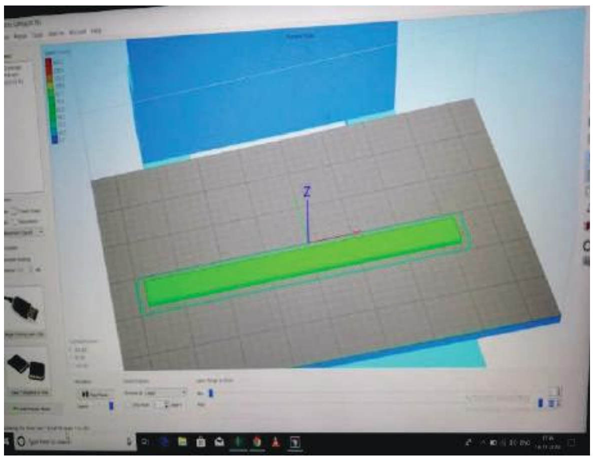

Figure 3. simplify3D slicing software

B. Sample Testing

Mechanical strength of the samples such as impact and tensile are tested and its results are used for optimization of the best sample. Here design of sample is made using design software and dimensions are under ASTM standard E4 (Fig.4 a & b) is used for printing the sample models shown in Fig.5.

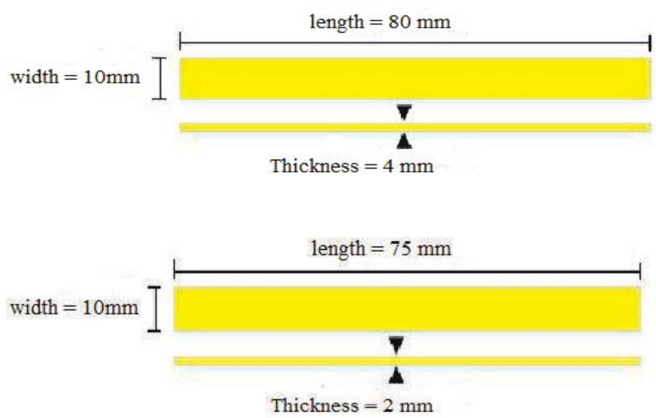

Figure 4. (a) Dimension of the sample for impact and (b) tensile testing

(a)

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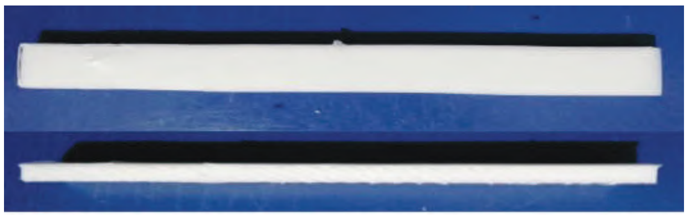


(b)

Figure 5. Sample printed using FDM (a) impact model (b) tensile model

C. Result

Result of the testing the samples is shown in Table 2. The better strength sample is taken from them and with that parameter, fender is fabricated.

Table 2: Test results

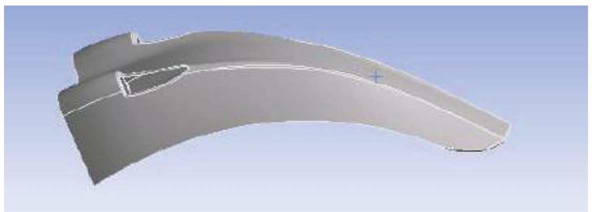
Sl No.	Sample Name	Max. Stress (N/mm^2)	Max. Strain (%)	Impact strength (J/m)
1	A	35.05	14.29	544.41
2	B	27.44	13.84	207.03
3	C	22.26	8.68	456.79
4	D	26.47	10.05	196.60
5	E	29.26	12.03	343.93
6	F	25.45	10.84	408.73

Here from the table we can take the best optimized sample as sample A it has better tensile and impact strength. So sample A design parameter is used for the fabrication of fender.

IV. DESIGN AND FABRICATION

Design of fender is made using design software Fig.6 (a & b) shows the design of fender and different views are also drafted.

(a)



(b)

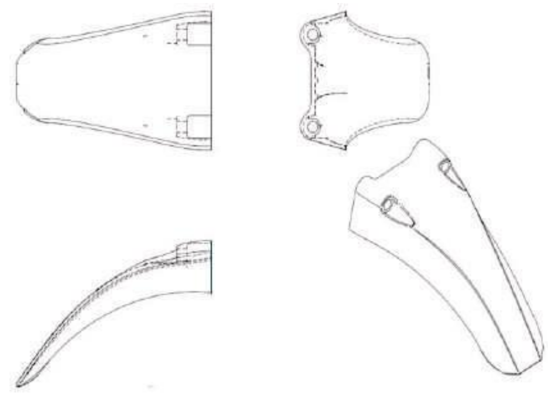


Figure 6. (a) 3D model of Fender (b) Drafted view of solidedge design

Fabrication of fender is done using FDM printer. The better optimized sample parameter is taken and the design is given to the slicing software simplify 3D for slicing (shown in Fig.7) After slicing is done so that the printing will be same as the sample parameter after this process the sliced file is given to the printing machine for printing. Finally the printing is done and we get the final prototype of the product (Fig.8).

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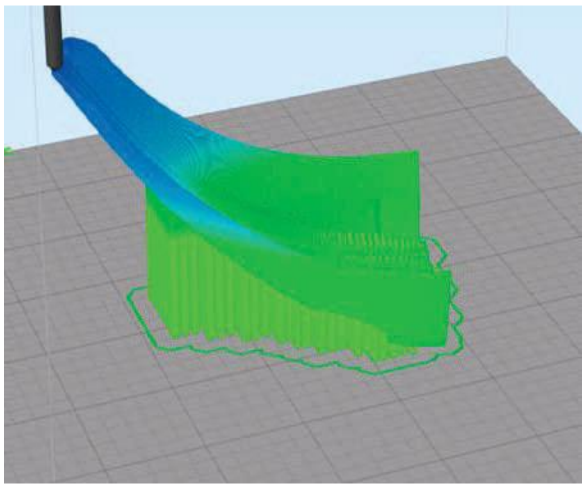

Figure 7. slicing of design (fender) using simplify 3D

Figure 8. FDM Fabricated ABS Fender

V. STATIC ANALYSIS OF DESIGN

Static and modal analysis of fender design is done using ansys 16.0 to simulate the service conditions.

A. *Static analysis*

In static analysis here in order to simulate the service condition the analysis is done. Load is given to the fender from downward as a reaction force acting from downward direction and the 2 studs are fixed then its total deformation, stress and strain are calculated. Static structural analysis of fender is shown in figures below.

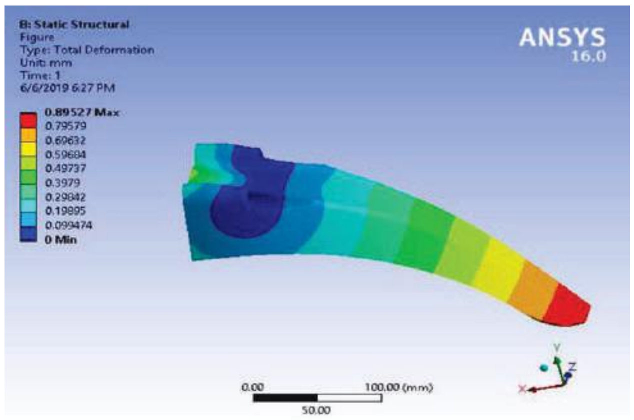

Figure 9. Total Deformation

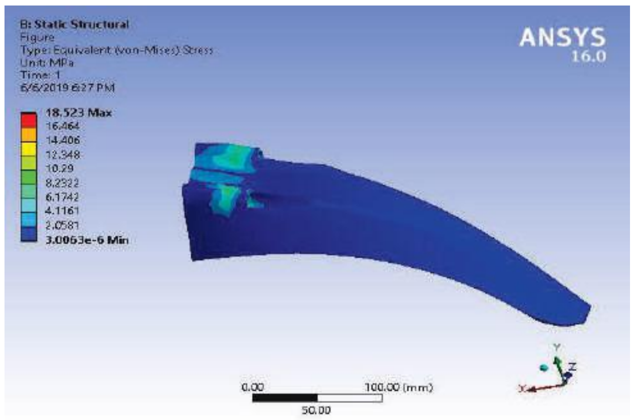

Figure 10. Equivalent stress

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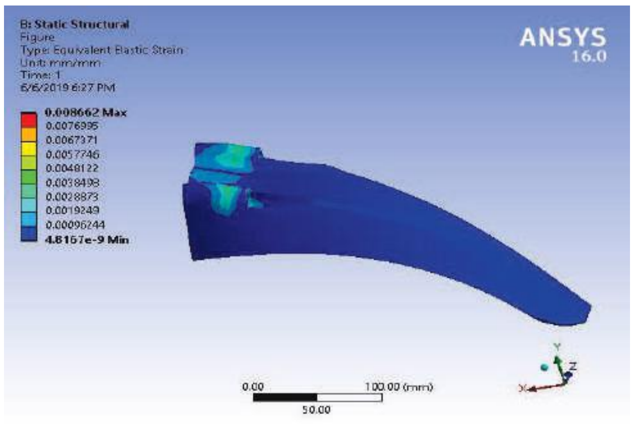

Figure 11. Equivalent strain

B. *Modal analysis*

A modal analysis determines the vibration characteristics (natural frequencies and mode shapes) of a structure or a machine component. First modal structural is selected and the model file for analysis is given to it, the engineering data such as its material properties and dimensions are given after that the file is meshed and here tetrahedral mesh is used for meshing because of the curved nature of the model. After meshing face are selected for fixing. Then in modal analysis a pre stress is given to the modal for getting its free vibrations. Free stress in the sense we give an initial load and then remove it so as to calculate the mode shape while the object is in free vibration. Its mode shapes and its frequency at each mode is noted. Different mode shapes are shown in figure below.

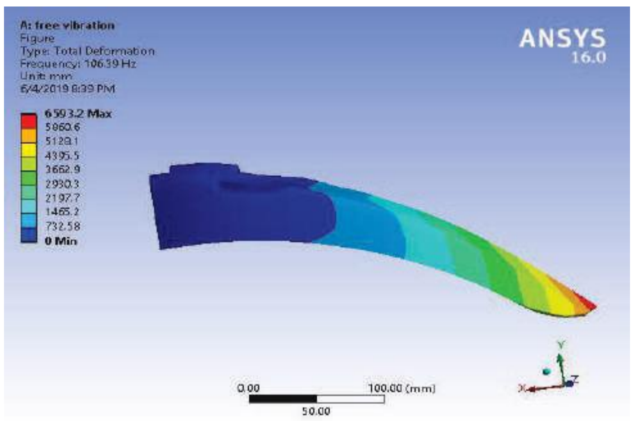

Figure 12. Mode shape 1

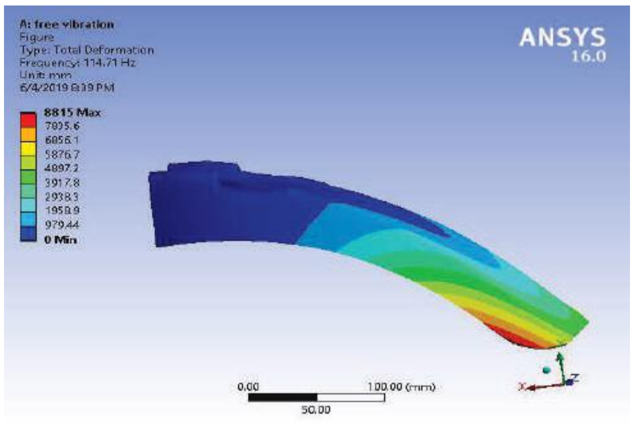

Figure 13. Mode shape 2

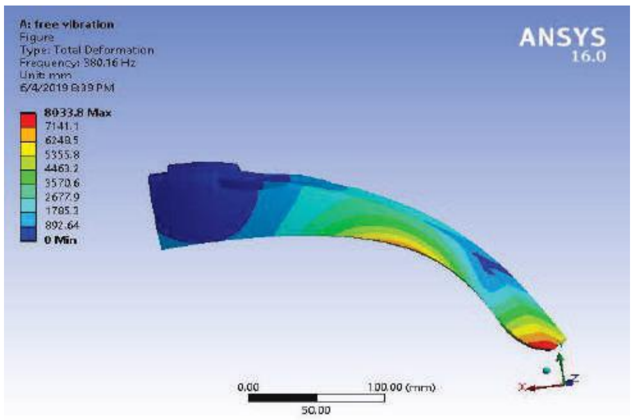

Figure 14. Mode shape 3

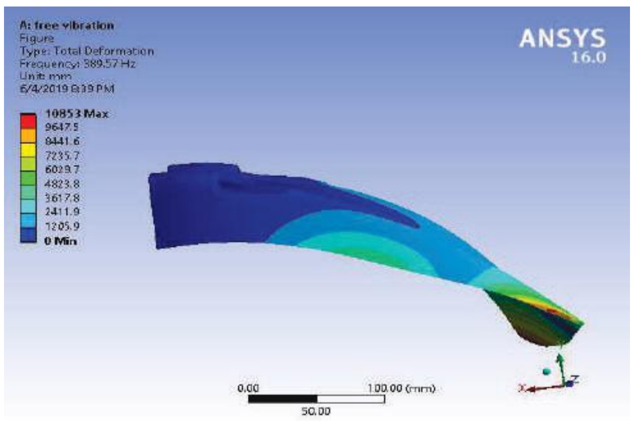

Figure 15. Mode shape 4

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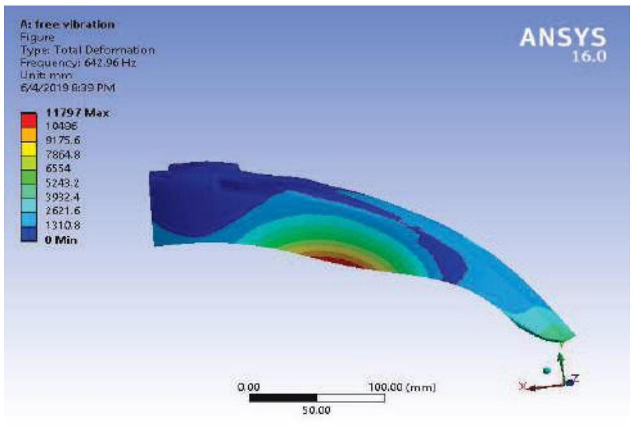

Figure 16. Mode shape 5

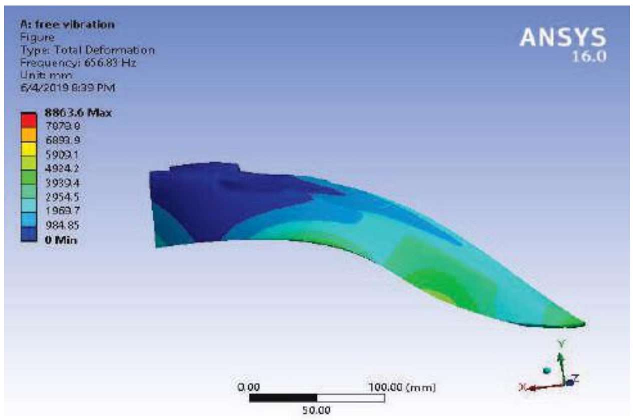

Figure 17. Mode shape 6

VI. CONCLUSION

In this paper we can conclude that the parameters in machining is having a major role in its strength and also it help in making a better product. Here we first optimize the machine parameters and then samples are made by reference to this by changing its orientation, volume fraction and its angle and better sample is taken for the fabrication of a product. From this we can say that the machine parameter and the parameters such as layer orientations, angles, volume fraction, infill density etc. that affect the strength of a product so by optimizing this all we can fabricate a better product. Also this 3D printing have a wide range in production side now a days we can also make outdated product from this machining process by 3D printing. If we are in need of a customized product for our end use we can go for this kind of production.

VII. LIMITATIONS & FUTURE SCOPE

A. Limitations

This study was conducted only in low cost FDM machine and the main limitation is the availability of machine and also the machine available will have a limitation in its work volume this affect the fabrication process. The parameter changes are also not possible using all software.

B. Future Scope

The study can be extended to fabrication of customized products. In future if there is a need for a customized product fabrication this process can be used for the production of customized product. Also strength and finish can be changed by changing its parameters.

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a. Organizations which helps in testing and fabrication of the samples and product.
b. NSS College of engineering, Palakkad Digital Library
c. Project Guide- Mr. Sreejith N K
d. Research Scholars of Dept. Of mechanical engineering, NSS College of engineering, Palakkad
e. Fellow Classmates

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Analysis of Bearing Failure in Pellet Mill

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Abstract: The main objective of this paper is to analyse the reasons for the failure of a heavy duty roller bearing supporting the pressure rollers of pellet mill. The pellet mill is loaded 24 hours in a day. The pellet mill mainly consists of two pressure rollers mounted in a closed die. The charge loaded is getting extruded by the action of the rollers. The pressure rollers are mounted in heavy duty roller bearings. The machine history of pellet mill revealed that the bearing failures occur well before its expected life. The cost of bearing, its replacement and associated down time also estimated high and hence it is worth if an analysis on bearing failure modes. Though this bearing is very costly, replacing it frequently without getting sufficient operation hours is a big loss.

Keywords: Roller bearing; pellet mill; bearing failure; roller bearing.

XX. INTRODUCTION

There are several reasons for a bearing failure. Previous studies state that improper lubrication is the major reason for bearing failure. The premature failing of bearing will leads to loss. In this research, two heavy duty greases are tested to find out which one is suitable for the current case. Lithium based grease and Calcite based grease is selected for the experiment. The bearings are mounted inside the bearing pressure roller. The roller is sealed to prevent the entry of pellet mill charge (mash) into the bearing area. However due to the continuous loading of the machine the mash will enter into the bearing area and contaminate the lubricant.

This contamination will degrade the bearing properties. Initially the temperature of the pressure rollers was recorded in several days. The temperature was recorded after applying two different greases in different days. This temperature analysis will help to get a preliminary idea regarding the performance of the grease in the bearing. Then two greases are subjected to four ball test. In this test, mash was added to different greases in different proportions and average scar diameter on the steel balls was recorded.

XXI. IDENTIFIED REASONS FOR BEARING FAILURE

In search of previous research papers different reasons for the bearing failure are identified. Various reasons that has been found out was displayed by using Fishbone diagram or Cause and effect diagram.

Improper lubrication constitutes of over lubrication, lubricant contamination and lubrication without renewing. Renewal of the lubricant should be done in proper intervals of time. Improper mounting of the bearing leads to load imbalance and uneven heating of the bearing. The chances for occurring material defects and manufacturing errors are less. However, if it happens its severity will be high.

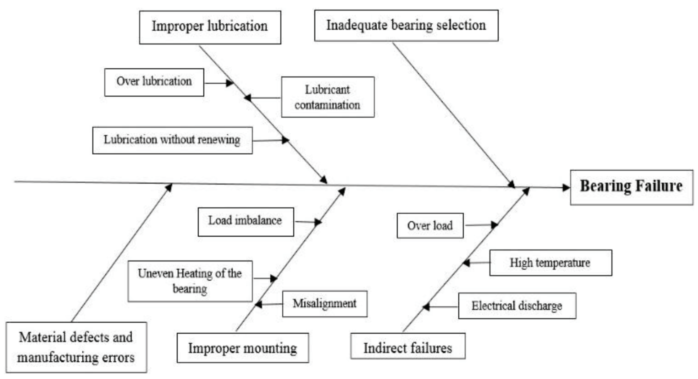

Fig. 1 Fishbone diagram.

The selection of bearing was also very critical. If the improper bearing is mounted, load imbalance will occur. The previous researches mention that lubrication issues are the major reason for the decrease in bearing life. The contaminants leaking in to the bearing area prevent the proper lubrication. Thus the frictional heat generation will increase which will lead to premature failure of the bearing.

XXII. TEMPERATURE ANALYSIS

The temperature of the pressure rollers is recorded using a thermal imaging camera. The temperature of the roller shells increases due to the improper lubrication in the roller bearing mounted inside it. This will decrease the bearing life which leads to premature failure of the bearing. The temperature of the roller shells was recorded in different days by using two different greases.

The average peak temperature of pressure rollers is 368.9K and 355.8K while using Lithium and Calcite based lubricants respectively. From this we can analyse that, in this case

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frictional heat generation while using lithium based grease is higher than calcite based grease. The temperature data are recorded after the continuous loading of the machine by six hours.

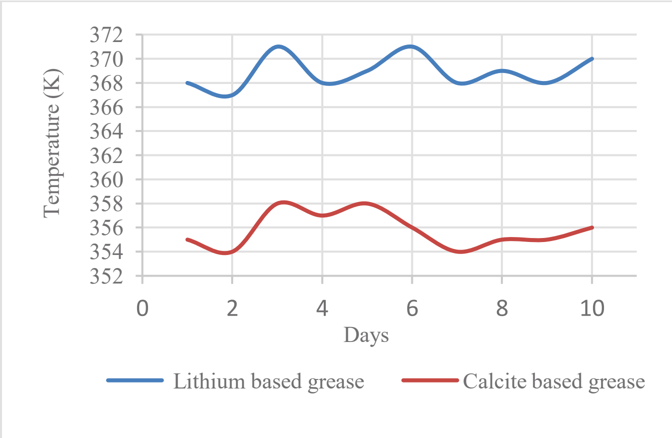

Fig. 2 Temperature of the pressure roller in different days

TABLE I

PEAK TEMPERATURE IN DIFFERENT DAYS

Peak temperature of the pressure roller (Kelvin)		
	Lithium based grease	Calcite based grease
Day 1	368	355
Day 2	367	354
Day 3	371	358
Day 4	368	357
Day 5	369	358
Day 6	371	356
Day 7	368	354
Day 8	369	355
Day 9	368	355
Day 10	370	356
Average Temperature	368.9	355.8

XXIII. LUBRICANT ANALYSIS

The contaminated lubricant is one of the major reason for the degradation of bearing life. Contamination leads to improper lubrication. For analysing the wear preventive characteristics of the lubricants four ball test was conducted. Various sample of each grease was prepared. Mash was added to each lubricant to make lubricant-mash mixture in different proportions. From this test we can analyse that which lubricant will resist the wear even in the risk of lubricant contamination. Actually this test gives the comparative results of both greases.

TABLE II

PEAK TEMPERATURE IN DIFFERENT DAYS

	Average scar diameter in micrometer	
Percentage of mash	Lithium based grease	Calcite based Grease
0	460.68	427.92
1	465.74	431.03
2	472.14	435.41
3	479.87	441.07
4	488.93	447.85
5	499.33	456.22
6	511.07	465.68
7	524.14	476.43
8	538.54	488.45
9	554.28	501.75
10	571.36	516.32

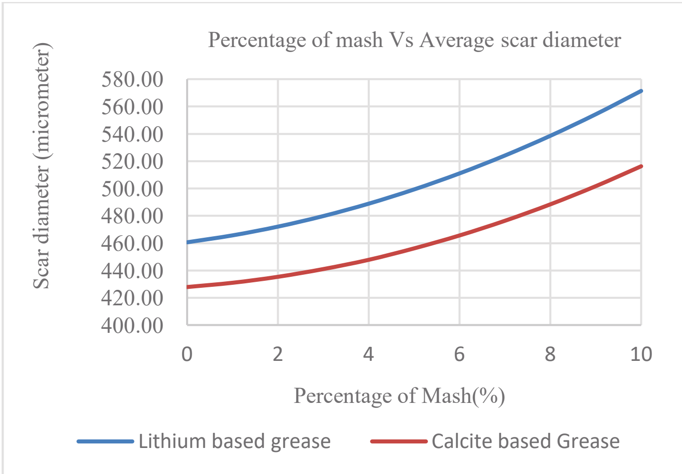

Fig. 3 Percentage of mash Vs Average scar diameter.

The average scar diameter increases when the proportion of mash increases. From the Fig. 3 we can analyse that Calcite based grease has lesser average scar diameter compared to Lithium based grease.

XXIV. CONCLUSION

In this scenario Calcite based grease has better performance than Lithium based grease. From the four ball test results it is clear that the calcite based grease have lesser average scar diameter in the steel balls. Hence we can understand that in this case, Calcite based grease perform better than the Lithium based grease even in the risk of lubricant contamination. The heat generation inside the roller bearings will also be reduced. Thus by using calcite based grease the life of the roller bearing mounted inside the pressure rollers may increase.

The bearing manufacturer suggests 40,000 to 50,000 operation hours for twenty-four hours running mills. In this scenario nearly 10,000 operation hours are achieved. So by changing the lubricant, bearing life can be increased from current state.

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Experimental Investigations on Natural Wood Powder Reinforced Polymer Composites

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Abstract: Wood powder reinforcing polymer matrix composites has been one of the epoch-making and pioneering study both from scientific and economical eye over the last decade, due to the eco-friendliness, biodegradability and aesthetical properties. Wood dust is suitable and beguiling filler for polymer resins due to its cost effectiveness, low density. This work compares the influence of different synthetic polymer/wood powder ratios on the mechanical and Water absorption properties of composite materials. The mass ratios were varied between 70:30, 60:40 and 50:50 respectively. More over the influence of particle size of wood powder on the resulting composite material properties are analyzed. Moisture absorption of composites reinforced with wood powder of various woods (two types of woods-teak and Jack) were investigated. Size is a viable parameter to control the properties of developed composites. As a result three different particle sizes as fine, medium and coarse sized wood particles were used to develop the composites. The characterization properties including tensile strength, moisture absorption, micro hardness, surface roughness after machining are analyzed. Microstructure analysis of the specimens were taken. An industrial safety helmet is fabricated with jack wood as the reinforcement. The fabricated helmet is undergone drop test to analyzed its property.

Keywords: polymer matrix composite; wood powder, reinforcement, particle size, mechanical properties.

XXV. Introduction

The recent world population growth has been one of the main factors for the technological development and innovation. In fact, exponential growth has taken place in the world population, being expected to reach 9 billion in 2042, compared to 3 billion in 1960. This has led to the use and development of new materials and products, which can respond to these increasing needs and trends. In this work, an experimental investigation is carried out to study the effect of different parameters on the different properties (Water Absorption, tensile strength, surface roughness, micro hardness) of the output product. The study is carried out by manufacturing wood powder composites from teak wood and jack wood with epoxy resin as the matrix, with different wood powder size and percentage composition.

XXVI. Objective

The objective of this research include

7. Fabricate different wood powder reinforced composite material
8. Calculate the tensile, water absorption, hardness and roughness properties of the wood fibre reinforced composites.
9. Optimizing the set of result and Fabricate an industrial safety helmet with best possible result.
10. Perform Drop test on manufactured helmet.

XXVII. Literature Survey

Anna Keskisaari et.al (2018) studied the profitability of using different waste materials and side fractions as a part of wood-plastic composites. Increased efficiency of waste recycling creates more materials for re-use.

R. Hariharan et.al(2018) In this present investigation, the industrial helmet of standard dimension reinforced with E-Glass fiber / Epoxy matrix is fabricated by resin infusion moulding (RIM) and analyzed for obtaining its maximum impact resistance.

Elanchezhian et.al (2016) conducted a review considering the mechanical properties of natural fibre composites. The Fibre is having superior properties such as high specific strength, low weight, low cost, fairly good mechanical properties, nonabrasive, eco-friendly and bio-degradable characteristics.

Joao Bessa et.al (2017) in the work compares the influence of different thermoplastic polymer/wood powder ratios on the mechanical and thermal properties of composite materials.

Amlana Panda et.al (2016) prescribed about the multivariate optimization. Therefore, the present investigation is undertaken to make a decision on parametric optimization of multi-responses during machining.

XXVIII. EXPERIMENTAL DETAILS

One of the most important factors to take into account on this study was the similarity of densities of the different materials, in order to guarantee a good and homogeneous mixture before the processing. All materials are presented in Fig. 1. Then, the wood powder from jack and teak is separated into fine, medium and coarse, shown which presents a density between 0.85 – 0.95 g cm-3. The polymer material used was purchased from flipcart with a BM1106 commercial reference. Table 1 shows particle size details.

Figure 1. Wood particle of particle size fine, medium and coarse

Table 1. Details of wood particles

Sl no.	Type of particles	Particle size
1	Fine particles	<600 Micron
2	Medium particles	600micron-1.18mm
3	Coarse particles	1.18mm-2.36mm

Generally composites are manufactured by different techniques including continuous processes, hot molding process, cold process and open mold processes. Open mold process is further classified into spray layup and hand layup. Among which hand layup is popular technique for manufacturing composite material with open mold. In which a pigmented gel coat is first applied to the mold by spray gun for a high-quality surface. When the gel coat has become tacky, fiberglass reinforcement (usually mat or cloth) is manually placed on the mold. The base resin is applied by pouring, brushing. Squeegees or rollers are used to consolidate the laminate, thoroughly wetting the reinforcement with the resin, and removing entrapped air. Layers of fibre glass mat or woven roving and resin are added for thickness. The specimens for tensile and water absorption test made by hand layup is show in figure 2.The homogenous mixing of epoxy with wood powder is obtained by using a mechanical mixer running at 200rpm.

Figure 2. Specimen manufactured using hand layup technique

The obtained samples were subsequently subjected to several characterization tests. The mechanical tests performed include tensile test, Fig. 3. The tensile tests were performed according to ASTM E4 standard micro UTM, using 18 samples of 2 mm width and at least 75 mm overall length. The test parameters used were a crosshead speed of 2 mm min-1 and 40 mm as initial distance between grips.

Figure 3. micro UTM

Water absorption test of the developed composites was carried out at ambient temperature. Specimens were immersed in water bath during a day at ambient temperature. It might be mentioned that before immersing in to the water all test samples were weighed properly. After a day, these immersed samples were taken out from the water samples and wiped off the surface water by rubbing with tissue paper on both sides of the surfaces and reweighed.The fig. 5 shows the analytical balance used for the testing. Again these test samples were immersed in the water bath. In the following weeks measurements was carried out in the same manner. The percentage of the water absorption was calculated from the following relationship.

$$A\% = 100 * \frac{W_{w-}m_d}{m_d} \quad (1)$$

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Where, M_w = Mass of sample at wet condition
M_d = Mass of sample at dry condition

Figure 4. Analytical Balance

Surface roughness (Ra) is an important factor to evaluate cutting performance. Roughness is measure of the texture of the surface. It is quantified by vertical deviations of a real surface from its ideal form. Surface roughness is an important measure of product quality since it greatly influences the performances of mechanical parts as well as production cost. Surface roughness has an impact on the mechanical properties like fatigue behavior, corrosion resistance, creep life, etc. Figure 5 shows surface profilometer.

Figure 5. Specimen on which turning operation performed and apparatus by which surface roughness measured (using Profilometer)

Figure 6. Microhardness testing machine (Vickers)

Hardness is a characteristic of a material, not a fundamental physical property. It is defined as the resistance to indentation, and it is determined by measuring the permanent depth of the indentation. The Vickers method is based on an optical measurement system. The Microhardness test procedure, ASTM E-384, specifies a range of light loads using a diamond indenter to make an indentation which is measured and converted to a hardness value. It is very useful for testing on a wide type of materials, but test samples must be highly polished to enable measuring the size of the impressions. A square base pyramid shaped diamond is used for testing in the Vickers scale. Typically loads are very light, ranging from 10gm to 1kgf. The Microhardness methods are used to test on metals, ceramics, and composites - almost any type of material. Figure 6 shows hardness testing machine.

A. Data Collection and analysis

Moreover, an increasing trend of moisture absorption with increasing wood powder ratio was clearly noticed. Comparing samples, it is verified an increased moisture absorption with increased composition of wood powder. This fact is probably related to the wood's morphology, which is a porous structure. Then, despite of hydrophobic surface, wood has the capacity to absorb moisture through these pores, once the interior is constituted by hydrophilic compounds. Table shows the result obtained.

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Table 2. Result table of Tensile strength and water absorption test

Sl. No.	Type of Wood Powder	Particle Size	% Composition	Tensile strength(US) (N/mm2)	% Water Absorption
1	TEAK	F	30	5.858	0.373
2	TEAK	F	40	8.79075	0.528
3	TEAK	F	50	21.6217	0.708
4	TEAK	M	30	4.20865	0.357
5	TEAK	M	40	7.6242	0.479
6	TEAK	M	50	17.5575	0.648
7	TEAK	C	30	4.34583	0.249
8	TEAK	C	40	6.1423	0.459
9	TEAK	C	50	12.95929	0.613
10	jack	F	30	6.7714	0.371
11	jack	F	40	14.9338	0.689
12	jack	F	50	23.7454	1.014
13	jack	M	30	6.7243	0.345
14	jack	M	40	8.4527	0.589
15	jack	M	50	18.20865	0.814
16	jack	C	30	4.34583	0.282
17	jack	C	40	5.758	0.52
18	jack	C	50	14.7148	0.772

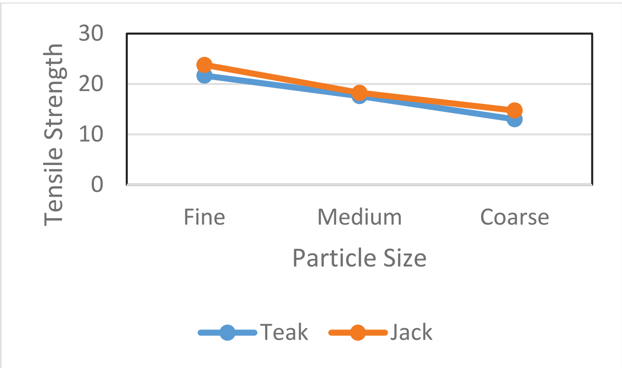

Figure 7. Effect of particle size of wood powder on the tensile properties of the composites at 50% wood powder composition

From the figure 7 it can be observed that the tensile strength increases with the decrease in particle size of wood powder.the figure shows the composites with 50% composition. Simillar trends are shown for 30 and 40 % wood compositions.and it can also be found that the strength is slightly higher for jack wood.

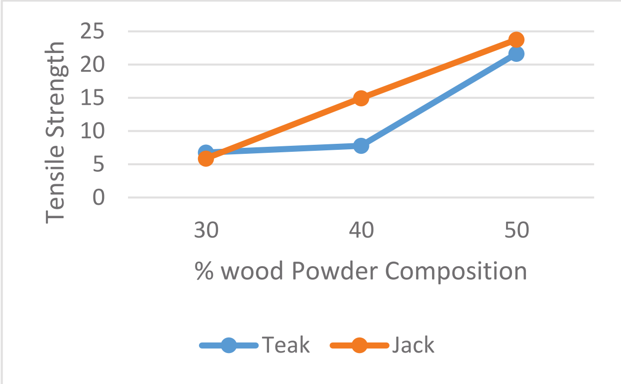

Figure 8. Effect of wood powder composition on the tensile properties of the composites with fine particle content

From the figure 8 it can be observed that the tensile strength increases with the decrease in wood powder composition.the figure shows the composites with fine particle inclusion. Simillar trends are shown for medium and coarse wood particles.And it can also be found that the strength is slightly higher for jack wood.

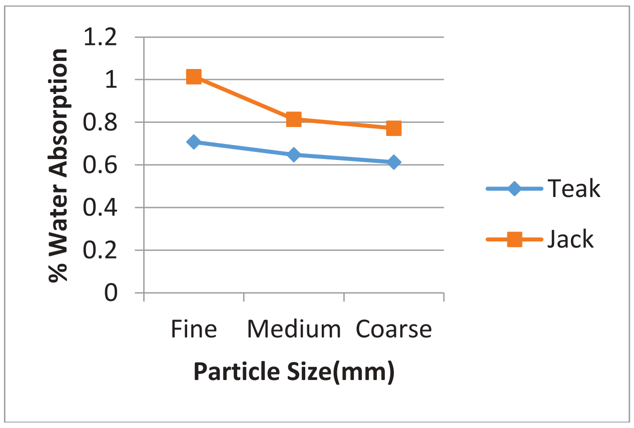

Figure 9. Effect of particle size of wood powder on the tensile properties of the composites at 50% wood powder composition

From the figure 9 it can be observed that the water absorption is higher for fine particle inclusive composite compared to the medium and coarse ones.jack wood composite show a slightly higher water absorption compared to teak wood composites. Simillar trends are shown for 30 and 40 % wood compositions.

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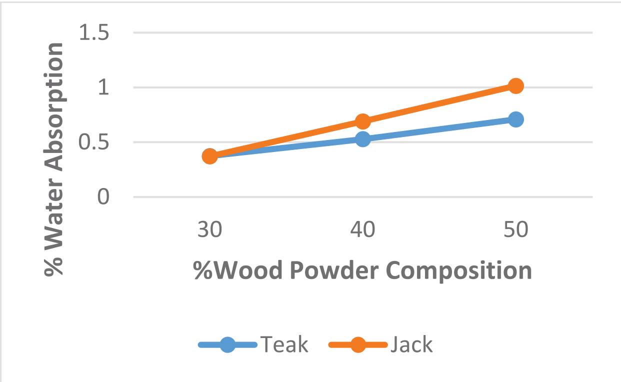

Fig 10. Effect of wood powder composition on the water absorption properties of the composites with fine particle content

From the figure 10 it can be observed that the water absorption is higher for fine particle inclusive composite compared to the medium and coarse ones.jack wood composite show a slightly higher water absorption compared to teak wood composites. Simillar trends are shown for medium and coarse wood particles.

Table 3. Result table for surface roughness and microhardness

Sl. no.	Surface roughness(Ra)		Micro hardness (VC)	
	Teak	**Jack**	**Teak**	**Jack**
1	4.44	4.062	43.2	52.6
2	5.906	3.882	39.1	59.1
3	5.794	4.441	38.7	60.2
4	4.467	4.122	35.1	53.1
5	4.179	4.253	42.3	52.4
Avg.	**5.112**	**4.152**	**39.68**	**55.48**

Better result of tensile specimen from the set of experiments is taken from both teak and jack wood composite is taken and surface roughness and and microhardness properties were evaluated to check the suitabilty for using it to fabricate aindustrial safety helmet.the test result shows in table 3 suggest that the jack wood show better surface roughness and hardness properties.figure 11 and 12 shows the roughness profile of the teak wood and jack wood composite at 50% wood powder composite with fine particle size.

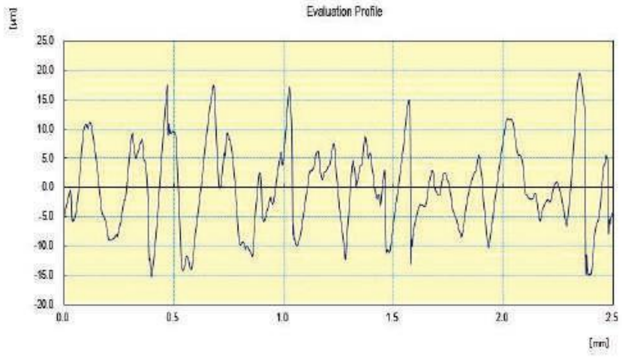

Figure 11. Roughness profile of machined teak powder composite (50% composition-fine powder)

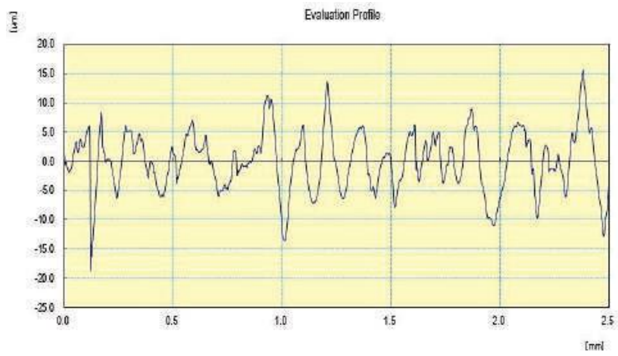

Figure 12. Roughness profile of machined jack powder composite (50% composition-fine powder)

The Micro structure of the one specimen each of both jack wood and teak wood composite with fine particle content and 50% wood powder composition is analysed. The fig 13 and fig 14 shows the micro structure of the respective composites.

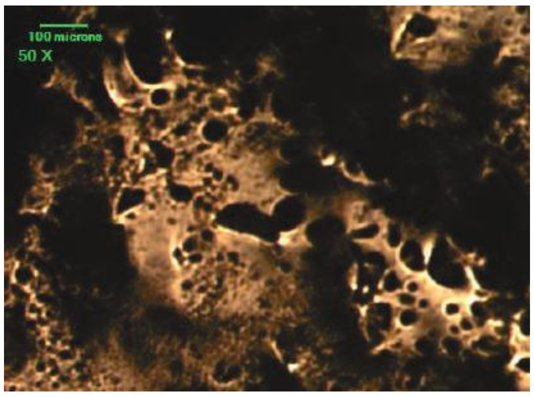

Figure 13. Microstructure of teak wood composite

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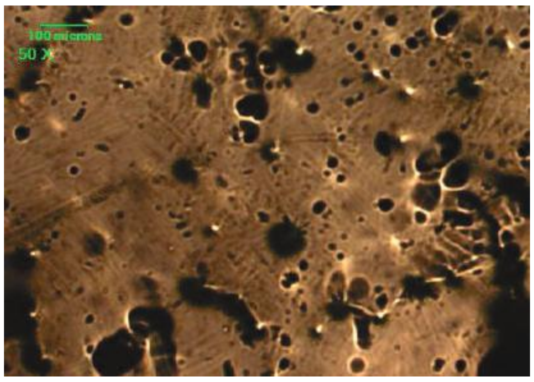

Figure 14. Microstructure of jack wood composite

B. Optimization

The taghuchi analysis gives the idea about the optimum parameter separately for tensile strength and water absorption.

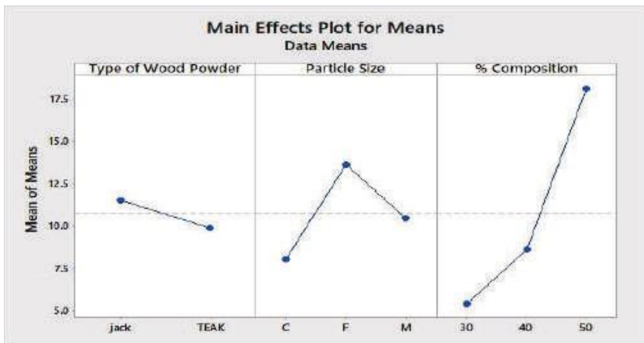

Figure 15. Main effects plot for means(for Tesile test)

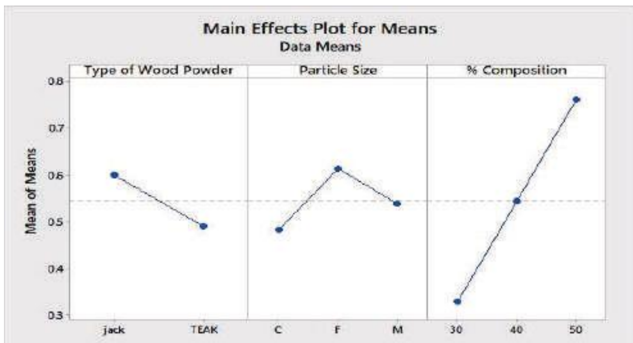

Figure 16. Main effects plot for means

(for water absorption)

As the tensile strength should be higher the optimum value is found to be fine jack powder particle with 50% composition (larger the better, which is shown in figure15).similarly for the water absorption test smaller is the better, and the optimum value is when composition is coarse teak powder with 30 % composition (smaller the better as shown in figure 16).

Grey relation Analysis is a multi-Objective Analysis. Grey relational coefficient is calculated to find the relationship between ideal and actual normalized experiment results. Grey relational coefficient is expressed as

$$\Phi i\ (k) = \frac{\Delta min+\delta\Delta max}{\Delta oi(k)+\delta\Delta max}$$

Where, $\Delta oi(k)$ is the deviational sequence of the reference sequence x_0^* (k) and the comparability sequence x_i^{k*}(k).

$$\Delta oi(k) = |\ x_0^*\ (k) -\ x_i^{k*}(k)\ | \quad (2)$$

$$\Delta max = \max |\ x_0^*\ (k) -\ x_i^{k*}(k)\ | \quad (3)$$

$$\Delta min = \min |\ x_0^*\ (k) -\ x_i^{k*}(k)\ | \quad (4)$$

Table no.4 Nominal best Result

Sl no.	GRG, Tensile	GRG, Water Absorption	Avg. GRG	Rank
1	0.353213	0.755183	0.554198	8
2	0.395112	0.578231	0.486672	15
3	0.821419	0.454545	0.637982	3
4	0.333333	0.779817	0.556575	7
5	0.377309	0.62449	0.5009	12
6	0.612196	0.489443	0.55082	9
7	0.334901	1	0.667451	1
8	0.356882	0.64557	0.501226	11
9	0.475243	0.512391	0.493817	14
10	0.365277	0.758176	0.561727	6
11	0.525747	0.465046	0.495397	13
12	1	0.333333	0.666667	2
13	0.364635	0.799373	0.582004	5
14	0.389783	0.529412	0.459597	18
15	0.638242	0.403694	0.520968	10
16	0.334901	0.920578	0.627739	4
17	0.35194	0.58531	0.468625	17
18	0.519623	0.422419	0.471021	16

The best result is found to be for set 7 but as strength is more important in safety helmet manufacturing. Larger the best result is chosen for fabrication. That is set 12 in table 4.

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XXIX. FABRICATION OF INDUSTRIAL SAFETY HELMET

An industrial safety helmet is manufactured from a better composition analysed by optimizing technique of taghuchi coupled with grey relation analysis. According to optimization the set 7 of table 4 is the better composition, but as water absorption is found to be less than 5%, we can neglect it and hence taken the next best result (set 12). The composition so used for the manufacturing is jack wood with fine particle content and 50% wood powder composition.figure.17 shows the safety helmet manufactured.

Figure 17. Industrial safety helmet manufactured from wood powder composite

The impact test on the helmet was performed by a drop test where the helmet was placed on a platform and a 3.4 Kg weight was dropped on it from a height. The test is run such that the impact occurs at different positions – the resulting damage is observed and quantified. A weight of 3.4 kg was chosen since it approximates the weight of a brick that is use for construction purpose.

Weight Dropped Test Results

In this weight dropped test first the composite helmet was dropped from different height and visual observations were made no visible damage to helmet and no dents were seen. The impact test on the helmet was performed by a drop test where the helmet was placed on a platform and a 3.4 Kg weight was dropped on it from a height.. From this results, there is no visible damage to helmet and no dents were seen When Dropped from 6 m height and failure occurs when dropped from a height of 11m.

XXX. CONCLUSION

This study shows that the use of natural materials, such as wood powder, allows the reinforcement of thermoplastic polymers and increase of mechanical properties of composite materials. Tensile tests showed an increase of tensile strength, between samples with 70:30 and 50:50 ratios. Moreover, it was also demonstrated that the increase of wood's mass fraction can slightly increase the moisture absorption, which is an adverse effect. It is also found that jack wood composite show better properties such as tensile strength, hardness and surface roughness properties after machining, except the moisture absorption properties. The surface roughness after a machining process(turning operation) and hardness properties are found to be better for composite made from jack powder Therefore, these conclusions are of paramount importance for some applications, namely in the automotive or building sectors. This Jack wood powder reinforced polymer composite can be a partial replacement for plastic. The Helmet thus made is undergone Helmet Drop test and Weight drop test. The helmet drop test show no significant damage to the helmet. The weight if fallen from a height of 6 m cause no significant damage to helmet. The damage occurs when weight is dropped from a height of 11 m.

C. Future Scope

The usage of the wood powder combined with carbon or glass fibre to for a composite, can give a better strength. This is scope for future study along with the analysis of other thermal properties of the composite. As it is a ecofriendly product which can make a better impact on society if utilized proper manner.

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b. NSS College of Engineering,PalaKKAD,Digital Library
c. Project Guide- Dr. Santhosh Kumar N.
d. Fellow Classmates

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Experimental Analysis and Optimization of Process Parameters on Friction Stir Welding of Aluminium(AA6061 T6) Alloy and Abs Plastic

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Abstract: Friction stir welding is a solid-state joining process which can produce high quality welds of different components with either similar or dissimilar materials which are difficult to weld by conventional fusion welding techniques. Friction stir welding utilizes frictional heating combined with forging pressure to produce high strength bonds virtually free of heat affected defects, even in case of dissimilar metal to polymer sheets. Material joining are gaining a great deal of attention in several industries, in particular where a trade-off between reduced weight, improved performance and cost reduction is required. Combination of ABS plastic and aluminium alloys is an alternative solution to this problem. This project aims to weld plates of aluminium (AA6061 T6) alloy and ABS sheet in the lap joint configuration. Optimize the process parameters using Taguchi method for higher shear strength and shore D hardness and to analyse the effect of process parameters such as tool rotational speed, welding speed and shoulder diameter on the output parameters of friction stir weldment. The feasibility of the process was identified by means of microstructure and mechanical analysis.

Keywords: FSW, ABS plastic, AA6061 T6 Aluminum Alloy, Shore D hardness, Shear strength

XXXI. Introduction

Recently, especially in automotive industries, widely used metals like steel are being replaced by the new lighter nonferrous materials such as magnesium and aluminium alloys. In addition, polymer technology developments led into modern structures. Modern thermoplastic materials as a specific type of polymer for having reshaped properties, are used in different engineering applications, such as automotive and aerospace industries, due to their lower cost, high toughness and stress ratios compared to their weight. These are one of the most commonly used materials in many industrial applications due to their easy manufacturing process. Even though thermoplastic materials offer wider choice of design or process, manufacturing of bigger and complex parts frequently need joining to different materials and alloys. These materials can be integrated with the polymer metal hybrid technologies in a monadic component. Studies and developments of such hybrid structures which led to the reduction of the weight of structures is increased in recent years. Lower fuel usage and co_2 emission are the main factors that persuade the engineers to produce these lightweight structures.

Joining of polymer-metal hybrid structures is more difficult by traditional welding process due to their big difference in physical and chemical features. Metal polymer joining limitations such as surface treatments and adhesive bonding time, motivated novel joining techniques.

FSW's success is due to a relatively simple concept. The process consists of a non-consumable rotating tool having a pin on a shoulder surface. As a first step, the rotating tool penetrates into the joining surface until the shoulder of the tool touches the top surface of the base metal. Then the tool transverses along the joining line under a load. The combined translation and rotation of the tool results in high frictional heating between tool and workpiece and this will change the weld zone to plastic stage and thus form a strong defect-free weld upon cooling. Since there is significant difference in mechanical as well as thermal properties of AA6061 T6 and Acrylonitrile Butadiene Styrene, the dissimilar FSW of these two materials is difficult due to their variation in material properties.

XXXII. Objective

The aim of this thesis to develop the fundamental knowledge on the possibilities to apply friction stir welding techniques to join an ABS plastic to Aluminium alloy sheet by

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using the conventional FSW method. In order to understand the metal-thermoplastic welding, the effect of welding parameters was investigated.

XXXIII. Literature Survey

Hamed Aghajani Derazkolaa et al (2018) The possibility of dissimilar friction stir welding between AA5058 aluminium alloy and polycarbonate (PC) in lap joint design was assessed.

Yongxian Huanga et al. (2018) conveys the material flow patterns highly depended upon the geometry of the tool pin, welding temperature, material flow and axial force.

Surjeet Singh et al. (2017) focuses on the success and strength of these joints mainly depends on the dimension of the joined area, the quality of the penetration of the teeth produced.

Anjal R. Patela et al (2018) studies the effect of relationship among the size of the Al anchor and the tool rotational speed. They have identified that while Increasing welding speed resulted in the increase in the size of the Al anchor.

.

Francesco Lambiasea et al (2017) investigates the importance of the tool geometry of the tool pin, welding temperature, material flow and axial force. And also identified that the transportation or material flow is highly influenced by welding parameters and peak temperature.

XXXIV. EXPERIMENTAL METHODS

The experimental setup consists of a vertical milling machine (Batliboi FA3V) and a welding fixture which is to be mounted on the work table to carry out friction stir welding.
An AA6061 T6 aluminium-magnesium alloys and Acrylonitrile butadiene styrene (ABS) polymer sheets utilized as the raw base materials. These plates were cut in the dimensions of 130×110×3mm. AA6061 T6 alloy is commonly used for automobile sheet panels and ABS is a special thermoplastic which shows good thermal and chemical stability that is usually being used for external and internal parts of automobile body. These initial materials have potential application in automobile body structure. The physical properties of the selected initial materials are presented in Table 1.

Table 1. physical properties of AA6061 T6 alloy and ABS polymer

Base material	AA6061 T6	ABS
Density(kg/m3)	2660	1010
UTS(MPa)	290	50
Elongation (%)	25	75
Shear strength (MPa)	207	101
Microhardness (HV)	50	-
Hardness (shore d)	-	72
Glass transition temp (Tg)	-	105
Melting point (°c)	580	200
Thermal conductivity(w/mk)	151	0.188

D.

Fig. 1. Experimental setup

E. Vertical Milling Machine

The conventional vertical milling machine having spindle speed up to 2000 rpm, feed range of 14-900 mm/min and spindle swivel from -45^0 to 45^0 was used for the present work. Automatic table movement by engaging the lever and manual movement is also possible in this machine. The experimental setup is shown in Fig. 1.

F. Fixture

The fixture consists of mild steel plate of thickness 18 mm having 200 mm X 200 mm size is prepared for fixing the base plates firmly. Two mild steel flat strips are used for holding the work pieces with eight bolts. The plate along with the strip arrest all the degrees of freedom.

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G. FSW Tool

In this present study, an FSW tool with plane shoulder along with a tapered probe or pin is used to increase the contact area of the probe with workpiece. This will lead to an increase in the frictional heat causing more plastic deformation. the tapered probe also promotes a high hydrostatic pressure in the weld zone, which is extremely important for enhancing the material stirring and the joint strength.

1) Tool Material:

Tool steel is the most widely used tool material for aluminium alloys which possesses a combination of high temperature strength and stiffness. The selection of tool material is determined by the approximate temperature reached during processing of Al alloy (in the range of 500-600 ^{0}C). Therefore, any tool steel with tempering temperature higher than 600 ^{0}C is ideal for FSW tool. In this study, the tool material was chosen as Hot Die Steel (H13 tool steel), which was heat treated to a hardness of 50 HRC.

2) Tool Geometry:

Tool pin profile was selected as tapered cylindrical shape. The selection of pin length is based on workpiece thickness, which is to be approximately 0.70-0.75 times of total workpiece thickness. In this present study three different shoulder diameter of 18,20,22mm and having same taper pin Figure 1 shows the view of FSW tool. It is having 18mm shoulder diameter and a tapered pin. The pin diameter is 6 mm diameter on the top (nearer to shoulder surface) and 4 mm at the bottom surface. Length of the pin used was 4.2 mm in order to avoid full penetration plate. The FSW tool is shown in fig.2.

Fig. 2. FSW tool

H. Workpiece

The weld coupon was prepared for lap joint configuration with 130x110 x 3 mm dimension so as to get a total width of 177 mm in order to tightly fit in the fixture and for readily preparing the workpiece for doing the tensile shear testing according ASTM D5868 standard. the aluminium alloy sheet were placed as bottom plate and the ABS sheet as top plate when arranged in lap joint configuration.

I. Shear and Hardness Testing Machines

Shear test samples were prepared from the welded sheets as per ASTM D5868. Test specimens were carried out on a SHIMADZU AUTOGRAPH testing machine with strain rate of 2 mm/min. The shore D test measures the penetration of a specified indentor in to the material under specified conditions of force and time. In this experiment, the hardness of upper plate or ABS sheet were measured through the joint line and the mean values were recorded. After successful pilot experiment, these upper and lower plate configurations were selected for further investigations, with design of experimentation based on Taguchi L27 design of experiments is listed in table 2.

Table 2. Taguchi L27 orthogonal array

Parametric conditions	Tool Rotational Speed(rpm)	Feed rate (mm/min)	Diameter (mm)
A1	500	14	18
A1	500	14	18
A1	500	14	18
A2	500	28	20
A2	500	28	20
A2	500	28	20
A3	500	40	22
A3	500	40	22
A3	500	40	22
A4	710	14	20
A4	710	14	20
A4	710	14	20
A5	710	28	22
A5	710	28	22
A5	710	28	22
A6	710	40	18
A6	710	40	18
A6	710	40	18
A7	1000	14	22
A7	1000	14	22

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A7	1000	14	22
A8	1000	28	18
A8	1000	28	18
A8	1000	28	18
A9	1000	40	20
A9	1000	40	20
A9	1000	40	20

XXXV. RESULT AND DISCUSSIONS

After successful experimental runs for each combination of metal to polymer according to Taguchi L27 orthogonal array, the result for different output parameters like shore D hardness and Shear strength at weld joint have been recorded in table 3.

Table 3. Shore D Hardness and shear strength (MPa) of welded joint

Parametric conditions	Average shore D Hardness	Average shear strength (MPa)
A1	53	11.5508
A1	50	10.6491
A1	48	10.8385
A2	55	10.9880
A2	57	10.9512
A2	53	10.8684
A3	58	10.6531
A3	61	10.6433
A3	60	10.8347
A4	57	12.8038
A4	50	13.0535
A4	54	12.8782
A5	61	10.8125
A5	63	9.7108
A5	58	9.3745
A6	54	11.4588
A6	52	12.0735
A6	53	11.3094
A7	51	9.8943
A7	47	10.9520
A7	49	9.0541
A8	59	11.2856
A8	57	11.2893
A8	54	11.0680
A9	56	11.8071
A9	55	10.5621
A9	50	11.4327

A. Taguchi Parametric Analysis

1. Effect of Process Parameters on Shore D Hardness

The observation of Shore D (Durometer) hardness of the welded joint is recorded in Table 3 as shown above. The output obtained for Shore D hardness of welded specimens were analysed on Minitab software under the condition larger the better is shown in Figure 3. It shows that maximum hardness is obtained at parametric condition of shoulder diameter 22 mm, feed rate 28 mm/min and rotational speed of 710 rpm.

It means higher shoulder diameter, medium feed rate and medium tool rotational speed gave the nearest base material hardness, but least shoulder diameter 18 mm, least feed rate 14 mm/min and high rotational speed of 1000 rpm for welding resulted in lowest hardness value. Molecular weight reduction is one of the influencing criteria for the change in hardness value. As the tool rotational speed increases, the heat due to friction increases which results in the reduction of molecular weight. This in turn decreases the hardness value. Maximum value of hardness is obtained at second level of tool rotational speed, second level of feed rate and third level of tool shoulder diameter at 710 rpm, 28 mm/min and 22 mm respectively.

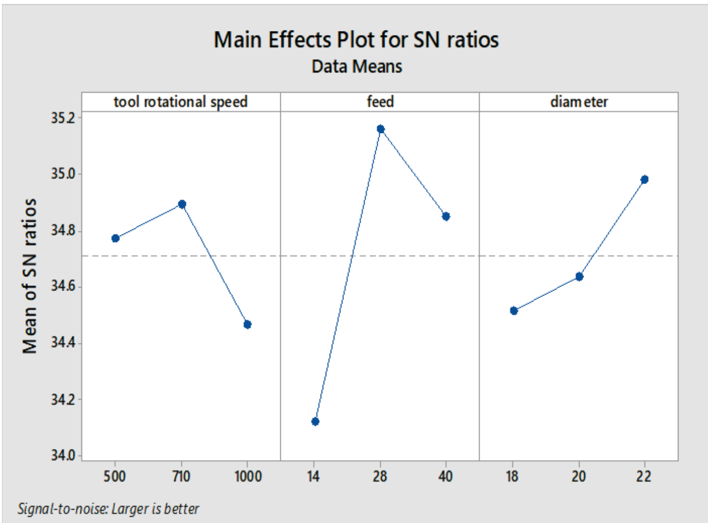

Fig. 3. Main effects plot for SN ratios of shore D hardness.

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Table 4. Analysis of variance of S/N Ratio

Source	DF	Adj SS	Adj MS	F	P	Contribution
Tool rotation Speed	2	0.2914	0.1457	0.42	0.707	9.52
Feed Rate	2	1.7177	0.8588	2.45	0.290	56.13
Diameter	2	0.3487	0.1743	0.50	0.668	11.39
Residual	2	0.702	0.351			22.94
Total	8					99.98

Table 5. Response table for signal to noise ratios (larger is better)

Levels	A	B	C
1	34.77	34.12	34.52
2	34.89	35.16	34.64
3	34.47	34.85	34.98
Delta	0.43	1.04	0.46
Rank	3	1	2

2. Effect of Process Parameters on Shear Strength

Shear strength is higher the better type characteristics. Effect of process parameters on shear strength was found out by evaluating mean and S/N ratio in Taguchi method. Fig.4 gives plot for SN ratio main effect of shear strength. Highest shear strength is observed at rotational speed of 710 rpm, feed rate 14 mm/min and tool shoulder diameter 20 mm. This is due to the fact that sufficient heat is generated at medium level of rotational speed and effective intermolecular dispersion at joint interface is occurred with lower feed rate. The shear strength characteristics are quite high for the medium diameter of shoulder, low feed rate and medium tool rotational speed. On the other hand, higher shoulder diameter of 22 mm, medium feed rate 28 mm/min and higher rotational speed of 1000 rpm for welding results in lower shear strength.

Table 6 gives the analysis of variance table for shear strength. Table 7 gives the response table for SN ratios of shear strength. From these tables we can see that shoulder diameter and tool rotational speed are the most influencing factor for shear strength with percentage contribution of 58.88 and 11.17 respectively. Thus the maximum value for shear strength is obtained at tool rotational speed of 710 rpm, feed rate of 14mm/min and tool shoulder diameter of 20mm.

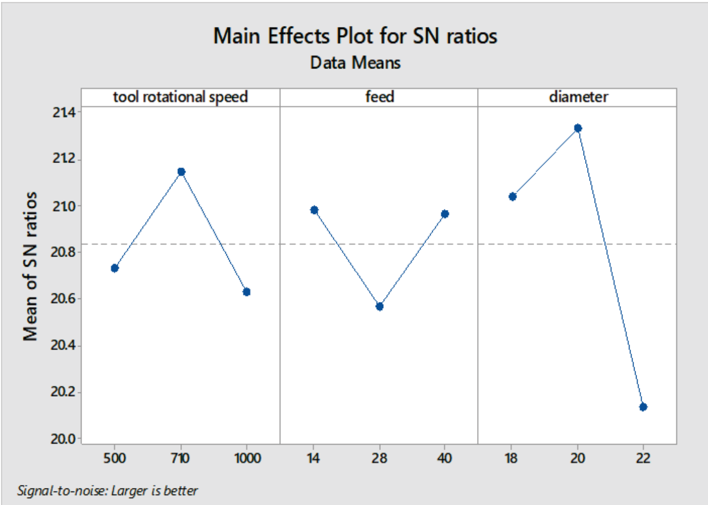

Fig. 4. Main effects plot for SN ratios of shear strength

Table 6. Analysis of variance of shear strength

Source	DF	Adj SS	Adj MS	F	P	Contribution
Tool rotation speed	2	0.4422	0.2211	0.52	0.659	11.17
Feed rate	2	0.3304	0.1652	0.39	0.721	8.34
Diameter	2	2.3305	1.1652	2.73	0.268	58.88
Residual	2	0.8544	0.4272			21.58
Total	8					99.97

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Table 7. Response table for signal to noise ratios (larger is better)

Levels	A	B	C
1	20.73	20.98	21.04
2	21.14	20.56	21.33
3	20.63	20.96	20.14
Delta	0.51	0.41	1.20
Rank	2	3	1

B. *Grey Relational Analysis*

Table 8. Grey Relational Grade and Rank

Trial No	GRG Avg. Shear Strength	GRG SHORE D	Avg. GRG	RANK
A1.1	0.570953	0.444444	0.507699	15
A1.2	0.454052	0.380952	0.417502	23
A1.3	0.474453	0.347826	0.41114	24
A2.1	0.491905	0.5	0.495953	16
A2.2	0.487494	0.571429	0.529461	13
A2.3	0.477848	0.444444	0.461146	22
A3.1	0.454465	0.615385	0.534925	12
A3.2	0.453455	0.8	0.626728	6
A3.3	0.474029	0.727273	0.600651	7
A4.1	0.701795	0.571429	0.636612	4
A4.2	1	0.380952	0.690476	2
A4.3	0.919398	0.470588	0.694993	1
A5.1	0.471549	0.8	0.635774	5
A5.2	0.374302	1	0.687151	3
A5.3	0.352139	0.615385	0.483762	19
A6.1	0.556336	0.470588	0.513462	14
A6.2	0.671106	0.421053	0.546079	11
A6.3	0.534135	0.444444	0.48929	17
A7.1	0.38762	0.4	0.39381	26
A7.2	0.487587	0.333333	0.41046	25
A7.3	0.333333	0.363636	0.348485	27
A8.1	0.530765	0.666667	0.598716	8
A8.2	0.531286	0.571429	0.551357	10
A8.3	0.50178	0.470588	0.486184	18
A9.1	0.616022	0.533333	0.574678	9
A9.2	0.445257	0.5	0.472628	20
A9.3	0.552325	0.380952	0.466639	21

In Grey Relational Analysis, experimental data i.e. measured features of quality characteristics of the product are first normalised ranging from zero to one. Next, based on normalised experimental data, grey relational coefficient is calculated to represent the correlation between the desired and actual experimental data. Then overall grey relation grade is determined by averaging the grey relational coefficient corresponding to selected responses. The overall performance characteristics of the multiple response process depends on the calculated grey relational grade. This response converts a multiple response process optimization problem into a single response optimization situation, with the objective function is overall grey relation grade. The optimal parametric combination is then evaluated by maximizing the overall grey relation grade. Based on Grey Relational Grade, rank of different experiments was obtained. With respect to the rank obtained, it is concluded that the optimum level of all parameters are comes on rank 1 and the values of the parameters are Tool rotational speed 710 RPM, feed rate 14 mm/min, Tool shoulder diameter 20 mm.

Fig.5. Rank profile for set of experiments

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C. Macro and Micro Images

The cross-sectional view of joints that has been shown in figure 6, 7 and 8 indicates that the stir zone (SZ) is formed as polymer-metal composite by mixing the ABS matrix and aluminium particles reinforcement.

Fig. 6 Cross-sectional view of joint welded at 500 rpm tool rotation , 14 mm/min feed rate and 20 mm shoulder diameter.

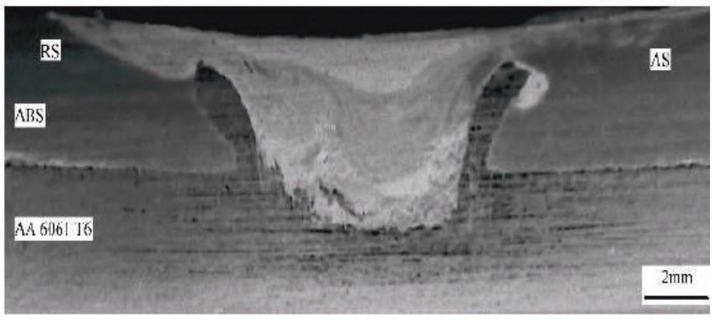

Fig. 7 Cross-sectional view of joint welded at 710 rpm tool rotation , 14 mm/min feed rate and 20 mm shoulder diameter.

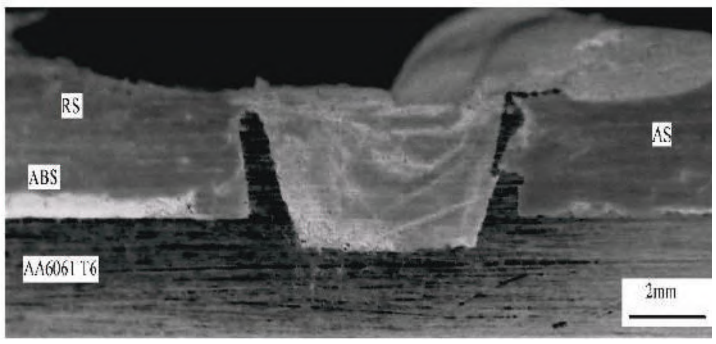

Fig. 8 Cross sectional view of joint welded at 1000 rpm tool rotation , 14 mm/min feed rate and 20 mm shoulder diameter.

During the FSW process, tilted pin, penetration aluminum base metal led to the high mechanical work rate. Subsequently, the AA6061 T6 twisted around the pin and the produced wavy dent in advancing and retreating side along the joint line. The aluminium wavy dent increases mechanical interlock between AA6061 T6 and ABS plastic in the lower area of stir zone. The results showed that by increasing tool rotational speed the length and width of aluminum ramus in advancing and retreating side will increase. Some tiny aluminum particles were spread in ABS matrix that fractured from AA6061 T6 alloy during stirring action.

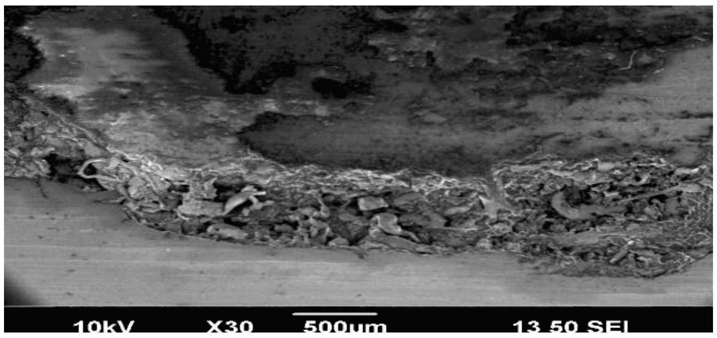

Fig. 9. SEM image of joint welded at 710 rpm, 14mm/min and 20 mm diameter.

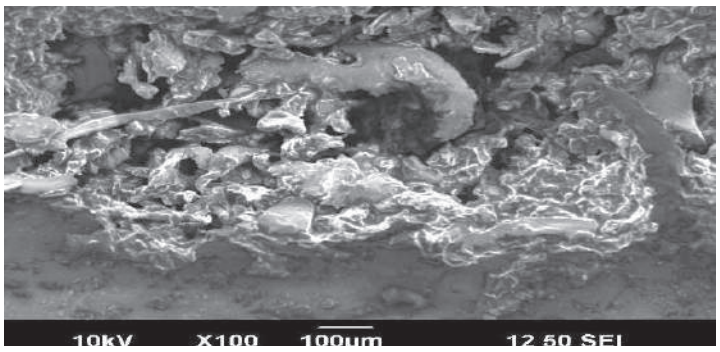

Fig. 10. Magnified SEM image of joint interface welded at 710 rpm, 14mm/min and 20 mm diameter.

The SEM image from cross-sectional view of joint welded at 710 rpm and 14mm/min and 20 mm shoulder diameter is shown in Fig.4.9. As shown figure , the joint interface between aluminum and ABS plastic is well mixed of aluminum and polymer particles . The micrograph under SEM of the Al powder used for the reinforcement is shown in Figure 4.10. The morphology of the Al powder revealed irregular shaped milled powder. In figure 4.10 its shows that, Some voids were formed at the lower end of the stir area, which could reduce the mechanical characteristics of the joint..

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XXXVI. CONCLUSION

The possibility of dissimilar friction stir welding between AA6061 T6 aluminum alloy and ABS plastic in lap joint design was established. The following conclusion can be extracted.

- Feasibility of the tapered pin with flat shoulder in the FSLW of ABS and AA6061 T6 alloy was verified. The solid mechanical interlocking by the large aluminum anchor has been accomplished.
- The aluminum anchor featured by the bended, deformed and elongated grains penetrated into the molten and resoldified polymer. Mechanical interlocking induced by the Al anchor attributed to the main joining mechanism.
- Optimum value for Shore D hardness is obtained at tool rotational speed of 710rpm, feed rate of 28mm/min and tool shoulder diameter of 22mm.
- Welding speed plays a vital role and contributes 56.13 % to the overall contribution and tool shoulder diameter and tool rotational speed have 11.39%, 9.52% influence on shore D hardness of joints respectively.
- The hardness of ABS after FSW decreased for all sample compared to the initial raw ABS sheet, because of the molecular weight reduction of the ABS due to the frictional heat during the process.
- Optimum value for shear strength is obtained at tool rotational speed of 710 rpm, feed rate of 14mm/min and tool shoulder diameter of 20mm. In these parameters, the shear strength reached close to 32% (40.5Mpa) of the raw ABS sheet strength.
- Tool shoulder diameter plays avital role and contributes 58.88 % to the overall contribution and tool rotational speed and welding speed have 11.17%,8.34% influence on shear strength of joint respectively.
- From Analysis of Variance, the percentage contribution of input parameters was found out for each output parameter.
- Based on Grey Relational Grade, rank of different experiments was obtained. With respect to the rank obtained, it is concluded that the optimum level of all parameters are comes on rank 1 and the values of the parameters are tool rotational speed=710 rpm, feed rate= 14 mm/min, Tool shoulder diameter=20 mm.
- The cross-sectional image shown that by increasing tool rotational speed the length and width of aluminum ramus in advancing and retreating side will increase.

XXXVII. FUTURE SCOPE

The present work is to determine the optimal process parameters for Friction stir welding of aluminium alloy (AA6061 T6) and ABS plastic based on a single tool profile, tool geometry, tool material. It would be useful to extend the present work by changing the tool pin profile to check for the improvement in weld quality. The process of FSW can be extended to different combinations of thermo-setting plastics.

Thermal analysis can be added to this work to study on the effect of heat effected zones in the weld area. The effect of post heat treatment of FSW joints with different ageing treatments to improve the shear strength can also be of another topic of discussion.

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CNC Multi Pass Programming, Trepanning and Analysis Of Ti6Al4V T-Block

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Abstract: Trepanning is the process that leaves the core while drilling which can be used for other purposes of manufacturing. Thus the wastage of material is reduced. It takes very less time for operation. A trepanning tool is the carbide cutting tool used for materials where deep hole boring and cutting large diameters is needed. Normally trepanning tool have multiple carbide tip at the cutting edge for the material removal process. Selection of material for the trepanning tool and cutting tips are based on the properties of the material to be machined. The process is done with the help of a CNC milling. The trepanning process is conducted on Ti6Al4V T block. This type of alloy is designed with good balance of characteristics which is commonly used in aerospace applications. The trepanning process is carried out to produce a inner shaft of diameter 210mm from a solid shaft of diameter 620mm and 620mm in length. The surface roughness is taken to validate the surface finish of the finished shaft. The wear and vibration in the tool during trepanning operation is also analysed with the help of softwares.

Keywords: Trepanning process, Ti6Al4V, Coated Carbide Inserts, Surface Roughness

I.INTRODUCTION

Titanium and its alloys have gained widespread applications in aerospace, biomedical industries and marine due to their favourable properties. They are light weight, possess high strength, have excellent fatigue performance and offer high resistance to an aggressive environment. Titanium is a chemical element with symbol Ti and atomic number 22. One of the primary ingredients to successfully machining titanium is a stiff and rigid machine tool and work holder. It is critical that the machine tool and fixture are capable of securing the work piece as it begins to vibrate, only those fixtures that have been designed with stability as its primary function should be used in titanium machining. Having a stiff and rigid machine design allows the machine tool to counter the high-torque, high-horsepower forces of the spindle and produce consistent part quality with less effort. A cutting tool must have good hardness, toughness and wear resistance in order to produce good quality and economical parts.

The tendency of work hardening increases with larger feed per tooth. It is always recommended to reduce the feed per tooth. High cutting speed is usually recommended. Tool life significantly gets reduced due to the high strength, low thermal conductivity and chemical reactivity of titanium with tool materials at elevated temperatures. When coolant is not appropriately applied in titanium, tools tend to wear quickly. During the machining of titanium, the tool tip can reach temperatures of 2,000ºF (1093ºC). This tremendous heat often causes super-heated steam to form in water-based coolants, making the coolant vaporize before it even touches the work piece. This leads to additional heating of the work piece instead of cooling, making accuracy even more challenging.

In the market standard titanium pipes are available. As per the customer requirement the size of pipe may get varied. If the pipe size doesn't belong to a standard size then trepanning process has to be conducted. Normally trepanning process is conducted on costly materials like titanium alloy. Trepanning reduces the waste and it gives the required size. For trepanning process it is always recommended to use Carbide tools for cutting process as it have high hardness over a wide range of temperatures, high thermal conductivity and high Young's modulus making them effective tool and die materials for a range of applications. Trepanning tool helps to create bore on the solid material. The trepanning tool does not machine the whole diameter it removes only a ring at the periphery. Instead of removing all the material in the form of chips, a core is left in the centre of the hole. The core material which is removed from the work piece is also in the form of a shaft which can further utilized for any other part production

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II.LITERATURE SURVEY

C.Veiga.et.al[1] In their paper highlighted the mechanical and thermal properties of the titanium and its alloy while with regard to application of aerospace, automotive and biomedical fields. Titanium and its alloys are actively used for intake and exhaust valves, connecting rods, retainers, and others, being the weight saving the major benefits of such applications.

Ronald G. Munro[2] in his paper described the physical, mechanical, and thermal properties of polycrystalline Titanium. In this section, the available mechanical and thermal properties are examined with the intent of providing a better understanding of how the properties depend on the composition, grain size, and density of the material.

R. R. Boyer[3] described that the Titanium and titanium alloys are excellent candidates for aerospace applications due to their high strength to weight ratio and excellent corrosion resistance; titanium and its alloys are immune to almost every medium to which they would be exposed in an aerospace environment.

Vinicius A.R. Henriques[4], in his paper highlighted the titanium metallurgy focused on aerospace applications. Automobile industries and study of thermal properties of titanium alloy.

Narasimhulu Andriya et.al[5],highlighted in their paper the usage of carbide tools for the machining purpose of titanium. These tools have high hardness, wear resistance and chemical stability.

Jose Mathew et.al[6] in their paper they highlighted the possibility of reducing the thrust and torque by using the concept of trepanning. The design considerations and development methodology of the trepanning tool are discussed. The appropriate tool geometry has been determined by using statistically planned experiments and analysis. Low production cost and ease of regrinding are its major additional advantages due to its simple geometry.

J. Nithyanandam et.al[7] highlighted the influence of cutting parameters of titanium alloy and the feed rate is the most influencing factor having followed by cutting speed and depth of cut. The optimal parameters are found to be high cutting speed, lower feed rate and low depth of cut. Also, the tool is investigated for general wear pattern. Low cutting speeds leads to the adhesion of work piece material on to the tool after a certain period of time.

Jose Mathew et.al[8] emphasized in their paper the peculiarities of trepanning over drilling of unidirectional composites. The models for prediction of critical thrust and critical feed rate during trepanning of unidirectional composites based on fracture mechanics and plate theory also have been presented. Mathematical models correlating thrust and torque with tool diameter and feed rate have been developed through statistically designed experiments and effect of various parameters on them have been discussed.

M.Narasimha et.al[9] highlighted the application of coating on carbide insert to be used in the manufacturing industry as cutting tool. To achieve this in an efficient way, experiments on a variety of coatings are conducted on AISI 1018 steel, AISI M42 tool steel (58-63 HRC) and Titanium alloys (Ti64).

Mohit K Pandya et.al[10] in their paper highlighted the performance of surface roughness of Ti-6Al-4V using the coated and uncoated carbide insert during machining of Ti-6Al- 4V alloy (grade 5 titanium alloy) under dry machining in CNC turning. Ti-6Al-4V is widely used in automotive, marine applications

III.EXPERIMENTAL WORK

Titanium Ti6Al4V T Block of 620mm x 620 mm is taken as the workpiece during the experimental set up.The trepanning and the boring process has experimented in this workpiece.The design to be machined in the workpiece is shown in the figure 3.1.The material removed in the trepanning and boring process should be same. The trepanning process and the boring process is carried out to produce a inner shaft of diameter 210mm from a solid shaft of diameter 620mm and 620mm in length.Trepanning process is conducted with the help of Vertical CNC milling centre.Multipass programming is used for machining the workpiece because of the huge size of the workpiece.This process involves three tools of same diameter and different lengths.The tool used in these process is HSS and inserts used is carbide tips. The dimension of the tools is given as Table 3.1.

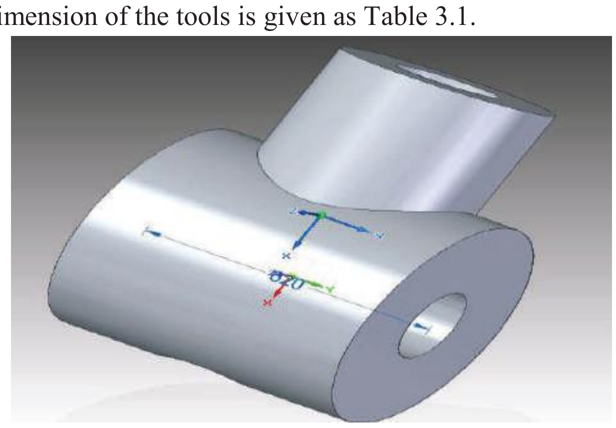

Fig 1: Design of Ti6Al4V T Block

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TOOLS	TOOL DIAMETER (mm)	TOOL LENGTH (mm)
TOOL 1	25	340
TOOL 2	25	280
TOOL 3	25	210

Table 1: Tool dimensions used

M/S Johnward Taiwan DMC-2100H Fanuc series is the vertical CNC machining centre used in the trepanning process.

IV.RESULTS AND DISCUSSIONS

The trepanning process is conducted on Ti6Al4V T block. The process is done at Steel Industries and Forging Limited Thrissur (SIFL). The inner shaft of 210 mm diameter is taken out during this process. The trepanning process of the Ti6Al4V T block is shown in the figure 4.1. Machined Ti6Al4V T Block is shown in the figure 4.2.

Fig 2: Trepanning process

Machining time is taken as the parameter in this work.The machining time taken for boring process is 66 shifts in which each shift has 8 hrs of operation.So the total time for machining this T block is 528 hrs.While experimenting the same operation by trepanning process the time taken for mschining is 60 shifts which is to be 480 hrs.

Specification of the machining centre taken for trepanning process is shown below

Distance between column	: 1300mm
X-Travel distance	: 2050mm
Y-Travel distance	: 1300mm
Z-Travel distance	: 800mm
Spindle speed	: 6000rpm
Maximum tool length	: 400mm
No. of tools allocated	: Arm 24

Fig 3:Trepanned Ti6Al4V T block

1. CALCULATION OF MRR

With the help of machining time the material removal rate of both the processes is calculated.

$$\mathrm{MRR} = \frac{\text{Volume of material removed by the process}}{\text{Time taken for machining}}$$

The material removed in both the processes is 210mm dia and 620mm length.In the first case the machining time for boring process is 528hrs.MRR for boring process is given by

$$\mathrm{MRR(Boring)} = \frac{\pi \text{ X } 105 \text{ X } 105 \text{ X } 620}{528 \text{ X } 60}$$

MRR(boring) = **677.85 mm^3/min**

Similarly, the MRR for trepanning process is calculated as

$$\mathrm{MRR(Trepanning)} = \frac{\pi \text{ X } 105 \text{ X } 105 \text{ X } 620}{480 \text{ X } 60}$$

MRR(Trepanning) = **745.63mm^3/min**

The MRR is calculated for both boring and trepanning process.From the values obtained above the MRR is higher for trepanning process as compared to boring process.Thus time taken for trepanning process is less than boring process.

2. CALCULATION OF SURFACE ROUGHNESS

The surface roughness is taken as the parameter to analyse the surface finish of the trepanned T block.The surface roughness is measured by using MITUTOYO SJ 210 SURFACE TESTER which is shown in the figure 4

Fig 4: Mitutoyo SJ 210 Surface Tester

The surface roughness of the trepanned T block is measured to be 3.1µm.The surface roughness measured on boring process is seems to be 3.6µm.So the surface finish obtained from trepanning process is better than boring process.

4.3 VIBRATION ANALYSIS

After trepanning process the deformation in the tool is analysed with the help of ANSYS.Deformation is obtained with the help of modal analysis.The deformation in the tool is shown as for the frequency 153.65Hz is shown in the figure 5

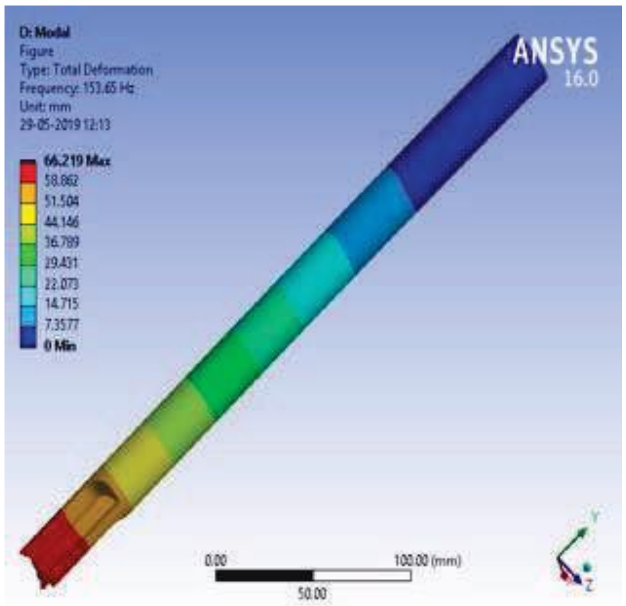

Fig 5: Deformation of tool in 153.65Hz

The frequency response is taken from the deformation of the tool and it is plotted as graph which is shown in the figure 6

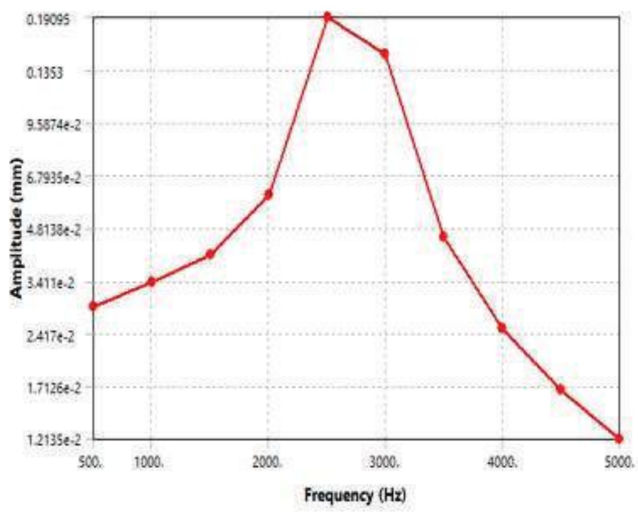

Fig 6: Frequency response obtained from modal analysis

The frequency response is taken from the model analysis using ANSYS software.From fig 4.5 maximum deformation is obtained at 2500Hz which tends to zero after the saturation frequency of 2500Hz.

4. WEAR ANALYSIS

The wear is analysed on the tool in both trepanning and boring process with the help of SEM(Scanning Electron Microscope).The SEM image of the trepanning tool is

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shown in the figure 7 which shows the wear in the trepanned tool.In figure 8 the SEM image of boring tool is shown which analyses the wear on this tool.

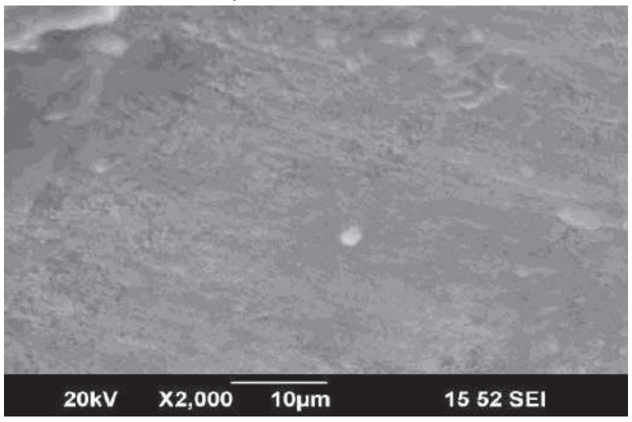

Fig 7: SEM image of trepanned tool

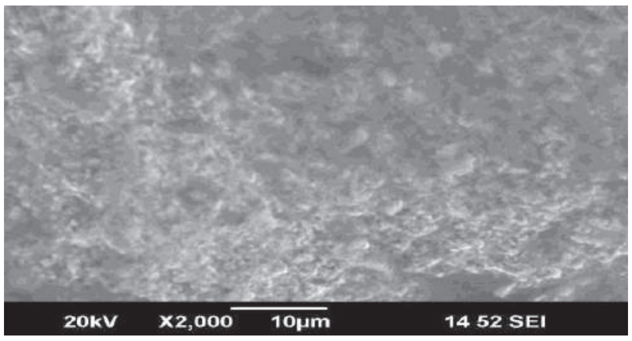

Fig 8: SEM image of boring tool

From figure 7 and 8 the wear of both the tools is analysed.From these images the trepanned tool has less impact on wear aspect as compared to boring tool.

4.5 HEAT AFFECTED ZONE

The Heat Affected Zone (HAZ) in the tool is analysed with the help of SEM.The HAZ in both trepanning and boring tool are shown in the figure 4.8 and figure 4.9 respectively.

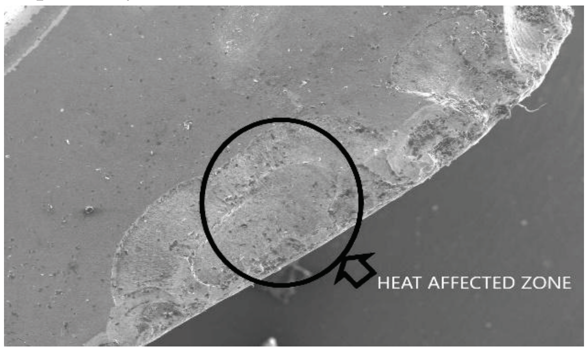

Fig 9: HAZ of Trepanned tool

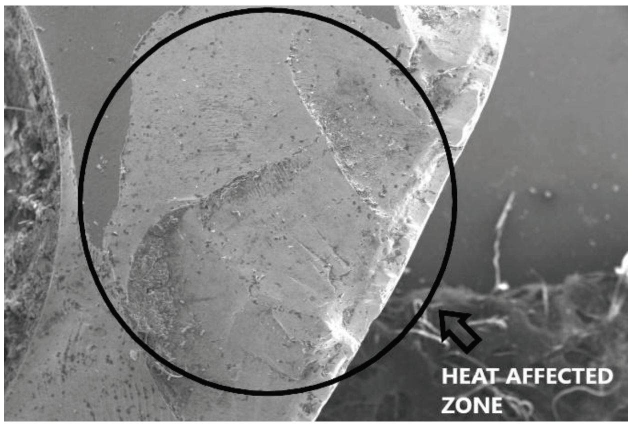

Fig 10: HAZ of Boring tool

From the SEM images the HAZ is observed more on boring tool (fig 10) than the trepanned tool (fig 9). The tool life of boring tool is more reduced as compared to trepanned tool due to the effect of HAZ.

.

V.CONCLUSIONS

- Ti6l4V T block was machined by both trepanning and boring process..
- MRR is calculated with the help of material removed in the process and machining time.MRR is observed more in trepanning process than boring process.
- Surface roughness is measured on the T block for treapnning process and boring process.From the values the surface finish of treapnning process is better than boring process.
- Frequency response is taken for evaluating maximum defromation in the tool.The maximum deformation of the tool is analysed at 2500Hz.
- Wear is analysed with the help of SEM images for both the processes.Trepanned tool has less wear as compared to boring process.
- HAZ is analysed in both the processes with the help of SEM images.HAZ is observed more on boring tool as compared to trepanned tool.

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An Experimental Study on the Effect of Manganese Dioxide & Ferric Oxide Nano-Particles for Sewage Water Decontamination

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Abstract: The vision of this paper is to investigate and introduce a technique to decontaminate, one of the most essential commodities of life that is, water. Unfortunately, about half of a billion people face the problem of water scarcity throughout the year. The treatment of wastewater namely sewage water can reduce these concerns however; the traditional methods of treatment are not efficient enough to completely remove the emerging pollutants. In this paper an experimental study was conducted for the effect of nano sized materials on the purification of sewage water. As a matter of fact, various nano-materials have been prepared and used for the removal of contaminants from water. Herein the mechanism of adsorption was taken in to consideration were manganese dioxide and ferric oxide nano particles were utilized as an adsorbent for decontamination of sewage water. The nano-materials were synthesized by means of planetary ball mills and characterization was done through x-ray diffraction and scanning electron microscope. In planetary ball milling the varying parameters such as speed of rotation and time causes considerable changes in the nano range and the scanning electron microscope results interpret the development of nano sized particles in the range of less than 60nm. Then the prepared nano particles were introduced in to the pre-tested water samples for contaminant adsorption. The pre-testing includes the testing of heavy metals using atomic adsorption spectrometer and general sewage water testings such as BOD & COD. It was observed that the nano-materials can adsorb contaminants like zinc, magnesium, cadmium, chlorides & sulphates to some extent and at 0.05ppm Fe_2O_3 concentration the rate of metal adsorption reaches maximum. A comparison between manganese and ferric oxide shows that the rate of adsorption varies between them. In addition to this, the treated water shows excellent water quality standards.

Keywords: Sewage water, Metal-oxide nano-particles, adsorption, heavy metals

XXXVIII. INTRODUCTION

In the modern scenario of scarcity of water resources, effective and viable treatment of wastewater is essential for growing economy. It is important to introduce and implement advanced wastewater treatment technologies with low capital requirements. The treatment of wastewater namely sewage water can reduce the current concerns to some extent. Among various treatments, recent advanced processes in nano-sized materials have been attracting the attention of scientists towards wastewater treatments [1]. This article investigates the utilization of metal oxide nano-materials for wastewater treatment processes. This includes the use of manganese dioxide and ferric oxide nano particles as nano-adsorbents.

One of the major advantage of nano-sized particles are the amount of surface they exposed to trap contaminants [4]. A surface phenomenon of adsorption is takes place in this large surface area and consequently hold the pollutants. The metal oxide particles have the ability to trap heavy metals in water,

Such as, zinc, mercury, lead etc. The heavy metal adsorption depends on the type of the parent metal [2]. The presence of heavy metals, dyes and microorganisms even in trace amounts, are very dangerous to human health, aquatic systems and the environment.

This paper will discuss the potential role of engineered nano-materials such as manganese dioxide and ferric oxide for the development of water purification systems. Sewage water samples were utilized to perform the adsorption experiments and a comparison is carried out between the two types of nano particles. In addition to this, the preparation of nano-adsorbents play a vital role in decontamination that is the preparation improves the particle nature. Herein, planetary ball mills were utilized to synthesize the nano particles. By

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varying speed and time for milling different nano-range can be achieved.

XXXIX. MATERIALS AND CHARACTERISATION

J. *Characterisation Of Water Sample*

One of the main aspects regarding the waste water selection is the type of sewage water, namely grey water. It is a type of water obtained from kitchen outlets. Here in a samples of grey water is collected, from kitchen sink. The collected samples were stored in a temperature of 15 degree Celsius with a dilution of concentrated sulphuric acid. Before that, collected water samples were tested for identifying the amount of contaminants present in the water. The initial testing is somewhat called characterization of sewage water and in environmental engineering there are two standard tests based on the oxidation of organic material, that is biological oxygen demand and chemical oxygen demand . The biological oxygen demand of a sample is the amount of oxygen required for the decomposition of organic matter present in the water sample. The chemical oxygen demand gives the measure of the oxygen required for chemical oxidation. The pre-testing results are as follows;

TABLE I: PRE-TESTING RESULTS OF WATER SAMPLES

Pre- tests	Kitchen outlet water	Canteen water
Dissolved oxygen	0.92mg/l	1.288mg/l
Chemical oxygen demand	128.4mg/l	102.72mg/l
Biological oxygen demand	136.4mg/l	157.6mg/l
Chloride	4.99mg/l	7.99mg/l
Sulphate	1606.805mg/l	2678.105mg/l
Alkalinity	1260mg/l	577.5mg/l
Acidity	79.2mg/l	52.8mg/l

In addition to this, the presence of heavy metals in water can be tested by means of an atomic absorption spectrometer. Generally the presence of heavy metals are arises due to chemical reaction between molecules of kitchen cleaning agents and decomposed sewage. The atomic absorption spectrometer observations are as follows;

TABLE II: HEAVY METALS IN WATER SAMPLES

Heavy metal	Kitchen outlet water	Canteen water
Zinc	Nil	Nil
Lead	Nil	Nil
Cadmium	Nil	Nil
Arsenic	Nil	Nil
Magnesium	32.14 mg/l	Nil

A. *Characterization of Nanomaterial's*

There are various adsorbents such as bio adsorbents, metal oxide and non-mental oxide adsorbents. From this, metal oxide based nano materials shows excellent adsorption capacity towards heavy metals in water [2]. Magnesium and ferric oxide materials show sublime capacity to hold contaminants in nano ranges. They were purchased in their oxide form and its grain size is determined through scanning electron microscope. Manganese oxide particles are initially in the range of 361.875 nm and similarly ferric oxide particles are 110.514 nm, their images are shown in figure 1 and figure 2.

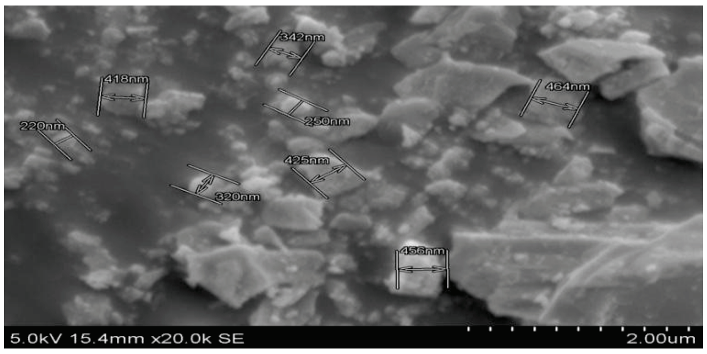

Figure.1. SEM image of manganese dioxide powder

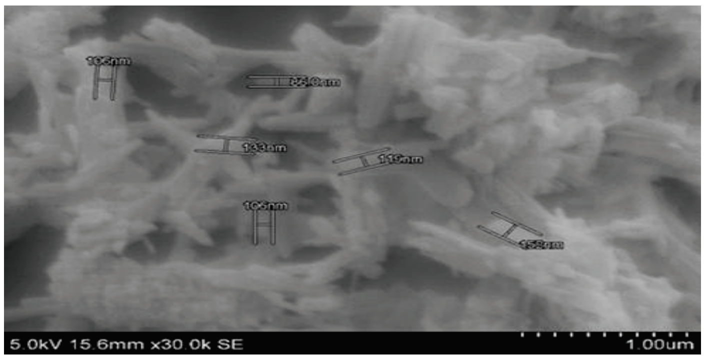

Figure. 2. SEM image of ferric oxide powder

The SEM results shows that the particle size were above 100 nm and thus it is to be reduced to below 100 nm .The

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nano-particles of MnO_2 and Fe_2O_3 were prepared using the process of high energy ball milling using the equipment RETSCH PM100. The samples were collected on completion of 80hours, 90hours and 100hours of milling operation and each of the samples were analysed for particle and crystal size. Table IVshows average particle size of each adsorbent

TABLE III : PARTICLE SIZE OF ADSORBENT

	Speed (rpm)	Time (hours.)	Size (nm)
Manganese dioxide	250	80	80.025
	250	90	71.73
	250	100	49.34
Ferric oxide	250	80	72.7
	250	90	63.73
	250	100	42.11

Characterization of nano materials includes the identification of average particle size and its crystal size. Samples were analyzed by **HITACHI SU 6600** Scanning Electron Microscope at NIT Calicut. Three samples at different conditions were observed through SEM at 30k magnification. The results of SEM are as follows:

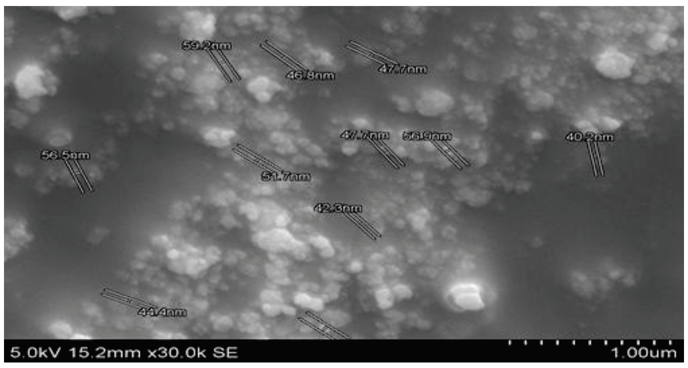

Figure.3. SEM image of MnO_2 at100 hours

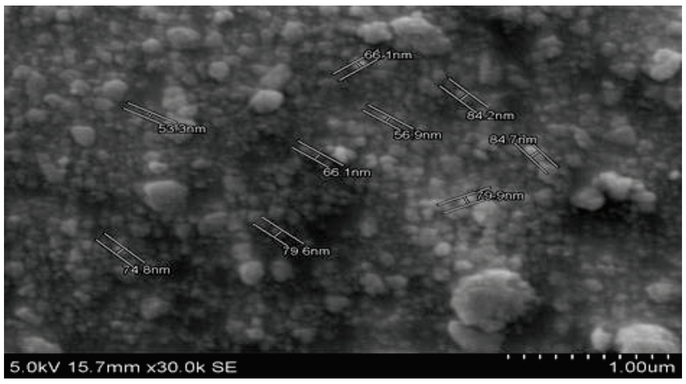

Figure.4. SEM image of MnO_2 at 90 hours

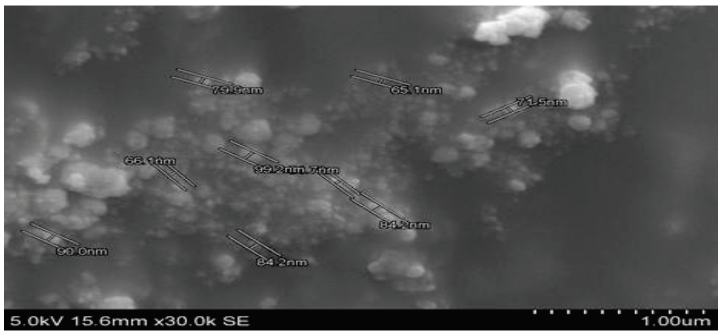

Figure 5. SEM image of MnO_2 at 80hours

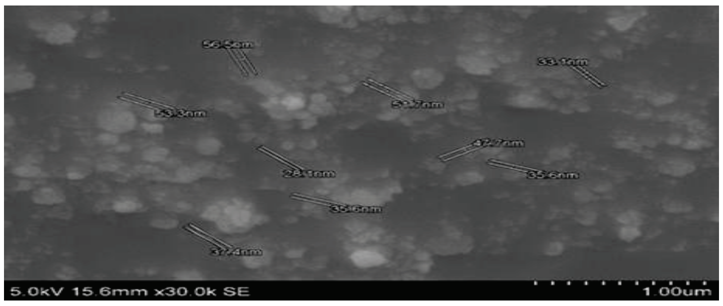

Figure. 6. SEM image of Fe_2O_3 at100hours

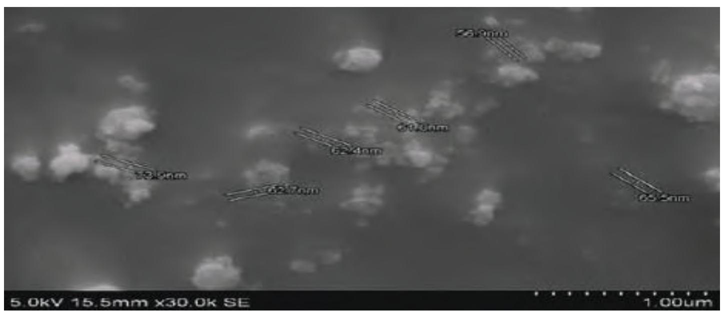

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Figure 7.SEM image of Fe_2O_3 at 90hours

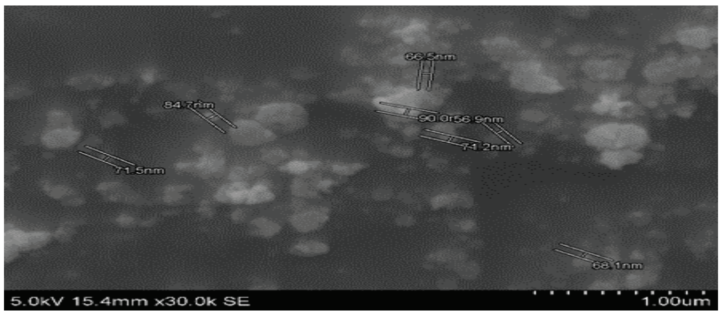

Figure 8. SEM image of Fe_2O_3 at 80hours

XL. TESTING AND EVALUATION

Testing and evaluation are the two premier component of this work. The pre-tested water samples was preserved in a low temperature atmosphere, this will reduce the chance of further chemical reduction in the water samples. The post-testing was carried out with mixing of nano particles. The two different sized nano adsorbents are introduced in to the testing samples for adsorption. The amount of adsorbent used was selected based on the total amount of contaminants present in the samples. It is necessasry to take a correction factor to avoid under and over adsorption of pollutants. Dilution and stirring of nano particles with wastewater was carried out by means of glass beakers and glass rods. After that the samples were undisturbed for adsorption to takes place. During that period the available voids or adsorption sites were attracting the contaminants present in the sample. After adsorption the water samples were extracted for post-testing. The same procedure is carried out with two metal oxide nano-powders.

XLI. RESULTS AND DISCUSSIONS

The post testing experiments were carried out with the nano powder mixed waste water samples with retention time 15 minutes and the corresponding results are as follows;

TABLE IV: POST TESTING RESULTS OF GREY WATER (100 HOURS)

Name of Test	Adsorbent Dosage in grams	MnO_2 Test Results in mg/L	Fe_2O_3 Test Results in mg/L
Dissolved Oxygen	0.01	1.578	1.478
	0.03	3.5768	2.9456
Dissolved Sulphate	0.01	834.03	1483.26
	0.03	412.01	659.22
Chloride	0.01	6.16	7.71
	0.03	1.54	3.08
Acidity	0.01	43.25	51.9
	0.03	17.3	25.95
Alkalinity	0.01	468	520
	0.03	312	416
Oil and Grease	0.01	68	92.4
	0.03	28	36
COD	0.01	50.8	76.32
	0.03	8.48	25.44
BOD	0.01	19.04	19.59
	0.03	7.035	7.59

TABLE V: POST TESTING RESULTS OF GREY WATER (90 HOURS)

Name of Test	Adsorbent Dosage in grams	MnO_2 Test Results in mg/L	Fe_2O_3 Test Results in mg/L
Dissolved Oxygen	0.01	1.578	1.478
	0.03	3.5768	2.9456
Dissolved Sulphate	0.01	1054.76	1186.6
	0.03	461.45	856.99
Chloride	0.01	7.60	7.71
	0.03	3.01	4.62
Acidity	0.01	47.575	51.9
	0.03	21.625	30.275
Alkalinity	0.01	520	520
	0.03	364	520
Oil and Grease	0.01	64.4	100
	0.03	40.8	56
COD	0.01	59.36	101.76
	0.03	25.44	33.92
BOD	0.01	19.04	19.59
	0.03	7.035	7.59

TABLE VI: POST TESTING RESULTS OF GREY WATER (80 HOURS)

Name of Test	Adsorbent Dosage in grams	MnO_2 Test Results in mg/L	Fe_2O_3 Test Results in mg/L
Dissolve	0.01	1.578	3.3664

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d Oxygen	0.03	3.3664	3.3664
Dissolve d Sulphate	0.01	1318.45	1499.74
	0.03	856.99	1104.20
Chloride	0.01	7.71	7.71
	0.03	7.60	7.71
Acidity	0.01	47.575	51.9
	0.03	30.275	47.575
Alkalinit y	0.01	520	520
	0.03	416	520
Oil and Grease	0.01	100	100
	0.03	64.4	68
COD	0.01	59.36	101.76
	0.03	42.4	67.84
BOD	0.01	19.04	19.59
	0.03	7.035	7.59

TABLE VII: POST HEAVY METAL TEST RESULTS OF FERRIC OXIDE

adsorbent dosage (mg/l)	mg concentration in mg/l	Adsorption (%)
0.025 MnO_2	18.8	41.5
0.05 MnO_2	21.13	34.25
0.10 MnO_2	25.09	21.93
0.15 MnO_2	29.05	9.61
0.025 Fe_2O_3	28.2	12.25
0.05 Fe_2O_3	10.98	65.83
0.10 Fe_2O_3	14.12	56.06
0.15 Fe_2O_3	15.84	50.71

While comparing table IV, V and table VI, it was clear that the rate of adsorption depends on the size of nano-particles, when the size of nano-particles reduces, consequently the rate of adsorption increases due to large adsorption sites. In case of dissolved oxygen test 0.03mg/l dosage improves the values than 0.01mg/l concentration in all cases. In addition to this, a maximum value of about 3.5768mg/l dissolved oxygen was found out at a concentration of 0.03mg/l MnO_2.

All tests except the test of dissolved oxygen shows reduction in initial concentration. More or less, again higher concentration of manganese di-oxide stands with better results than ferric oxide particles. In table VI of post testing with 80 hour milled nano particles, adsorption rate is lesser than the other and most values remains unchanged from a 90 hour milled particle test.

In table VII of magnesium metal test, adsorption rate is not uniform with the concentration of adsorbents. In case of manganese nano particles lesser dosage has the capacity to adsorb magnesium at a maximum rate, whereas ferric oxide shows changing adsorption characteristics throughout.

XLII. CONCLUSION

There is no debate on efficiency of utilizing nano-materials in wastewater treatment; however this technology has some serious upsides that need to be implemented in detail. Here the adsorption with metal oxide nano particles was quiet successful in decontamination. The results elucidate that the sewage water pollutants will trapped when nano pores are available. Firstly the milling time will considerably enhance the surface area by reducing particle size, here also 100 hour milled samples shows a nano range of about 40 – 70 nm. In most of the cases adsorption improves when adsorbent dosage increases, noticeably 0.03mg/l dosage of manganese di-oxide shows better results. The magnesium metal adsorption of ferric oxide and manganese di-oxide is somewhat interesting that is, at a minimum dosage of 0.025mg/l of manganese di-oxide the adsorption was about 41.25 % and after that adsorption decreases with dosage, whereas ferric oxide shows maximum adsorption of about 65.83% at 0.05mg/l dosage. After adsorption with nano powders the sewage water samples characteristics approaching towards drinking water specifications. Until now, most of the nano materials have not been cost-competitive when compared with conventional materials thus future applications will focus on efficient processes which will reduce the financing problem related to nano science.

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This research work was supported by faculty members of production engineering, chemical engineering and civil engineering departments of government engineering college Thrissur. And in addition to this we greatly indebted to NIT Calicut, C-MET Trissur and Poluchem Laboratories Kalamassery for their great support and advices for our research work

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An Assessment on the Effect of Titanium Dioxide & Iron Oxide Nano-Particles in Industrial Waste Water Decontamination

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Abstract: The aim of this paper is to identify a technique to detoxify the industrial waste water using metal oxide nanoparticles. Waste water from manufacturing or chemical processes in industries contributes to water pollution. Industrial waste water usually contains specific and readily identifiable chemical compounds. It destroys aquatic life and reduces its reproductive ability. Eventually it is hazardous to human life. Most major industries have treatment facilities for industrial effluents but this is not the case with small-scale industries, which cannot afford enormous investments in pollution control equipment. In this paper, an experimental study was conducted to study the effect of titanium dioxide and ferric oxide nanoparticles in detoxification of industrial waste water. Here the adsorption property of these nanoparticles was used for the detoxification of industrial waste water. The nanomaterials were synthesized using high energy ball milling machine and the characterisation was done through scanning electron microscopy. After the preparation, these Nano sized titanium dioxide and ferric oxide powder were introduced to the pretested waste water. Due to the adsorption property of these nanomaterials, it is observed that the contaminants like sulphate, cadmium, lead and chlorides are adsorbed to some extent.

Keywords: Detoxification, industrial waste water, nanomaterials, adsorption, heavy metals.

I. INTRODUCTION

Water pollution has been a major problem across the globe. The availability of safe drinking water has also been a prior concern across the globe. The water resources are depleted due to some reasons like, growth in population, extended droughts and pollutants from many industrial wastes. About 5 million people die each year from water related diseases and about 2.3 billion more suffer from diseases related to the drinking of contaminated water [7]. So the need for appropriate and cost effective wastewater treatment processes become essential for environmental conservation. The general wastewater treatment consists of two main processes: the first stage, where large objects such as sticks, stones and rags are removed, and the second stage is the biological treatment process, where the wastewater is purified by removing most of the contaminants [2]. This study is concentrated on the second stage process with the use of Titanium dioxide nanoparticles and ferric oxide nanoparticles as the adsorbent for the decontamination process. Nanotechnology has been used for the purification of water in the recent years, as it is highly effective in the decontamination of pollutants found in wastewater [2]. The effectiveness of waste water treatments using nanotechnology to other existing techniques is high due to the high surface to volume ratio of the nanoparticles and hence the ability to reach all targeted compounds in the water [4].

This study aims at the utilisation of metal oxide Nano materials for the decontamination of industrial waste water. These include titanium dioxide nanoparticles and ferric oxide nanoparticles. The metal oxide particles have the ability to trap heavy metals in water, such as zinc, cadmium, lead etc. The synthesis of these nanoparticles where carried out using high energy ball milling machine at a constant speed. Different samples were prepared by varying the time for synthesis at constant speed. Industrial waste water samples were collected and was used for conducting adsorption experiments. Finally, a comparison study between these prepared nanomaterial samples were conducted and identifies which Nano-sample have maximum adsorption rate.

II. MATERIALS AND CHARACTERISATION

A. Characterisation of Water Sample

The collection of wastewater sample for the study was an important aspect. The wastewater sample was collected from Milma Diary Thrissur. The collected wastewater sample was stored in a temperature of 15˚C with a dilution of concentrated sulphuric acid. Pretesting was conducted to identify the

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contaminants present in the sample before adsorption experiments. Pretesting include testing of Dissolved Oxygen, chloride, sulphate, acidity test, alkalinity test and oil & grease test. The amount of free oxygen present in a water sample is generally termed as dissolved oxygen. The alkalinity and acidity results interpret the pH value of the sample. The pre-testing results are as follows,

TABLE Ⅰ: PRE-TESTING RESULTS OF WATER SAMPLES

Pre- tests	Wastewater sample (Milma)
Dissolved Oxygen	1.012 mg/l
Chloride	27.179 mg/l
Dissolved Sulphate	1985.922 mg/l
Alkalinity	4567.5 mg/l
Acidity	118.8 mg/l
Oil & Grease	452 mg/l

Furthermore, the heavy metal presence in the waste water sample was found out using atomic absorption spectrometer. The observations obtained from atomic absorption spectrometer are as shown in table Ⅱ,

TABLE Ⅱ: HEAVY METALS IN WATER SAMPLES

Heavy Metal	Wastewater sample (Milma)
Zinc	nil
Lead	nil
Cadmium	nil
Magnesium	nil

Table Ⅱ shows that there are no heavy metals in the collected waste water sample. In order to determine the efficiency of titanium dioxide and ferric oxide nanoparticle towards heavy metal adsorption, heavy metals are added manually to the waste water sample. 1g/L of cadmium sulphate and 1g/L of lead nitrate is mixed with the waste water sample. This manually prepared waste water sample was inspected through atomic adsorption spectrometer, and the pre-test results are as shown in table Ⅲ,

TABLE Ⅲ: HEAVY METAL ADDITION IN WASTE WATER SAMPLES

Heavy Metal	Concentration of heavy metal in wastewater sample
Cadmium	250 mg/L
Lead	20 mg/L

B. Characterization of Nano Materials

Nanoparticles formed by metal or metal oxides are inorganic nanomaterials, which are used broadly to remove heavy metal ions in wastewater treatment [5]. Nano sized metal oxide provides high surface area and high adsorption rates. Also, metal oxides have low impact on environment and low solubility and no secondary pollution [3]. So for this study, titanium dioxide and ferric oxide were selected and the size was determined using Scanning Electron Microscope (Hitachi SU6600). Titanium dioxide particle are in the range 134nm and ferric oxide in the range of 117nm which is shown in the figure 1 and figure 2.

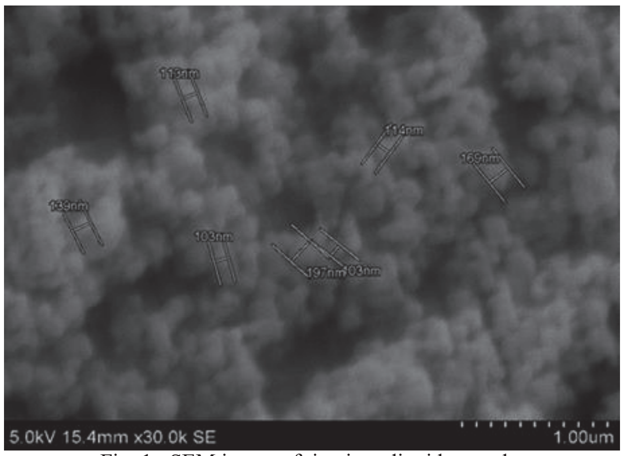

Fig. 1. SEM image of titanium dioxide powder

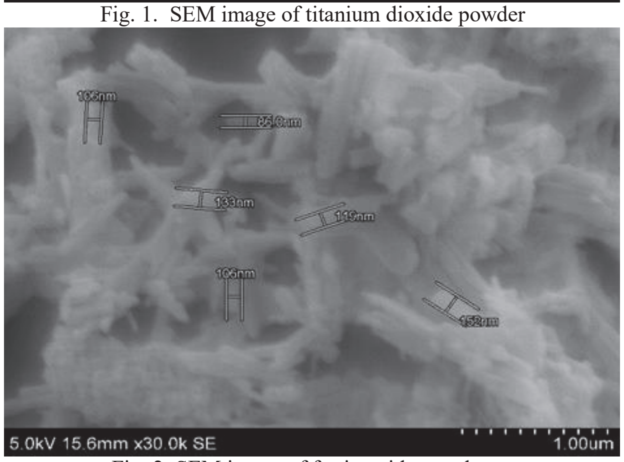

Fig. 2. SEM image of ferric oxide powder

The synthesis of Nano materials from micro sized particles were carried out using high energy ball milling machine. Different range of nano particles were obtained by varying time (100hrs, 90hrs and 80hrs) at constant speed during the synthesis process and the average size of the particles are shown in the table Ⅳ.

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TABLE IV: PARTICLE SIZE OF ADSORBENT

	Speed (rpm)	Time (hours.)	Size (nm)
Titanium dioxide	250	80	84.225
	250	90	71.9
	250	100	58.3
Ferric oxide	250	80	72.7
	250	90	63.73
	250	100	42.11

The size of the nanoparticles was measured using a Scanning Electron Microscope (Hitachi SU6600). The SEM images of the titanium nano particles and ferric nanoparticles are shown in the below figures.

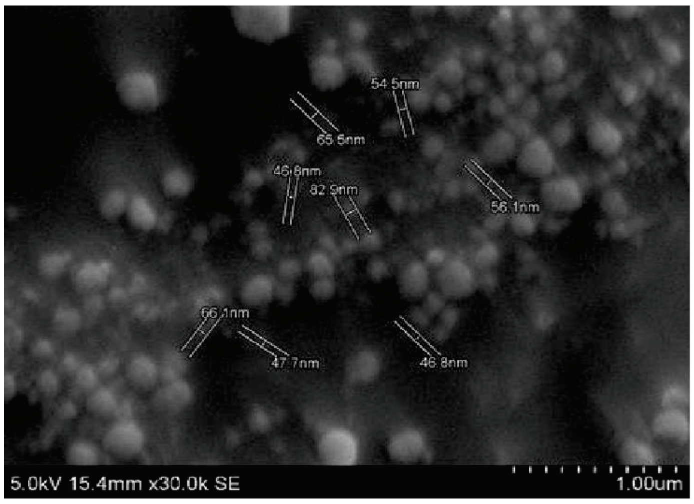

Fig. 3. SEM image of TiO_2 powder after 100hours of milling process

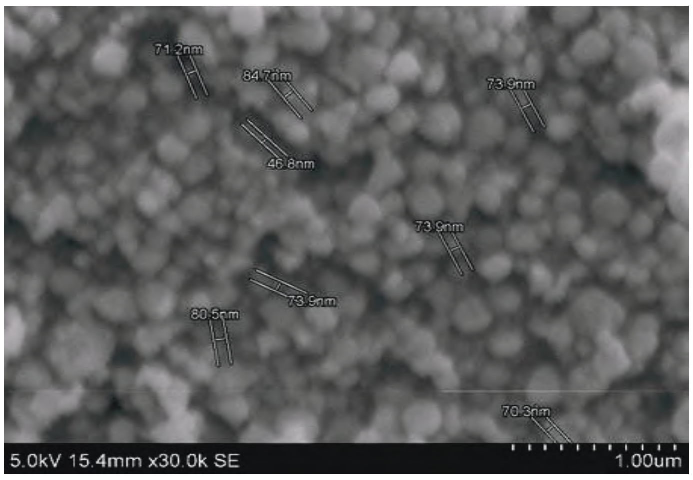

Fig. 4. SEM image of TiO_2 powder after 90hours of milling process

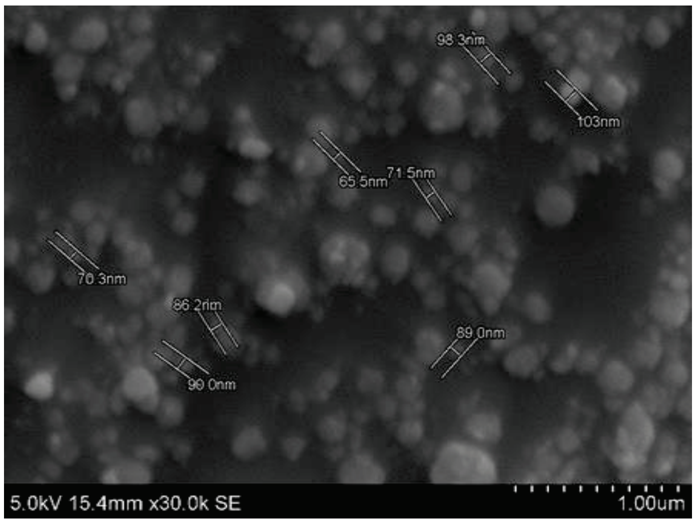

Fig. 5. SEM image of TiO_2 powder after 90hours of milling process

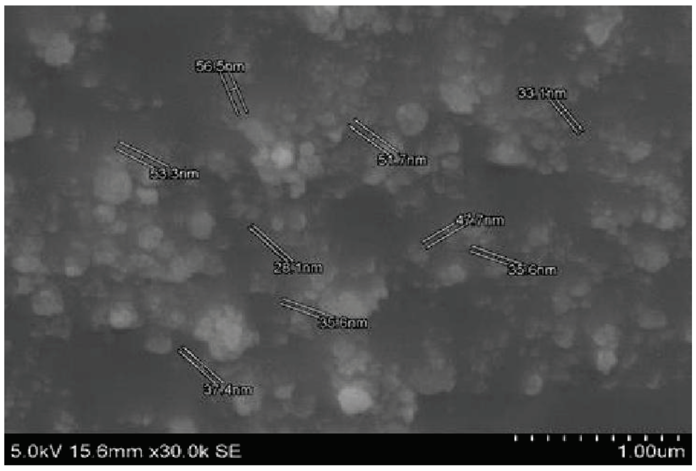

Fig. 6. SEM image of Fe_2O_3 powder after 100hours of milling process

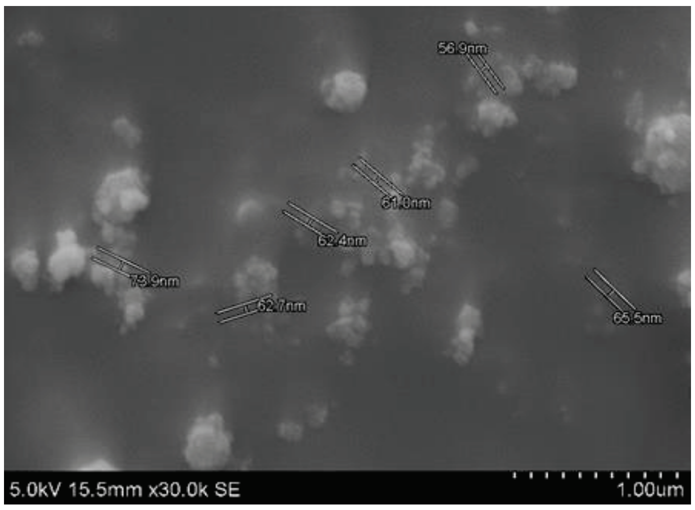

Fig. 7. SEM image of Fe_2O_3 powder after 90hours of milling process

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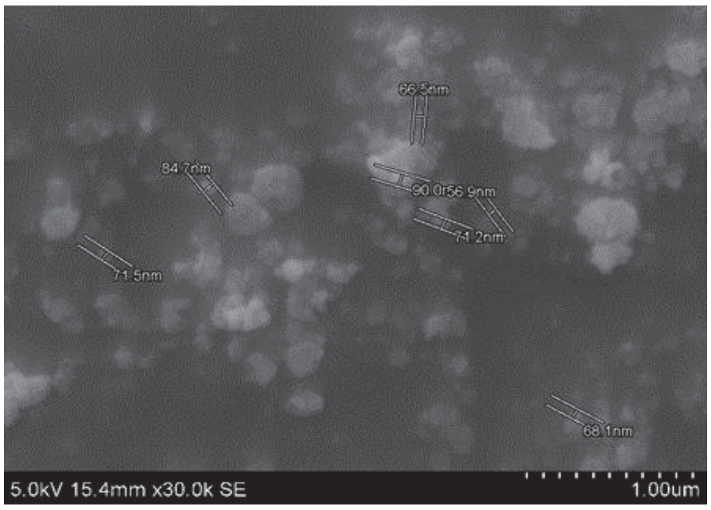

Fig. 8. SEM image of Fe_2O_3 powder after 90hours of milling process

III. TESTING AND EVALUATION

After pretesting, the water samples are kept at lower temperature to reduce further chemical reduction. The post testing was carried out by mixing the nano particles synthesized with waste water sample. The three different sized nano powders of each metal oxides were introduced into the testing wastewater samples for adsorption. A total of 6 samples were prepared for post testing. Trial and error method was used for selecting adsorbent concentration. The nano adsorbent was mixed to the wastewater sample using a glass beaker and glass rod. Then the sample was shaken well for 15 minutes for the adsorption to take place. During adsorption the voids present in the nano powder attracts the contaminants. After adsorption, the water sample was taken for post testing. Post testing includes heavy metal testing, Dissolved oxygen test, Alkalinity test, Acidity test, Chloride test, Sulphate test and oil and grease test. Heavy metal testing is done using Atomic Adsorption Spectrometer. Winkler's method with starch as indicator was the basic principle of Dissolved oxygen test. The method of analysis of oil and grease in a water sample involves extraction of emulsified oil and grease from water by an extracting solvent. Chloride test was conducted by means of titration of standard silver nitrate solution with chromate indicator. The common solvents used are hexane and trichloro-trifluroethane. The level of Sulphate in waste water sample was measured by turbidity metric method. Acidity of waste water sample was calculated through titration with a strong base to a designated pH and similarly alkalinity was measured with a strong acid namely hydro chloric acid. Same procedure is carried out using the two metal oxide nano powders, namely titanium dioxide and ferric oxide.

IV. RESULTS AND DISCUSSIONS

The post testing experiments were carried out with the nano powder mixed waste water samples with retention time 15 minutes and the corresponding results are as follows,

TABLE V: POST TESTING RESULTS OF WASTE WATER SAMPLE (100 HOURS)

Name of Test	Adsorbent Dosage in grams	TiO_2 Test Results in mg/L	Fe_2O_3 Test Results in mg/L
Dissolved Oxygen	0.01	0.748	0.823
	0.03	0.973	1.048
Dissolved Sulphate	0.01	1219.57	939.39
	0.03	741.63	807.55
Chloride	0.01	22.731	19.48
	0.03	17.86	16.56
Acidity	0.01	40.05	48.95
	0.03	31.15	40.05
Alkalinity	0.01	3940.5	4100.25
	0.03	3780.75	4047
Oil and Grease	0.01	244	252
	0.03	172	196

TABLE VI: POST TESTING RESULTS OF WASTE WATER SAMPLE (90 HOURS)

Name of Test	Adsorbent Dosage in grams	TiO_2 Test Results in mg/L	Fe_2O_3 Test Results in mg/L
Dissolved Oxygen	0.01	0.748	0.823
	0.03	0.823	1.048
Dissolved Sulphate	0.01	1285.49	988.89
	0.03	774.59	856.94
Chloride	0.01	25.978	24.35
	0.03	21.107	18.18
Acidity	0.01	53.4	80.1
	0.03	44.5	66.75
Alkalinity	0.01	4153.5	4473
	0.03	3940.5	4313.25
Oil and Grease	0.01	384	392
	0.03	256	268

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TABLE Ⅶ: POST TESTING RESULTS OF WASTE WATER SAMPLE (80 HOURS)

Name of Test	Adsorbent Dosage in grams	TiO_2 Test Results in mg/L	Fe_2O_3 Test Results in mg/L
Dissolved Oxygen	0.01	0.823	0.898
	0.03	0.898	0.973
Dissolved Sulphate	0.01	1351.41	1087.72
	0.03	889.95	939.39
Chloride	0.01	27.601	25.65
	0.03	22.731	21.43
Acidity	0.01	71.2	93.45
	0.03	57.85	80.1
Alkalinity	0.01	4313.25	4526.25
	0.03	4206.75	4419.75
Oil and Grease	0.01	420	440
	0.03	328	400

TABLE Ⅷ: POST HEAVY METAL TEST RESULTS OF FERRIC OXIDE

Heavy Metal	Adsorbent Dosage in grams	TiO_2 Test Results in mg/L	Fe_2O_3 Test Results in mg/L
Cadmium	0.025	150	140
	0.05	240	210
	0.1	370	235
	0.15	500	260
Lead	0.025	16.7	16
	0.05	14.3	11.5
	0.1	12.5	4.2
	0.15	14.6	15

Comparing table Ⅰ and table Ⅴ, it was clearly seen that the level of dissolved oxygen, dissolved sulphate, chloride, acidity, alkalinity and oil & grease content in the waste water sample reduced to some extent. In case of dissolved oxygen, ferric oxide improves the amount of free oxygen in the water sample at 0.01g of 100 hour milled adsorbent addition. From table Ⅴ, it was clearly seen that at 0.03 g of nano ferric oxide addition the acidity of the waste water sample decreased to 30.05 mg/L from 118.8 mg/L of the pre waste water sample while titanium dioxide nanoparticle addition reduced the value to 31.15 mg/L. Also it can be observed that the acidity of the waste water sample can be reduced by increasing the adsorbent dosage. From table Ⅴ, Ⅵ and Ⅶ, it is observed that the adsorption capacity reduced when the milling time decreased. While observing table Ⅷ, the maximum adsorption of cadmium and lead take place at 0.05g and 0.1g of adsorbent addition respectively. Also it can be observed that, after a certain level of adsorbent addition, the adsorption process seized. The above results show that the nano pores can adsorb general pollutants like chlorides, sulphates and heavy metals from water.

V. CONCLUSION

Nanotechnology for water and wastewater treatment is gaining momentum globally. The unique properties of nanomaterials and their convergence with current treatment technologies present great opportunities in the area of water and wastewater treatment. In this study the adsorption with metal oxide nanoparticles was successful in decontamination. The preparation of nanoparticle depends on the speed of rotation and milling time. The particle size of 42.11 nm and 72.7 nm were obtained from 100 hours and 80 hour milling of ferric oxide. Similarly, titanium dioxide having 58.3 nm and 84.225 nm size were obtained under same condition. Correspondingly the particle size increases as the milling time reduces. It is clear that the heavy metals and other contaminants get trapped in the pores of nano materials. Also the rate of adsorption depends on the adsorbent used. Here ferric oxide nanoparticles have greater adsorption efficiency than titanium dioxide nanoparticles towards cadmium and lead, that is 44% and 79% respectively. In case of dissolved oxygen, ferric oxide improves the amount of free oxygen in the water sample at 0.01g of 100 hour milled adsorbent addition. Similarly, ferric oxide shows better result in chloride and acidity tests. Whereas titanium dioxide shows better performance towards dissolved sulphate, alkalinity and oil & grease test compared to ferric oxide. Collectively we can say that ferric oxide nano materials shows better adsorption towards heavy metals whereas titanium dioxide has greater results in general water quality tests. Further study can be conducted using different nanomaterials to study their adsorption rates and its feasibility in industrial installation. Until now most of the nano materials are costly compared to conventional methods thus the future focus should be on reducing the financial problems associated with nanotechnology.

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Design and Fabrication of Self Balancing Robot with Robotic Arm

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Abstract: The dominated approach of robotics conquered world of engineering. Moreover, it even astonishing humanity by replicating them in every mode of life. This project paper focus on the design and fabrication of self-balanced robot with robotic arm. This two-wheel self-balancing robot is actually based on the concept of Inverted pendulum theory. This fabricated system architecture incorporates a pair of DC motor and an Arduino microcontroller board; MPU 6050 which is employed for attitude determination and also couple of MG996R, MG90S,SG90S servo motor along with 16-Channel 12-bit PWM/Servo Driver I2C interface PCA9685 for the arm as well. In addition, a complementary filter is implemented to compensate for gyro drifts. Bluetooth module HC-06 and prepared application made by app inventor connect the system with android devices which makes it more convenient. Self-balancing robots have wide application prospects due to their advantages of compact design, space control, and self-balanced flexible movement. Along with robotic arm it became even more phenomenal.

Keywords: Robotics, Arduino microcontroller board, MPU 6050

I. INTRODUCTION

In the past decade, mobile robots have stepped out of the military and industrial settings, and entered civilian and personal spaces such as hospitals, schools and ordinary homes. While many of these robots for civil applications are mechanically stable, such as Aibo the Sony robotic dog, or four-wheel vacuum cleaners. The self-balancing robot, concept of two-wheel inverted pendulum has gained momentum in research over the last few years. Inherently self-balancing robot is unstable, and it would roll around the wheels' rotation axis without external control and eventually fall. The robot returns to right position if motor driving occurs in right direction. The robot is naturally unstable although, it has many favours over the statically stable multi wheeled robots.

A special electromechanical system in which the robot has to be based on balances itself onto a pair of wheels while standing tall. If the base on which the robot stand is not stable or the platform is not balanced, the robot tends to be falling off from the vertical axis. One of the key enablers for this project in the academia is arguably the increasing affordability of MPU 6050 sensors and microprocessor boards. This is needed to provide the PID controller about the angular position of the base of the self-balancing robot [1]. Arduino is an open prototyping platform based on AT mega processors and a C language-like software development environment and can be connected with a variety of sensors. It is fast becoming a popular platform for both education and product development, with applications ranging from robotics to process control and networked control.

A self -balancing algorithm is programmed into the controller and the controller drives the encoder motors either clockwise or anticlockwise to balance the basement by a pulse width modulation (PWM) control signal. The robot has to be work upon any type of surface based on two motors constructed with wheel one for each .Along with this couple of MG996R High Torque Metal Gear Dual Ball Bearing Servo, MG90S, with one bearing servo, SG 90S servo are used in order to move the arms of the robot which is controlled by 16-Channel 12-bit PWM/Servo Driver I2C interface PCA9685 make the robot more flexible and convenient compared to similar robots.

II. LITERATURE REVIEW

Ling Peng, Chunhui Zhou in 2018 designed self-balancing robot, by using the STM32 microprocessor as the main controller, and the attitude sensor MPU6050 is used to collect the obliquity and angular velocity. They discovered that the gyroscope and the accelerometer make noise interference and drift error, the Kalman filter algorithm, therefore, is used to fuse the obliquity and angular velocity, in order to obtain the optimal obliquity.[1]

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Aminu Yahaya ZimitHwa Jen YapMukhtar Fatihu HamzaEmail authorIndrazno SiradjuddinBilly HendrikTutut Herawan in 2018, investigated the Proportional Integral Derivative (PID) controller on Two-wheeled self-balance robot. The PID is used for the purpose of balancing the robot to stand still at upright position and to receive command via Bluetooth to follow the desired trajectory smoothly. The dynamic model of TWSB robot was developed using Lagrangian method. The PID gains were tuned until the optimum values are achieved.[2]

In 2017 A.K.M Ashfaque Shakil Shaon, Subrata Bhowmik, Bikash Kumar Bhawmick, Piyas Das and Nipu Kumar Das, implemented a self- balancing robot which can handle tilt angle maximum 12 degree. The robot moves forward and backward continuously within a range of about -3 cm and +3cm around the balancing spot in order to balance itself on the flat surfaces. [3] The PID formulation is also more convenient in this paper. Changing the set point for the PID controller individually for two motors can control the translational motion of the robot. The motor power increases by the proportional term as the system leans further over and decreases the motor power as the system approaches the upright position. A gain factor, Kp, determines how much power to apply to the motor for any given lean, as follows:

Proportional Term = Kp * Error

The differential term of the PID algorithm acts as a damper reducing oscillation. Another gain factor, Kd, determines how much power is applied to the motor according to the following equation:

Differential Term = Kd * (Error -Last Error)

Finally, neither the proportional nor differential terms of the algorithm will remove all of the lean because both terms go to zero as the orientation of the system settles near vertical. The integral term sums the accumulated error tries to drive the lean to zero as follows:

Output Integral Term = Ki * (Sum of Error)

The output of the PID controller is

PWM = Proportional Term + Integral Term
+ Differential Term

The output of the Motor PWM as above will be used as the set-point for the motor.

Error of motor Speed
= Motor Setpoint -Current Speed Reading of Motor

Output Proportional Term of Motor
= Kp * Error of Motor Speed

Output Differential Term of Motor
= Kd * (Error of Motor Speed – Last Error of Motor Speed)

Output Integral term of motor
= Ki * Sum of Error for Motor Speed
And finally,

Motor Speed = Proportional Term of Motor + Differential Term of Motor + Integral Term of Motor

For tuning the PID control of motor speed, the value of Kp, Ki and Kd is get by trial and error method.

III.DESIGN PROCESS

The self- balancing robot gets balanced on a pair of wheels having the required grip providing sufficient friction. For maintaining vertical axis two things must be done, one is measuring the inclination angle and other is controlling of motors to move forward or backwards to maintain 0˚angle with vertical axis. For measuring the angle, two sensors, accelerometer and gyroscope are used. Accelerometer can sense either static or dynamic forces of acceleration and Gyroscope measures the angular velocity.

The outputs of the sensors are fused using a filter. Sensors measure the process output say α which gets subtracted from the reference set-point value to produce an error. Error is then fed into the PID where the error gets managed in three ways. After the PID algorithm processes the error, the controller produces a control signal μ. PID control signal then gets fed into the process under control. Process under PID control is two wheeled robot. PID control signal will try to drive the process to the desired set-point value that is 0˚ in vertical position by driving the motors in such a way that the robot is balanced. Along with this PWM driver controls the servos which is connected to the micro controller so that the arm movement will be achieved. The simplified block diagram is shown in Figure 1.

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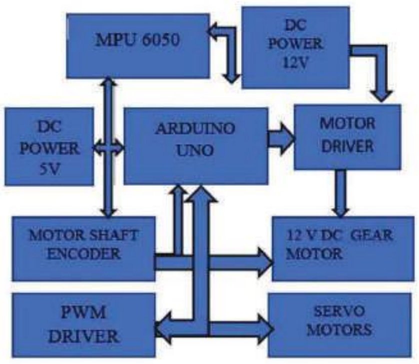

Fig.1: Block diagram of self - balancing robot

IV. CONTROL ALGORITHM

The control system of the two wheels balancing robot in this project is illustrated by the block diagram in fig.2

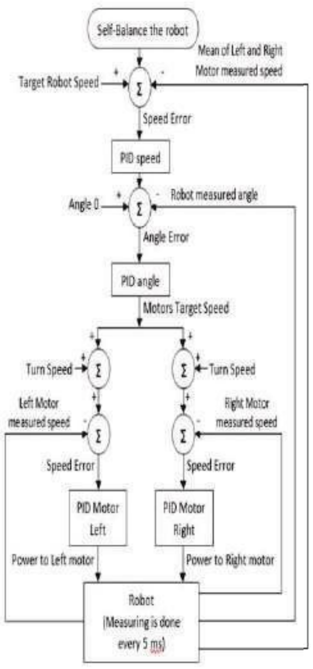

Fig.2: flowchart based on PID algorithm

V. CAD DRAWING

The cad drawing has been made by using Solid Edge ST8. Which is shown below,

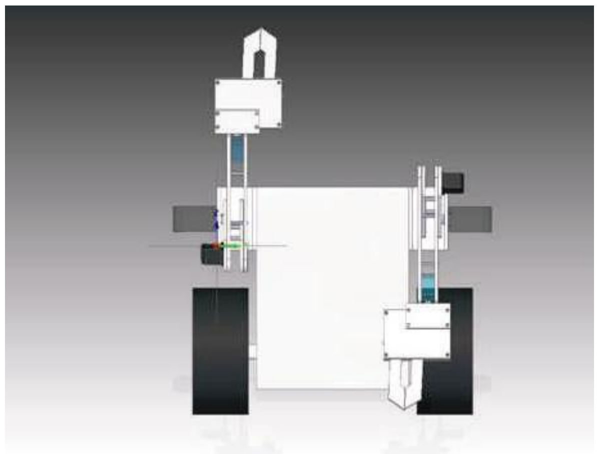

Fig 3. Front view of self-balancing robot with robotic arm

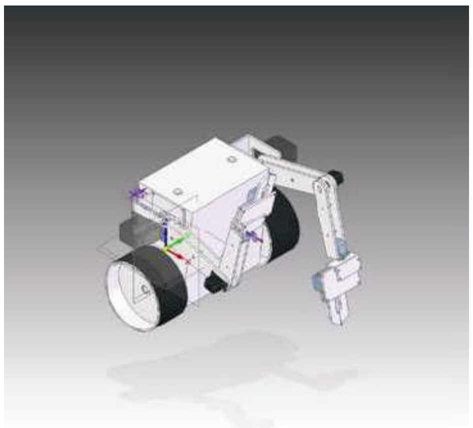

Fig 4. Side top view of self-balancing robot with robotic arm

3d cad modelling with solid edge contributed in initialising the fabrication of self-balancing robot with robotic arm. Moreover, it also helped in understanding what could be the practical difficulties in fabrication of real time robot.

VI. MOTORS AND WHEELS

To determine the appropriate motors for the robot, [4] the first consideration was the minimum torque required. To estimate the torque, the model to the right was considered. The relationship between torque, τ, and force, F, is given by

$$\tau = \| \; \| r \| \; \| F \| \; \| \sin\theta$$

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Where $\boldsymbol{r}$ is the position vector and θ is the angle between force and position vectors. Assuming the distance between the pivot point and the centre of mass (L) is 16cm, the maximum tilt angle (θmax) is 40° and the mass of the robot (m) is 2kg, the minimum torque required is

$$\tau = L*mg*sin\theta = 0.16*2*9.81*\sin(40)$$
$$= 0.530\ Nm$$

There are two motors, the torque required per motor is 0.265Nm. In this scenario, the inertia is not taken into account and the robot is assumed to start moving at θmax.

Looking solely at the parameters mentioned, the chosen motor was 30:1 Metal Gearmotor with 48 CPR Encoder. The motor has a stall torque of 0.4412Nm and the encoder outputs 2248.86 counts per revolution. However, this was not the appropriate manner to choose the motors. The wheels and the RPM also have to take into consideration. The torque required to move the wheel is also given by Equation X, where $\boldsymbol{r}$ would be the radius of the wheel and θ would be 90 degrees, thus for a given force the torque is proportional to the wheel radius. The trade-off of choosing smaller wheels such that lower torque is required is lower circumference of the wheel, requiring the motors to spin faster to get under the centre of mass of the robot.

The dispute between torque and RPM is also present with the distance between the centre of mass and the pivot. As shown by Equation X, as L increases, the torque required also increases, on the other hand the natural frequency, ωp of the pendulum, is given by

$$\omega p = \sqrt{g/L}$$

Increasing L has the effect of reducing the natural frequency of the system, decreasing how fast the actuators have to perform.

To attempt to improve the system's performance the battery was moved to higher position to increase the centre of mass. In addition, the wheels were changed from 80mm to 100 mm in diameter.

VII. ANDROID APPLICATION FOR SELF-BALANCING AND ARM MOVEMENT

MIT App Inventor is an intuitive, visual programming environment that allows to build fully functional apps for smartphones and tablets. their blocks-based tool facilitates the creation of complex, high-impact apps in significantly less time than traditional programming environments. With the help of MIT app inventor an application for convenient movement of robot is prepared.

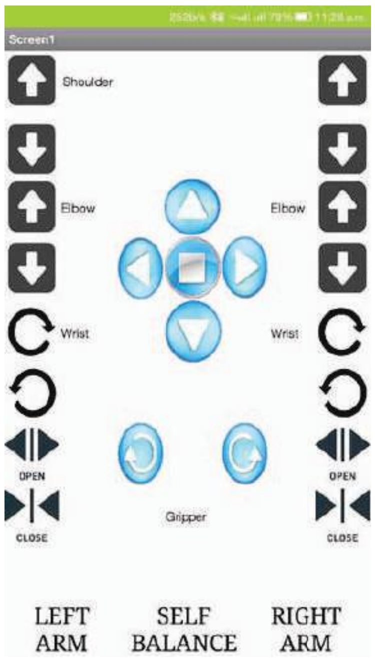

Fig .5. Application screen

VIII. ROBOT AFTER FABRICATION

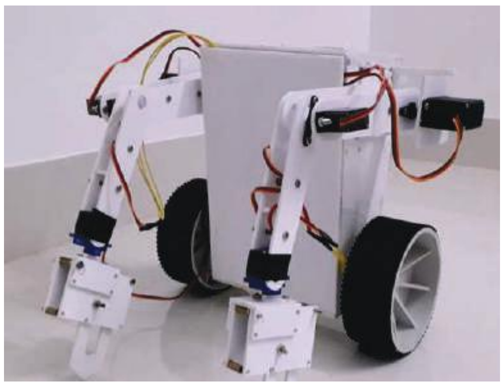

Fig.6 Fabricated Robot

IX. TESTING AND RESULTS

The self-balancing of the fabricated robot is achieved remarkably. initially after switching on power switch two seconds delay is found for calculating position and tilt. After this without much vibration it self-balance much accurately.

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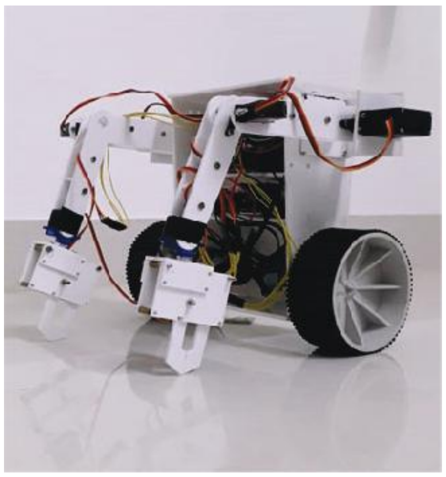

Fig 12. Testing of robot

Initially arm will be placed in pre-programmed manner which was also functioned successfully.

X. CONCLUSION

The self-balance robot worked efficiently. The robot moved in every direction along with clockwise and counterclockwise rotation. An initial couple of seconds delay is there but it is acceptable. Robotic arm also functions properly while controlling with android application.

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b. NSS College of engineering Digital Library
c. Project Guide- Sreejith N.K.
d. Fellow Classmates

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Investigations For Enhancing Conversion Efficiency Of Solar Photovoltaic Cell

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Abstract: Solar cells can be made at a low cost with the help of multi-crystalline Silicon due to its inexpensive growth technique. Photovoltaic installations can operate for a longer period of time with little maintenance. The efficiency of the photovoltaic cell plays an important role in the conversion of energy and this can be achieved by various techniques like proper orientation of PV panels, photonic band gap material, using anti-reflective coatings, reducing the temperature of PV cells and by texturing the surface of Silicon. Among the various texturing methods like mechanical texturing, reactive ion etching, acid texturing, laser surface texturing is used to texture the surface of silicon. Laser surface texturing (LST) can create different patterns like pyramid, inverted pyramids or groove on the surface of the silicon so that the reflection of the solar radiation can be decreased up-to a certain level. This work focuses on enhancing the conversion efficiency of the photo-voltaic solar cell using laser texturing as well as to simulate the solar cell properties using different softwares like SIMULINK, PC1D and PV Factory.

Keywords:Multi-crystalline silicon, Laser Surface Texturing, photovoltaic cells

I. Introduction

A silicon solar cell or photovoltaic cell is an electrical device which converts light energy into electricity by the photovoltaic effect, which is both physical and chemical effect. It is a device in which the electrical properties such as current, voltage or resistance vary with the exposure of light. Regardless whether the source is sunlight or artificial, solar cell is considered as photovoltaic. They are used as a photo detector, or measuring light intensity, or detecting light or electromagnetic radiation near visible range. For the operation of a photovoltaic cell, there are mainly three basic characteristics, which include absorption of light, generating electron-hole pairs, separation of charge carriers of opposite types and separate extraction of those carriers to an external circuit. Individual solar cell devices can be combined to form modules, also known as solar panels. An individual solar cell can produce open circuit voltage in the range of 0.5 to 0.6Volts. Solar cell efficiency plays an important role in the making of solar panel. The efficiency of solar cell is a combination of reflectance efficiency, thermodynamic efficiency, charge carrier separation efficiency, and conductive efficiency. The fraction of incident power converted into electricity is the main parameter of the power conversion efficiency of a solar cell. A solar cell has voltage dependent efficiency curve, temperature curves, and allowable shadow angles.

II. Objective

The objective of this research is to

1. The objective of this project is to develop mathematical model of a solar photovoltaic cell using SIMULINK software

2. To study texture characteristics in PC1D 5 software.

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3. To study texture characteristics with different thickness in PV Factory

4. To study how the surface features affect the voltage current output experimentally and to how it contributes to the enhancement of cell efficiency

III. LITERATURE SURVEY

An attempt to improve the conversion efficiency of crystalline silicon solar cells by texturing it on both front and backside was carried out so that the absorption of infrared sunlight is increased. The conversion efficiencies of thin film solar cells for commercial applications are low and backside texturing [1] and reflective structures can improve the conversion efficiency of the thin film microcrystalline and amorphous silicon solar cell from 20% to 40% and thick multicrystalline silicon from 10% to 20%.

Laser texturization was found[2] to be a promising alternative compared to the conventional methods of texturization of multi-crystalline silicon. Due to the high power density of the laser beam, it is easy to form multi-crystalline surface. The more precise the surface processing required, the laser beam of lower order transverse mode should be applied.

he SEM image indicated that the reactive ion etching process produced dense nanoscale ridge-like structures based on acid textured surfaces and these exhibit[3] good anti-reflective effect. The average reflectance of the of the acidic+RIE textured mc-silicon wafers without and with SiNx layers are reduced into 8.5% and 2.3%. After incorporating the RIE process and other machining process, maximum full area efficiency of 18.49% was achieved.

SiO_2 nanosphere based Anti-reflective coating[4] were grown by spin coating of an aged silica sol and the microstructure was controlled by changing the spin-coating speed from 400 to 4000rpm. The PV performance of the solar cell with silicon nanosphere was improved from 14.81% to 15.82%. less angular dependence for incident light was obtained with the silicon nanosphere coating.

Implemented direct laser texturing into passive emitter and rear solar cells(PERC) on monocrystalline float zone silicon wafers and achieved an independently confirmed energy[5] conversion efficiency of 19.9%.different etching depths of 3.2,3.8 and 5.8micrometer and the smallest applied etching depth results in the best cell performance.

Attempted to enhance the light absorption in ultra-thin film silicon solar cell by introducing a double-sided grating design, where the front and backside of the cell [6] are separately optimized for anti-reflection and light trapping respectively. The optimized structure yielded a photo-current of 34.6mA/cm² at an equivalent depth of 2 micrometer.

IV. SIMULATION

A. SIMULATION

Simulink is a graphical programming environment for modeling, simulating and analyzing multi-domain dynamical systems. Its primary interface is a graphical block diagramming tool and a customizable set of block libraries. It offers tight integration with the rest of the MATLAB environment and can either drive MATLAB or be scripted from it. Simulink is widely used in automatic control and digital signal processing for multi-domain simulation and model-based design. The characteristic I(V) is a non-linear equation with multiple parameters classified as follows: those provided by constructors, those known as constants and the ones which must be computed.

$$I = I_{ph} - I_d \quad .....(1)$$

I_{ph} is the photocurrent, I_d is the diode current which is proportional to the saturation current and is given by the equation:

$$I_d = I_o[\exp\left(\frac{V}{A.N_s V_T}\right) - 1] \quad .....(2)$$

V is the voltage imposed on the diode.

$$V_T = \frac{k.T_c}{q} \quad .....(3)$$

I_o is the reverse saturation or leakage current of the diode.
T_c is the actual cell temperature and k is Boltzmann constant.
V_T is called the thermal voltage since it is dependent on the temperature.
The final output current is given by the equation:

$$I = I_{ph} - I_0\left(\exp(\frac{V + I.R_s}{a}) - 1\right) - \frac{V + R_s.I}{R_p} \quad .....(4)$$

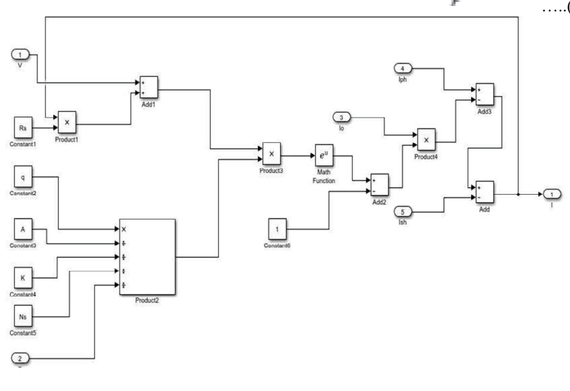

Fig4.1. PV current

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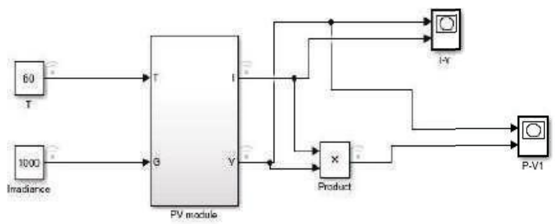

Fig.4.2. Setup of the whole PV model

Simulation of the PV model was carried out with varying temperatures and irradiance and a set of graphs were obtained.

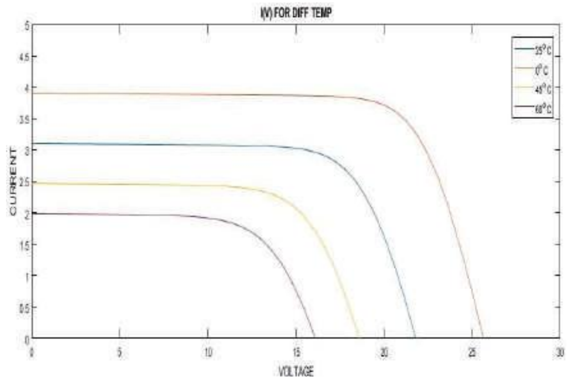

Fig.4.3. I-V characteristics for different temperature

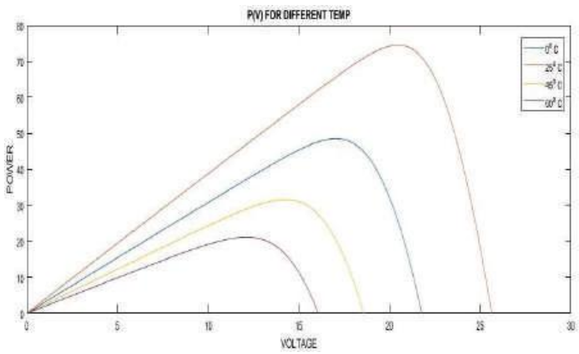

Fig4.4. P-V characteristics for different temperature

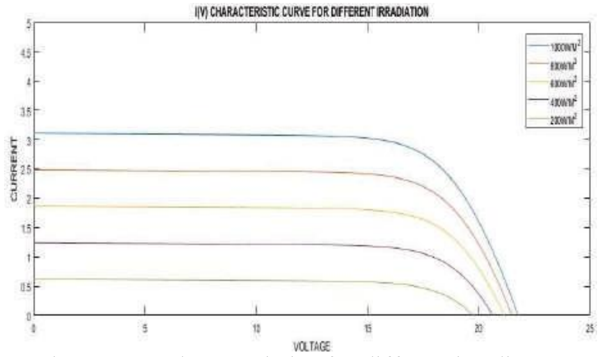

Fig.4.5. I-V characteristics for different irradiance

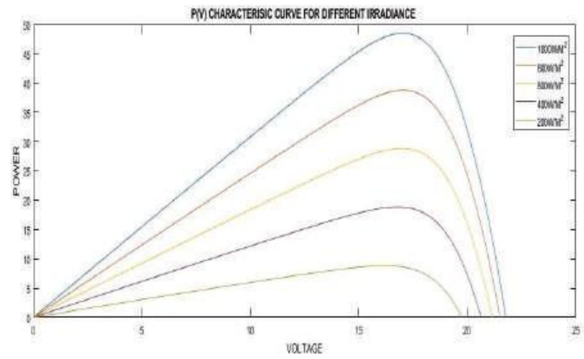

Fig.4.6. P-V characteristics for different irradiance

This work is the detailed modeling of a solar PV cell module. With this data we can determine the I(V) and P(V) characteristics of any PV cell module under various parameters and new conditions like Temperature and Irradiance.

B. PC1D 5

PC1D is a software for modeling a solar cell. It is a computer program for personal computers that solves the fully coupled non-linear equations for the quasi-one-dimensional transport of electrons and holes in crystalline semiconductor devices, with emphasis on photovoltaic devices.
Simulation was carried out with texture and without texture.

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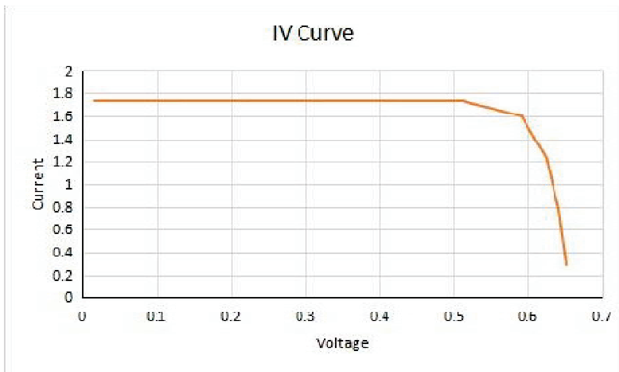

Fig.4.7. IV curve for plane cell in PC1D 5

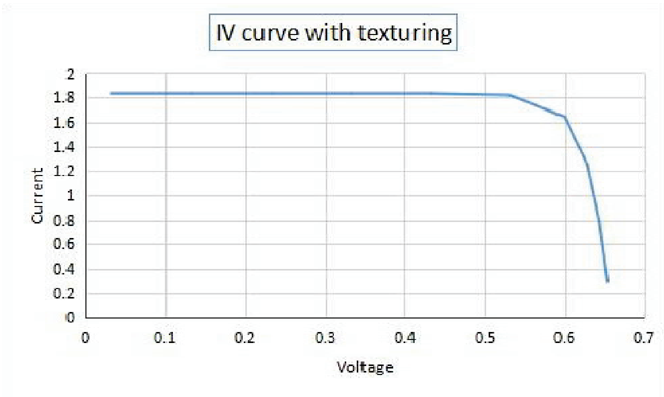

Fig.4.8. IV curve with texturing on the cell

C. PV FACTORY

Silicon wafers remain the dominant cost of making a solar cell. Many solar cell manufacturers purchase silicon wafers as the starting point for their production. Some manufacturers, however, also produce their own silicon wafers which can be either a single crystal of silicon (i.e., mono-crystalline) or comprise multiple crystals (i.e., multi-crystalline) silicon.Wire saws are used to slice ingots of mono-crystalline silicon or bricks of multi-crystalline silicon into thin slices called wafers. The slicing process wastes some silicon, the waste silicon being referred to as kerf loss. It also introduces damage to the silicon wafer surface, known as saw damage, which has to be subsequently removed in the cell fabrication process.

Values with different thickness was measured and graph plotted.

Table.4.1. IV curve data for the thickness 160um

Cell	V_{oc} (V)	Jsc (mA/cm2)	FF (mV)	Efficiency (%)
mean	0.586	28.54	0.744	12.45
1	0.57	28.07	0.745	11.93
2	0.585	28.75	0.742	12.48
3	0.57	28.14	0.745	11.95
4	0.6	28.93	0.737	12.79
5	0.614	28.77	0.762	13.48
6	0.592	28.84	0.74	12.62
7	0.582	28.48	0.745	12.35
8	0.594	28.8	0.739	12.64
9	0.572	28.21	0.745	12.02
10	0.576	28.45	0.744	12.19

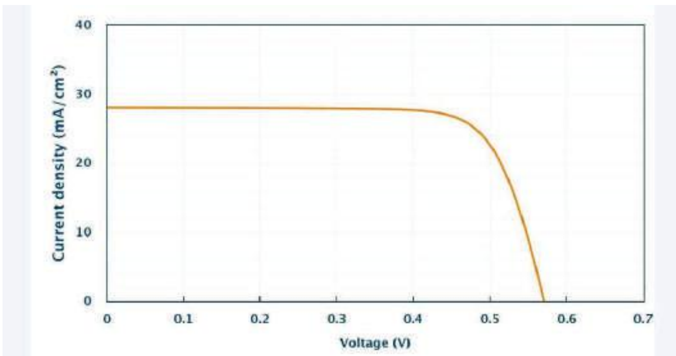

Fig.4.9. JV Graph for thickness 160um

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Table.4.2. IV curve data for thickness 180um

Cell	Voc (V)	Jsc (mA/cm2)	FF (mV)	Efficiency (%)
mean	0.59	28.73	0.746	12.64
1	0.588	28.67	0.742	12.5
2	0.584	28.84	0.743	12.51
3	0.577	28.62	0.743	12.27
4	0.572	28.34	0.745	12.06
5	0.583	28.86	0.743	12.5
6	0.613	28.68	0.763	13.4
7	0.613	28.97	0.761	13.53
8	0.591	28.97	0.738	12.63
9	0.591	28.85	0.74	12.61
10	0.585	28.54	0.744	12.42

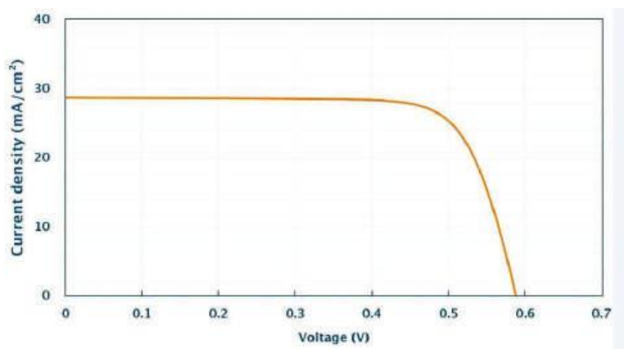

Fig.4.10. JV graph for thickness 180um

D. RESULTS AND DISCUSSIONS

In the SIMULINK software the characteristic curves of the PV panel were obtained with different temperatures and irradiance. In PC1D software the curves were plotted for an N-type semi-conductor device with texture and without texture and can see that there is an increase of voltage and current in the textured cells which in turn increases the cell potential. PV Factory deals with the wet chemical etching and texturing. Different thickness was given to the solar cell and curves plotted for the same. Here 180um gives the optimal thickness where a mean efficiency of 12.64 is obtained.

EXPERIMENTAL DETAILS

A. DEVELOPMENT OF TEST RIG

The test rig was created as per the schematic diagram and the specimen selected for experiment was multi-crystalline silicon wafer and solar cell.

Solar wafer and solar cell were bought and halogen lamp for mimicking sunlight. A test sample of solar panel with 10 cells with an output of 5V was assembled

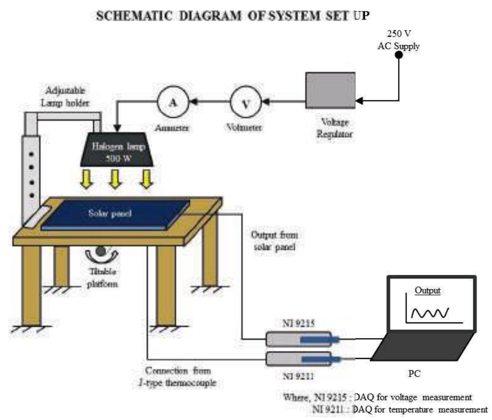

Fig.5.1. Schematic representation of the test rig

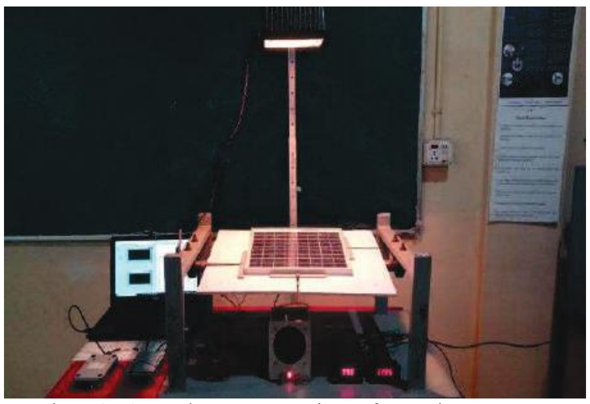

Fig.5.2. Actual representation of test rig

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B. SURFACE TEXTURING

Laser surface texturing (LST) is a surface engineering process that is used to improve the tribological properties of a material. Patterned micro-structures can be produced using lasers. In this experiment the patterns created are dimples and grooves for the solar panel. Laser surface texturing is carried out in both wafer and solar panel and the following results were obtained:
SOLAR WAFER: For this chemical etching was also carried out and then the optical reflectance was plotted between plane and textured wafer.

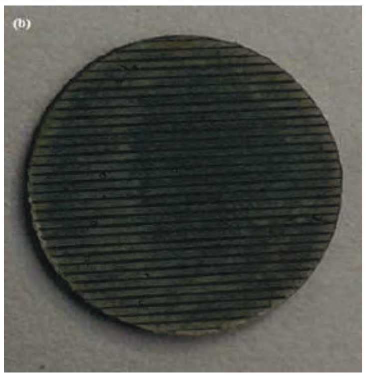

Fig.5.3. Textured wafer

The wafer was textured with a groove depth of 30micrometer. The reflectance of both un- textured and textured silicon wafer samples are measured using Specord S600 UV-Vis spectro-photometer with an integrating sphere.

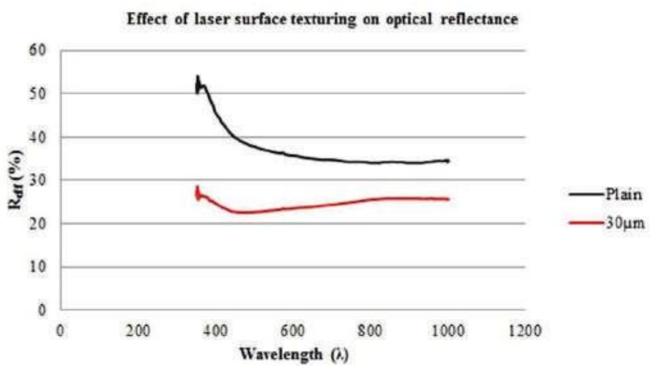

Fig.5.4 Effect of laser surface texturing on optical reflectance

Fig. shows the reflectance curves for both plane sample and textured sample with a groove depth of 30 μm and a pitch of 100 μm.

SOLAR PANEL: Fibre laser machining was carried out on the solar cells and the current and voltage characteristics was studied.

Table.5.1. Characteristics of fibre laser

Number of passes	1
Frequency	40Hz
Power	60%
Speed	400mm/sec

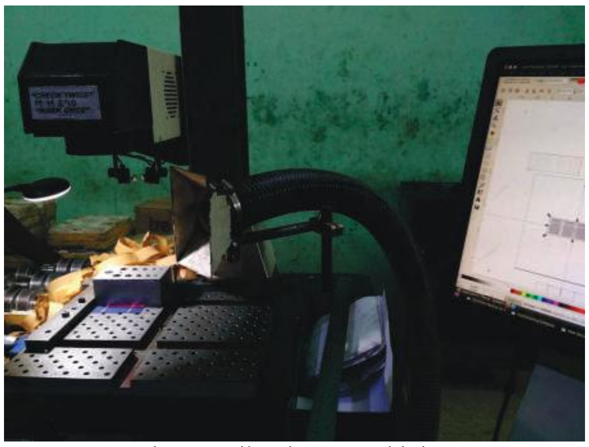

Fig.5.5. Fibre laser machining

For plane cell and textured cell the test was carried out and voltage,current and temperature characteristics were noted. Micro-structure images for both plane and textured solar cell was obtained from CMTI, Bengaluru. Texture was created in two patterns, dimple and groove. The micro-structure images of both the plane cell and textured cell at different magnifications is as follows:

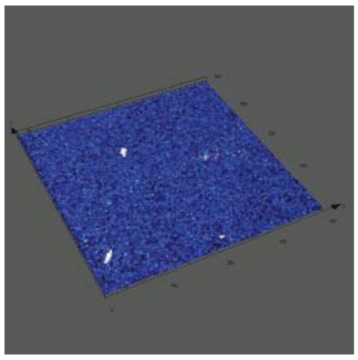

Fig5.6. Plane cell at 20X magnification

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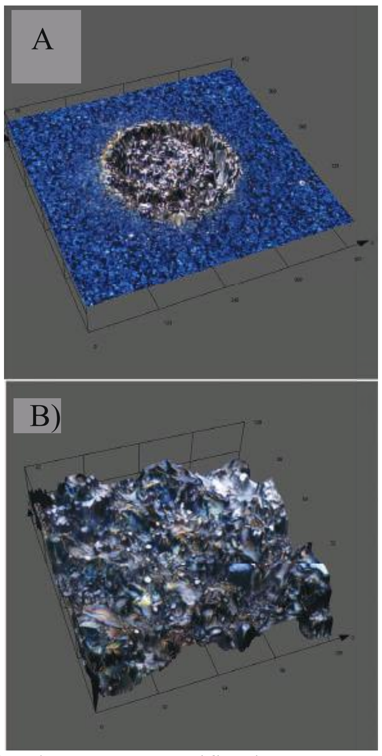

Fig.5.7.A) Dimple at 20X magnification
Fig.5.7.B) Dimple at 100X magnification

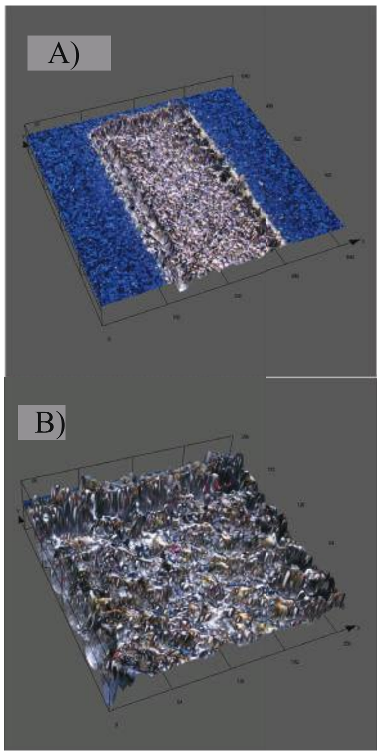

Fig.5.8.A) Groove at 20X magnification
Fig.5.8.B) Groove at 50X magnification

The experimental result for a plane cell at different height(time interval of 3mints):

Table.5.2 Readings of plane cell panel

Height cm	Vout Volts	Iout Amp	Temp T
75	4.22	0.01	34.5
70	4.32	0.02	35.2
65	4.37	0.02	36
60	4.45	0.02	36.8
55	4.51	0.02	37.7
50	4.59	0.03	38.5
45	4.66	0.03	39.8
40	4.74	0.04	43.8
35	4.82	0.05	48.6

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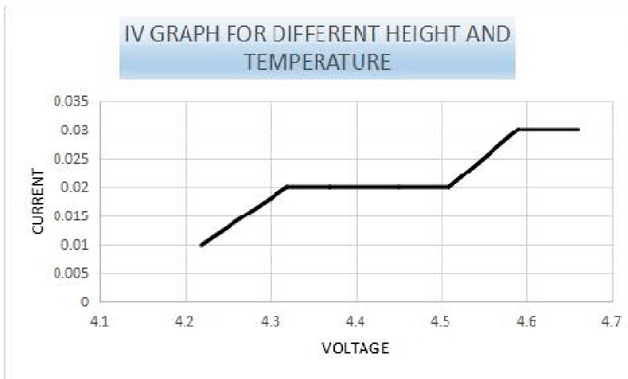

Fig.5.9. IV graph for different height and temperature

The temperature effect on a plane cell and textured cell with different height, an input of 105.3Volts and 1.223Amps was obtained.

Table.5.3. Temperature effect

Height cm	Plane Cell ^{0}C	Textured cell(groove) ^{0}C
75	34.2	34.1
70	35.6	35.5
65	36	35.9
60	36.8	36.6
55	37.4	37.3
50	38.4	38.2
45	39.3	39.2
40	40.5	40.4
35	42	41.6

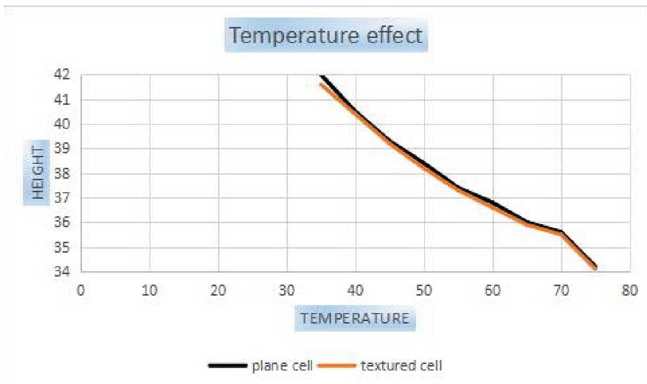

Fig.5.10. Temperature effect due to varying heights in plane and textured cell

Voltage effect on a plane cell and textured cell was obtained at its maximum height(75cm).

Table.5.4. Voltage effect

Height cm	Plane cell V	Textured	
		Dimple V	Groove V
75	0.49	0.33	0.18

C. RESULTS AND DISCUSSIONS

From the experiment, when the texturing is done on the silicon solar wafer, the results from the graphs shows that the laser texturing results in significant decrease in the value of effective reflectance compared to un-textured surface. Laser surface texturing creates grooves on the surface of silicon wafer, which enhances the number of absorbed photons which results in a lower effective reflectance. When the texturing is done on the multi-crystalline solar cell at 0.2mm depth, the voltage decreases drastically and temperature decreases up to an extend thus reducing the efficiency of the cell.

V. CONCLUSIONS

In the simulation part we created a mathematical model of a plane cell using SIMULINK software and with this model we can check whether the textured cell meets the characteristics of the plane cell. Graphs were plotted for different irradiance(1000-200W/m^2) and different temperature(0-60^0). With these graphs we can determine how the temperature affects the solar panel. In PC1D 5 simulation was done on textured and non- textured cell and graphs were plotted accordingly and we can see that there is an increase in the voltage and current in the textured part and with this increase, the efficiency also increases. PV Factory is another simulation software where wet chemical etching is done on the solar panel through simulation and graphs obtained for different texture sizes and we can see that maximum efficiency is obtained for the texture of size 180um.

In the experimentation part laser surface texturing with a depth of 300micrometers is done on the silicon wafer and the effect is studied. The optical reflectance is significantly reduced in the silicon wafer and with this efficiency is increased. In the multi-crystalline silicon solar cell,when laser surface texturing is done with a depth of 0.2mm,there is a decrease in the voltage and temperature effects which in-turn affects the optical reflectance of the cell thereby decreasing

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the efficiency. This is due to the laser machining parameters which affects the depth of the top textured layer. If we are able to do in the nanometer range then, the reflectance can be reduced effectively.This problem can be overcome if we are able to do the experiment with a better laser equipment with better parameters.

VI. LIMITATIONS AND FUTURE SCOPE

A. LIMITATIONS

Even-though there was an increase in the efficiency of silicon wafer, we couldn't obtain an increase in the efficiency in the multi-crystalline silicon cell.

B. FUTURE SCOPE

Future scope will be to do machining using another type of laser with better laser parameters so that we get a significant positive change in the cell efficiency. Optimization of the machining parameters can also be studied.

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b. Project Guide- Dr. Sudeep U
c. KSCSTE for funding this project
d. Fellow Classmates

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Selection of Optimal Prototype Design of a Pen using Hybrid Hierarchical Fuzzy Best-Worst Axiomatic Design Approach

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Abstract:

The aim of this paper is to investigate the adoption of a Hybrid Hierarchical Group Decision Making strategy based on Axiomatic Design principles and Best Worst Method under fuzzy environment to select the optimal prototype design. A case study is carried out at EAZI Pen industry for evolving new models of pen quickly in accordance with the diversification needed. Literature study was done to identify the current trends in the global pen design requirements. Design and system ranges were formulated in accordance with the brainstorming section held with the production managers and designing engineers at the industry. Design of four alternate pen prototypes were developed using 3D Modelling and Rapid Prototyping (Fusion Deposition Modelling) technique. Appropriate design is selected using Fuzzy Best Worst Method (FBWM) which is done with the help of questionnaire survey and Axiomatic Design (AD) approach is carried out to evaluate the Hierarchical decision criteria in selecting the optimal prototype hence increasing receptivity of the practitioners over adopting this hierarchical method for design selection. Using the above proposed Hybrid Multi-Criteria Decision-Making method, an optimal prototype design is selected among four candidate pen prototypes considering the problem criteria including design, practical and technical factors.

Keywords: Motivational Factors, 3D Modelling, Rapid prototyping, Fuzzy Best Worst, Axiomatic design

I. Introduction

A pen is a writing instrument used to apply ink to a surface, usually paper, for writing or drawing. Historically, reed pens, quill pens, and dip pens were used, with a nib dipped in ink. Modern types include ballpoint, rollerball, fountain and felt or ceramic tip pens. In this paper study is done on ballpoint pens. Additive manufacturing technique is employed for prototype designing. Additive Manufacturing (AM) is an appropriate name to describe the technologies that build 3D objects by adding layer-upon-layer of material. Common to AM technologies is the use of a computer, 3D modeling software (Computer Aided Design or CAD), machine equipment and layering material. Once a CAD sketch is produced, it is sliced with the help of Cura software so that the AM equipment reads in data from the CAD file and lays downs or adds successive layers of liquid, powder, sheet material or other, in a layer-upon-layer fashion to fabricate a 3D object. Here Ultimaker 3+ is used for prototyping. The selection of the optimal prototype design is a complicated decision-making problem. Multiple Criteria Decision Making (MCDM) approaches are quite useful for such problems. One of the most significant decision-making techniques developed is Best Worst Analytical Hierarchical Process based on design principles considering fuzzy set data. Best worst method is a practical systematic technique for designers in various fields such as engineering and organizational management to streamline the whole design process. Based on AD principles, the designer's idea of the characteristics of favorite design in terms of specified preferences and tolerance is called design range and the data obtained from the system is named system range. The focus of the present paper is to introduce a optimal model based on a hierarchical group decision-making structure to assess candidate conceptual prototype designs of pen. Only a few studies have considered the best worst approaches to select the optimal prototype design, but no studies have considered various design properties such as aesthetic concepts and inclusive design characteristics. This paper uses the proposed best worst analytical hierarchical approach for a practical problem of pen design selection.

II. Methodology

A. Additive Manufacturing and Prototyping

Based on the result of literature survey, the main aim was to provide a hybrid hierarchical multicriteria decision making

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structure for protype design selection. This was accompanied by the identification of a candidate product. For this a traditional Pen manufacturing company was opted and surveyed. A brainstorming section was held with the designers and production Managers in the respective company in order *to determine the system and design ranges needed for* formulating candidate conceptual designs of pen. Different criteria and sub criteria adopted by the practitioners over pen designs are listed out with the help of literature survey and feedback from the designers in the industry. Almost 3 criteria and 11 sub-criteria were listed out. Specific design and system ranges were tabulated in accordance with the criteria and sub criteria selected under fuzzy environment. Four pen prototypes were designed compactedly with the criteria and sub-criteria and the conceptual models of pen were modelled with the help of CAD and Creo Parametric software. These files were converted to STL file format for 3D printing and was further processed through CURA software for the slicing activity needed for printing. Additive manufacturing serves aa an important emerging manufacturing process in which material is added layer upon layer and fused together to form the 3D product.this has got wide range of applications in the field of manufacturing All the parts of conceptual pen designs has been prototyped using the 3D printer ULTIMAKER 2+.

B. Triangular Fuzzy Numbers (TFN)

In most direct-life problems, data may be collected in the form of linguistic terms or as ranges In such uncertain environments Fuzzy Set Theory can be utilised to find the optimum value. In the present study triangular fuzzy theory is being employed for data collection and interpretation of the problem function.
If a is defined as a fuzzy set, it can be described as a pair of (U ,m) in which U is a set of numbers and m is the membership function donated by (µ x) which is considered by each element of x, discourse X can be identified to a real number in the mentioned interval, i.e., (0,1)

$$\mu_{\tilde{a}}(x) = \begin{cases} \frac{x-a_1}{a_2-a_1}, & a_1 \le x \le a_2 \\ \frac{x-a_3}{a_2-a_3}, & a_2 \le x \le a_3 \\ 0 & \text{otherwise} \end{cases}$$

It is necessary to identify that in any fuzzy MCDM problem, there is no numerical value for the qualitative indicators and their assessment value is calculated by the verbal quantities of decision-makers, in this case the designers and proction managers.

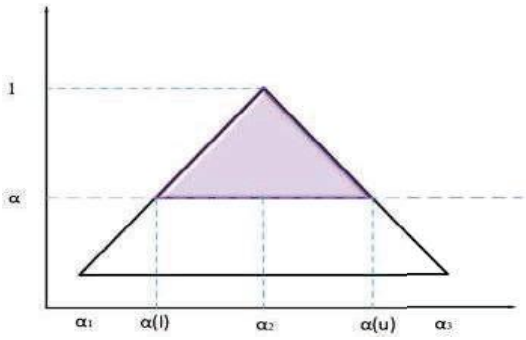

Figure 1: A typical TFN.

C. Fuzzy Best Worst Method

Best worst method (BWM) is a multicriteria decision making (MCDM) method developed by Dr. Jaffar Rezaei to select the best and worst indicators that define the characteristics of the final product. In this study best-worst criteria is done in a fuzzy environment so as to optimize the values. It is mainly used in various decision-making problems where aesthetic and technical factors play a major role. The salient features of BWM are: (i) it requires less comparison data, (ii) leads to more consistent pair wise comparison which shows more reliable results. The fuzzy comparison matrix is defined as A a = [ij] where aij represents the relative fuzzy preference of criterion i to criterion j as a TFN. The steps are listed below:
Step 1. Determine a set of decision criteria.
For instance, in the selecting the best prortype design, the decision criteria can be aesthetic design considerations(C1), practical(C2) and technical design considerations(C3).
Step 2. Determine the best (e.g. most desirable, most important) and the worst (e.g. least desirable, least important) criteria . A questionnare is used at this stage which is duly responded by the designers and production practitioners in the respective company. In this step, the decision-maker identifies the best and the worst criteria in general. No comparison is made at this stage.
Step 3. Determine the preference of the best criterion over all the other criteria using fuzzy traingular numbers
Step 4. Determine the preference of all the criteria over the worst criterion using the same as above
Step 5. Find the optimal weights.

The optimal weight for the criteria is the one where, for each pair of best to others and others to worst criteria are compared.
Fuzzification: geometric mean to calculate weights

A1 * A2 = (l1, m1, u1) * (l2, m2, u2)
= (l1×l2, m1×m2, u1×u2)

Fuzzy geometric Mean Value = r̃ (fourth root)

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Table I: The corresponding numbers based on linguistic terms for FBWM

Linguistic term	Completely equal importance	Equal importance	Moderate importance	Strong importance	Very strong importance	Extremely more importance
Abbreviated linguistic term	CI	EI	MI	SI	VI	EMI
Triangular fuzzy number	1,1,1	1,1,3	1,3,5	3,5,7	5,7,9	7,9,9

Fuzzy Weights (Wi)= Geometric mean * Reciprocal of sum of weight
Reciprocal of sum= 1/ (l, m,u)
Defuzzification: Using Centre of Area Method
Centre of Area (COA): Wi= (l, m,u)/3
Total weight is calculated and checked whether greater or less than 1
Normalised weight= Wi/Total=1
According to the study of Rezaei (2016), BWM can be transformed into the following nonlinear programming problem:

$$\min \max \{|w_B - a_{Bj} w_j|, |w_j - a_{jW} w_W|\}$$

$$\text{s. t.} \begin{cases} \sum_{j=1}^{n} R(w_j) = 1 \\ a_{1j}^{w} \leq a_{2j}^{w} \leq a_{3j}^{w} \\ a_{1j}^{w} \geq 0 \\ j = 1, 2, \cdots, n \end{cases}$$

Consistency Ratio (CR) is a crucial indicator to evaluate the consistency degree of pairwise comparison. To include the group decision-making model and the essential elements of each criterion in the proposed method, a hierarchical structure influenced by AHP method has been considered. AHP method concerns a hierarchical base structure based on the pairwise comparison (Saaty, 1980, 2007) which help in finding relative importance of each criteria opted. The group decision-making procedure has been demonstrated in Fig. 2. After obtaining the best and worst criteria in the procedure of the FBWM with the help of questionnare created, individual viewpoints of each decision-maker are obtained. Further formulation regarding best-to-others and others-to-worst fuzzy preferences for each decisionmaker is done and finally the group decisions of different experts are integrated considering weights of specified criterias.

C. Axiomatic Design (AD) approach

AD approach can be useful for engineers to overestimate the whole process of the design and implementation phase (Khandekar, Antuchevičienė, & Chakraborty, 2015). AD principles can be a measuring tool to evaluate system capabilities by calculating the satisfaction degree of the functional requirements (FRs) (Kulak et al., 2015). AD principles are based on two axioms, Independence Axiom that keeps the independence of Functional Requirements(FRs) and Information Axiom which keeps the information content at the minimum level (Hafezalkotob & Hafezalkotob, 2016b). Subsequently, based on Information Axiom, the optimal design has the lowest value of information content. The relationship between Design Parameter (DP) and (FR) vectors can be represented as follows:
FR= A×DP, where A denotes the design matrix which outlines the design.
The two axioms usde in AD approach are:
Axiom 1: The Independence Axiom, maintain the independence of the functional requirements(FRs)
Axiom 2: The Information Axiom, minimize the information content of the design
The logarithmic function has been used because the information content will be an added information in the case where several FRs have to be satisfied simultaneously (Kulak et al., 2010). In any design situation on the basis of AD principles, the success probability of the design consists of two crucial elements: design range, which is the designers considerations to be obtained in terms of the expected domain, and system range, which is the capability of system delivery (Hafezalkotob & Hafezalkotob, 2016b; Kulak et al., 2015). The overlap of design and system ranges is called common range, which is the domain of
the acceptable design solution (Kulak & Kahraman, 2005a). Fig. 3 shows how overlapping of design and system ranges can form a common range where x-axis illustrates the functional requirement and y-axis denotes the function of

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probability density. When the probability distribution function (PDF) is uniform, pij is obtained as follows:

Pij= (Common area/ System area)
Thus, information content Iij can be reformulated as:
Iij = log2 (System area/ Common area)

D. Hierarchal Best-Worst Fuzzy Axiomatic Design (HBWFAD) approach

In design selection problems, the importance of criteria in decisionmaking often varies. Therefore, the relative importance of criteria should be considered in order to obtain an optimal design solution. . Subjective weights are achieved from the opinions of experts through questionnare while objective weights are obtained by employing the values of decision matrix without utilizing the judgments of experts. The integrated weights are then used to generate information content Iij (w*) of HBWFAD approach as follows:

Iij(w*)= {(Iij)^1/w*j, 0 ≤ Iij ≤ 1 or
{ (Iij) ^w*j, Iij > 1 or
{ wj*, Iij= 1

The total information content Tiw* and the optimal alternative based on HBWFAD method are formulated as:

Tiw*= €j=1 Iij w*

III. FINDINGS AND RESULTS

The purpose of this study is to present a hierarchical hybrid approach based on FBWM and FAD techniques based on a hierarchical group decision-making structure (HBWFAD.The necessary research data for this case study has been collected through questionnare survey which was based on linguistic terms listed in Table I. The respondents were three industrial design experts and high level managers who are directly dealing with prototype selection of multiple.. The results were utilized as the input data to calculate of criteria weights and to construct decision matrix. related studies. The description of criteria and their related sub-criteria are collected in Table II. The evaluation criteria in the current study have been identified based on an extensive literature review from the previous research studies related to design and multicriteria desicion making approaches. Table 3 shows

the prototype alternatives designed inaccordance with the literature survey done. The computer modeling and the rendering process of the design procedure have been prepared with CAD and Solid works. Prototypes were modelled using ULTIMAKER 2+. According to three criteria which consist of eleven sub-criteria, the decision matrix has been structured with linguistic conversion as shown in Table IV. Table V and VI provides the fuzzy preference degrees of the proposed subcriteria where the fuzzy best-to-others and others-to-worst vectors of sub-criteria preference degrees have been obtained based on response of the experts and so for the criteria. Table VII formulates the optimal weights of sub-criteria for the selection of the optimal prototype which has been computed throughout HFBWM procedure for which AHP acts as the base. Table IX shows the calculated system ranges, common ranges and informations contents obtained. Table X indicates the rankings of the designed prototypes. Based on this Model D was determined as the optimal model considering the problem criteria.

IV. CONCLUSION

One of the most effective techniques in every production process is prototyping the final product. In this context, the current study presented a novel MCDM approach named HBWFAD based on FAD and FBWM considering hierarchical group decision-making structure. A practical case study concerning the selection of the optimal prototype for the conceptual design of loudspeakers was tackled using the proposed methodology. After calculating the weights of attributes by HFBWM approach, the final assessment of the optimal prototype was done using FAD approach. Suggestions for future developments of this study are as follows. First, the proposed hybrid approach in the current study can be applied in various applications such as risk assessment procedure in which the input data is often uncertain. Second, FAD and FBWM approaches can be extended for the cases in which the data of the problem may have different mathematical forms such as interval values, extensions of fuzzy sets, or linguistic terms. Third, risk factors can be considered in the proposed HBWFAD to consider higher degree of uncertainty or unexpected situations. Fourth, the suggested design selection process can be applied in conceptual design of any product based on different aesthetic concepts and design techniques such as minimalism.

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Table II: Candidate alternatives (3D printed prototype designs)

Candidate alternative prototype designs	Description
Model A 	Prototype Model A is designed from the influences from Staedtler Lumocolor models. The presented prototype has taken a lot of influence from the Pilot G2 Ultrafine model. The triangular housing provides a flip side because of which ink comes out so sparingly, so there is literally no bleed through or smudging. Negative marking from decision makers comes under material wasting due to triangular corners which is to be notified.
Model B 	Prototype model B is designed in accordance with characteristics of Uni ball Jetstream model proving firm gripping at the adaptor part excluding the need for rubber gripper.it is round conical at the adaptor and gripping part while hexagonal shaped for the remaining housing part.
Model C 	Prototype model C is designed in accordance with design parameters obtained from Pentel arts slicci 0.50mm extra fine. Hexagonal housing is provided for easy gripping and smooth writing. The hexagonal ridges serve ergonomic purposes focussing on student customers.
Model D 	The padded grip and overall fine finish make this pen comfortable to use for extended periods of time. This prototype design has been executed in accordance with the design of Pentel R.S.V.RT. nib thickness of about 0.7mm is used that provides fine and smooth writing reducing the smudging activity. It also resists the frictional resistance thereby enhancing the smoothness in writing activity

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Table III: Decision-makers preference degrees of the loudspeaker prototype selection sub-criteria

Criteria	Sub criteria	Decision maker 1 Best Sub criterion: SC7 Worst Sub Criterion: SC		Decision maker 2 Best Sub criterion: SC2 WorstSub Criterion:SC10		Decision maker 3 Best Sub criterion: SC7 Worst Sub Criterion:SC9	
		Best to Others	Others to Worst	Best to Others	Others to Worst	Best to Others	Others to Worst
C1	SC1	3,5,7	1,3,5	1,1,3	1,9,5	5,7,9	5,7,9
	SC2	1,3,5	5,7,9	1,1,1	3,5,7	1,1,3	1,1,3
	SC3	1,3,5	1,1,1	1,3,5	1,3,5	1,3,5	1,1,3
	SC4	1,1,3	1,1,3	1,1,3	3,5,7	1,3,5	1,1,1
C2	SC5	5,7,9	1,3,5	5,7,9	1,3,5	7,9,9,	3,5,7
	SC6	3,5,7	1,3,5	1,3,5	1,1,3	3,5,7	5,7,9
	SC7	1,1,1	1,3,5	3,5,7	1,1,3	1,1,1	5,7,9
C3	SC8	1,3,5	3,5,7	1,3,5	1,3,5	3,5,7	3,5,7
	SC9	5,7,9	1,3,5	3,5,7	1,1,3	7,9,9	5,7,9
	SC10	1,3,5	1,3,5	5,7,9	1,1,1	5,7,9	7,9,9
	SC11	1,3,5	1,3,5	3,5,7	1,1,3	3,5,7	5,7,9

Table IV: Decision-makers preference degrees of the loudspeaker prototype selection criteria

Criteria	Decision maker 1 Best criterion: C2 Worst Criterion:C3		Decision maker 2 Best criterion: C3 Worst Criterion:C2		Decision maker 3 Best criterion: C2 Worst Criterion:C1	
	Best to Others	Others to Worst	Best to Others	Others to Worst	Best to Others	Others to Worst
C1	1,3,5	1,1,1	1,1,3	3,5,7	3,5,7	1,1,1
C2	1,1,1	3,5,7	1,3,5	1,1,1	1,1,1	1,1,3
C3	5,7,9	7,9,9	1,1,1	5,7,9	1,3,5	7,9,9

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Table V: System and design ranges as well as weights of the sub-criteria for the prototype selection process.

Criteria	Sub Criteria	Candidate alternatives of loudspeaker prototypes				Design ranges	HFBWM Optimal Weight
		MODEL A	MODEL B	MODEL C	MODEL D		
C1	SC1	1,1,3	1,1,3	1,3,5	7,7,9	5,7,9	0.014979
	SC2	1,3,5	1,1,3	1,1,3	3,5,7	3,5,7	0.0007596
	SC3	1,1,3	1,1,3	1,3,5	1,3,5	3,5,7	0.0006741
	SC4	1,3,5	1,1,3	1,3,5	7,9,9	5,7,9	0.0055928
C2	SC5	1,1,3	5,7,9	3,5,7	7,9,9	1,1,3	0.014554
	SC6	3,5,7	1,3,5	3,5,7	5,7,9	3,5,7	0.009714
	SC7	1,1,3	3,5,7	1,3,5	5,7,9	5,7,9	0.2042128
C3	SC8	1,1,3	1,3,5	3,5,7	5,7,9	1,3,5	0.023752
	SC9	1,3,5	1,3,5	1,3,5	3,5,7	3,5,7	0.002099
	SC10	1,1,3	1,1,3	1,3,5	1,3,5	5,7,9	0.020836
	SC11	1,1,3	1,1,3	3,5,7	5,7,9	3,5,7	0.004875

Table VI: Calculated system ranges for the pen prototype selection problem.

Criteria	Sub Criteria	Candidate alternatives of loudspeaker prototypes			
		Model A	Model B	Model C	Model D
C1	SC1	2	1	2	2
	SC2	1	1	1	2
	SC3	2	1	2	2
	SC4	1	1	2	1
C2	SC5	2	2	2	1
	SC6	1	2	2	2
	SC7	2	2	2	2
C3	SC8	1	2	2	2
	SC9	1	2	2	2
	SC10	1	1	2	2
	SC11	1	1	2	2

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Table VII: Calculated common areas for the loudspeaker prototype selection problem

Criteria	Sub Criteria	Candidate alternatives of loudspeaker prototypes			
		Model A	Model B	Model C	Model D
C1	SC1	1	1	1	1
	SC2	1	1	1	0.5
	SC3	1	1	1	1
	SC4	1	0.5	1	2
C2	SC5	1	0.5	0.5	2
	SC6	2	1	0.5	1
	SC7	1	0.5	1	1
C3	SC8	1	1	0.5	1
	SC9	2	0.5	1	0.5
	SC10	1	1	1	1
	SC11	1	0.5	0.5	1

Table VIII: Information contents of FAD method.

Criteria	Sub Criteria	Candidate alternatives of loudspeaker prototypes			
		Model A	Model B	Model C	Model D
C1	SC1	2	0	2	2
	SC2	0	0	0	2
	SC3	2	0	2	2
	SC4	0	1	0	1
C2	SC5	2	2	2	2
	SC6	2	2	2	2
	SC7	2	2	2	2
C3	SC8	0	2	2	2
	SC9	2	1	2	1
	SC10	0	0	2	2
	SC11	0	0	1	0

Table IX: Information contents of HBWFAD method.

Criteria	Sub Criteria	Candidate alternatives of pen prototypes			
		Model A	Model B	Model C	Model D
C1	SC1	1.10143678	0	1.10143678	1.10143678
	SC2	0	0	0	0.000526658
	SC3	1.000526653	0	1.00046736	1.00046736
	SC4	0	0.0055928	0	0.0055928
C2	SC5	1.00046736	1.01013912	1.01013912	1.01013912
	SC6	1.00384157	1.006755951	1.006755951	1.006755951
	SC7	1.01013912	1.15209157	1.152059157	1.152059157
C3	SC8	0	1.001455975	1.001455975	1.001455975
	SC9	1.001455975	0.002099	0.002099	0.002099
	SC10	0	0	1.01454721	1.01454721
	SC11	0	0	0.004875	0

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Table X: Total information contents and rankings of PEN prototype selection problem

Alternatives of pen prototype	Total Information Contents HBWFAD	Rankings
Model A	6.026910045	3
Model B	5.178093003	4
Model C	7.202542451	2
Model D	8.20408001	1

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Sustainability Assessment and Determination of Sustainability Index for Manufacturing Industries

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Abstract: All over the world the deterioration level and quick consumption and exhaustion of natural resources is a growing concern. It has been recognized that environmental activities are important to the survival of manufacturing companies. Yet manufacturing companies continue to degrade the environment, over exploit natural resources and generate huge amount of wastes. Manufacturing is not just about financial profits, but it should also be conscious of the long-term impacts on living standards of both our present and future generations. Assessment of industrial sustainability is an important step towards converting the theoretical goal of sustainable development into practice. One of the important tool for sustainability assessment is indicators. Indicators is considered as a useful tool to summarize the complex data into meaningful information and to keep track performance progress over time. The purpose of this paper is to identify the key performance indicators (KPIs) to assess the sustainability of the manufacturing organizations and to develop a sustainability index to quantify the impact of manufacturing activities on the environment. This research is an attempt to encourage manufacturing companies to report their organization's sustainability via an index that aid in driving both profits and growth. It takes into account the social, economic and environmental issues affecting manufacturing companies and provides a Sustainability Index that can be used as a sustainability performance measurement indicator, helping in the alleviation of ceaseless business challenges. The derived sustainability index, that combines the principal sustainable indicators, has been used as a single decision-making tool for serving manufacturing companies realize their sustainable development goals.

Keywords: Sustainability Assessment; Key Performance Indicators; Sustainability Index.

I. INTRODUCTION

Sustainable development is the organizing principle for meeting human development goals while simultaneously sustaining the ability of natural systems to provide the natural resources and ecosystem services upon which the economy and society depend. The desired result is a state of society where living conditions and resources are used to continue to meet human needs without undermining the integrity and stability of the natural system. Sustainable development can be defined as development that meets the needs of the present without compromising the ability of future generations. The concept of sustainability is composed of three pillars: economic, environmental, and social also known informally as profits, planet, and people. Sustainability has become the subject of concern for discussion in the business and trade press, at conferences and in everyday conversations. It is an initiative increasingly essential to the core business model of companies. The increasing amount of human activities is responsible for the amount of pollutants dumped onto land, into water and the atmosphere, causing various pollution problems to the environment, hazardous wastes generated from economic activities and ozone depletion from chlorofluorocarbons. The planet is in environmental crisis and these environmental problems are obviously interrelated.

This paper aims to identify the the key performance indicators (KPIs) to assess the sustainability of the manufacturing organizations and to develop a sustainability index to quantify the impact of manufacturing activities on the environment. This research is an attempt to encourage manufacturing companies to report their organization's sustainability via an index that aid in driving both profits and growth.

II. LITERATURE REVIEW

A. The Concept of Sustainability

Today, sustainable development is a hot issue for nations, companies, and individuals. Since the term was first coined in 1987 by the Brundtland Commission, many researchers, governments and organisations around the world began to demonstrate efforts in translating the theoretical goal of sustainable development into practical usage. In particular, manufacturing companies are facing increasing pressure from

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government and customers to think beyond economic benefits and consider the environmental and social effects.

B. Sustainable Manufacturing

Manufacturing industries contribute to a significant part of the world's consumption of resources and generation of wastes. This sector requires massive fossil energy such as coal and natural gas. Massive fossil energy consumption due to industrial production emits large amounts of carbon dioxide (CO_2) and affects people's lives (Kopidou et al., 2016). Lyu (2016) reckons that due to the lingering increase in the concentration of carbon dioxide in the atmosphere, causing cataclysm in the original carbon balance, the energy, ecological, water, food and environmental security will be affected to an extent that human survival will be threatened. It becomes imperative for the industry to explore means and ways to stop this haemorrhage. However, manufacturing industries have the potential to become the driving force for the creation of a sustainable society. Integrated sustainable practices can be designed and implemented in order to develop products and services that contribute to better environmental performance. A shift in the understanding of industrial production is needed and a more holistic approach in conducting business perception and is required. Indicators are used to help manufacturing companies understand environmental issues surrounding existing production systems, define specific objectives and monitor progress towards sustainable production. There are numerous sustainability indicators in the literature that are diverse in nature and have been developed on a voluntary basis for the purpose of promoting sustainable business practices. Table 1 provides a list of indicator sets most widely quoted.

TABLE I
LIST OF SETS OF INDICATORS FROM REVIEW OF LITERATURE.

No	Indicator set	Components
1	Global Report Initiative (GRI)	70 indicators
2	Dow Jones Sustainability Index (DJSI)	12 criteria based single indicator
3	2005 Environmental Sustainability Indicators	76 building blocks
4	2006 Environment Performance Indicators	19 Indicators
5	United Nations Committee on Sustainable Development Indicators	50 indicators
6	OECD Core indicators	46 indicators
7	Indicator database	409 indicators
8	Ford Product Sustainability Index	8 indicators
9	ISO 14031 environmental performance evaluation	155 example indicators
10	Walmart Sustainability Product	Index 15 questions
11	Environmental Indicators for European Union	60 indicators
12	Science and Technology Indicators	13 indicators

Data source: NIST, Sustainable manufacturing indicators repository (Hoek and Johnson, 2010)

There are some articles in the literature which reflects the environmental measures of sustainability in manufacturing. Kaur and Singh (2017, 2018) addressed the environmental sustainability of procurement and logistics in manufacturing organizations. Sushil et al (2018) derived the hierarchical relationship of factors affecting the fly ash handling process including environmental and sustainability aspects. Park and Kremer (2017) categorized environmental sustainability indicators by using text mining approach. Li and Mathiyazhagan (2018) attempted to develop sustainability measurement indicators for auto component manufacturing industries in India. Few articles provide economic measure but social measures of sustainability in manufacturing environment have been hardly studied. Sutherland et al. (2016) also emphasized the lack of social indicators along manufacturing supply chains and highlighted the existence of challenges to internalize and operationalize social sustainability. Hence, it is better to incorporate the sustainability indicators in the assessment framework, which makes it easy to understand and also data collection will be easy. Moreover, the KPIs should address the whole product life cycle (integrated supply chain) as well as the three dimensions of sustainability. Sangwan et al. (2018) addressed the topic of sustainability assessment of manufacturing organizations through the integrated resource consumption across the life cycle of the products and processes.

C. Sustainability measurement

Sustainability measurement is a crucial activity in a manufacturing company and in an organization management system. The evaluation or measurement can be done through indices or set of indicators whose major role are to help decision makers evaluate a company's sustainability performance as well as plan for future actions (Jang and Kim, 2011). The combination of indicators facilitates the development of a multi-item measurement tool called a sustainability index with sufficient dimensionality, reliability and validity.

D. Importance of sustainability indicators

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One common representation of sustainability is the "three pillars" concept which requires the reconciliation of environmental, economic and social demands. Attributable to the vague definition and lack of clear concept on sustainability, there exist diverse conceptualizations of sustainability and no apparent methods for its practical measurement [1]. Parris and Kates (2003) have reported more than 500 concepts for measuring sustainability [2].Nonetheless, its unclear definition actually created room for interpretation of sustainability because ideas about sustainability could be discussed and improved upon over time and place [3]. This also resulted in numerous works on sustainability assessment [4-6]. Furthermore, it drives the development of more scientific and objective methodologies for sustainability assessment since how one defines sustainability largely determines how one goes about assessing it [7]. Indicators are one category of sustainability assessment tools and techniques..

According to Amrina et al. (2011), to measure sustainability in a holistic way, values that represent the quantification of items in evaluation should be interpreted as indicators. OECD (2001) declares that sustainability measure involves more than one group of indicators. Thereby, there are many factors involved such as: environmental, economic and social, each represented by a group of indicators. O'Brien (1999) claims that the result of this measure should be the support to the PS to identify specific areas to apply improvements related to sustainability in their areas activities. As stated in US (2009), the sustainability scale can be used as a metric to evaluate the system performance. There is a set of process performance indicator pattern in the market, called key performance indicator (KPI). KPI is a set of performance values measured to quantify and to qualify process performance evaluation. In the standard ISO22400 (ISO224001, 2010; ISO224002, 2014), the performance measure is treated as part of an industrial process creation value.

III. METHODOLOGY

The set of economic, environmental and social indicators identified from the four sustainability frameworks were compiled and analyzed for their relevance to the local manufacturing companies. The main objectives of the survey were two fold:

i. To test Key Performance Indicators for sustainability assessment of the manufacturing industries
ii. To develop a sustainability index model to quantify the impact of manufacturing activities on the environment
iii. To calculate the sustainability index of different companies.

Part A of the questionnaire covers details of the organization and part B scoring the 105 identified indicators on a scale of one to five relevant to their sustainability performance level. The survey questionnaire was sent to a representative sample of 100 large manufacturing companies: 26 textile companies, 27 Electrical and Electronics companies , 26 Paper products companies and 26 others (medical device manufacturing, wood industries etc). Survey data was collected through interview of respondents who were finance executives, manufacturing engineers, production engineers and production supervisors. Based on the findings, the most pertinent and most often used indicators were selected to be incorporated in the sustainability index model. The data collection phase confirmed the argument of Maria and Dos (2014) that people can only assess a small number of criteria when making meaningful decisions.

A. *Criteria for selection*

The selected indicators, in general, should possess the following three criteria:

- Understandable: Indicators should be simple to understand, use, and implement by non-experts.
- Applicable: Indicators should be applicable to manufacturing industry and represent key concerns of local SMEs.
- Relevant: Indicators should be directly relevant to continuous sustainability improvement..

B. *Analysis*

Factor analysis is used to arrive at the key performance indicators. Stepwise multiple regression analysis was used to get the sustainability index model. A non-parametric statistic such as the Kendall coefficient of concordance, W which is distribution free, and can deal directly with scores while remaining valid, even when normality assumptions are violated (Mittal and Sangwan, 2014) was used to test the rationale of the analysis.

IV. RESULTS AND DISCUSSIONS

A. *Analysis of survey questionnaire*

All companies in the sampling frame positively responded to the survey and actively participated in the research. The respondents from the three selected manufacturing sectors were equally distributed.

B. *Identification of indicators*

Upon review of literature, and assessment of various existing frameworks and models indicators were identified as applicable and mostly suitable to manufacturing companies.

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i. Factor analysis results of economical sustainability indicators

The factor analysis formed five factors of economic sustainability indicators. These five factors loads 20 KPIs and 11 indicators were deleted. Factor 1 consists of indicators related to financial performance. The list of indicators in this factor are Income, Return on investment, Capital employed , Annual sales volume, Earnings per share, Return on equity . These indicators are established financial indicators for any industry's economic assessment as they used frequently over time for sustainability assessment (Azapagic, 2003; Adams and Ghaly, 2006; Garbie, 2014). The second economic factor consists of indicators related cost incurred to the company during operations, warranty, transportation and technology and innovation. The list of indicators in this factor are Technology and innovation cost, Transportation cost, Warranty cost, Maintenance and improvement cost. The third economic factor includes indicators related to employees. The list of indicators in this factor are Training opportunities, Career development opportunities, Remuneration, Employee benefits. The fourth economic factor includes indicators related to shareholder. The list of indicators in this factor are Reduction in Operational cost, Growth in Market Value, Growth in Profit. The last economic factor includes indicators related to Govt. Policies. The list of indicators in this factor are Taxes, Tax breaks, Penalties due to violation of rules.

ii. Factor analysis results of environmental sustainability indicators

Four factors emerged for environmental sustainability indicators covering 19 KPIs. A total of 13 KPIs were deleted because of poor factor loading. Factor 1 is related to emission intensity. The list of indicators includes Reduction in Emission /unit of Production, Dust emissions, Wicked smell in air, Noise emissions, Green house gas emissions. Factor 2 is related to resource intensity. The list of indicators includes Reduction in Material Usage/ Output, Reduction in Energy/ Fuel usage, Material input per service, Percentage of renewable energy used, Resources consumed in maintenance/service/repair, Water used, Fossil fuel used. The third factor is related to waste intensity. The list of indicators includes Reduction in Environmental Business wastage, Solid waste used, Fraction of wastewater reused, Fraction of reused material . The fourth factor is about process efficiency. The list of indicators includes Focus on environmental process, Focus on environmental product, Sales per unit of material input.

iii. Factor analysis results of social sustainability indicators

The analysis of factor loadings for social sustainability indicators results into four social factors covering 24 KPIs. 8 Indicators were deleted because of poor factor loading. Factor 1 related to employees covers indicators like Safety and Health, Labour Relationship, Training and Education, Level of growth and opportunity, Fraction of employees covered through performance appraisal, Level of social security. These findings are also observed by Saratun (2016), who observed that employee engagement as a potential factor for an organizations' ability for being innovative, competitive, effective and sustainable. The second factor for social sustainability is related to work-related accidents/incidents and supplier from the local area. This factor includes indicators such as Fraction of worker with work-related disease, Number of work-related accidents/incidents, Fraction of local employee, Fraction of supplier from local area. The third factor is related to labour issues. It includes Average employee cost to company, Expenditure in social development, Stakeholders empowerment, Average social benefits to average, Investment in employee health and safety. Fourth factor is related to employee satisfaction. It includes Fraction of skilled labor, Number of promotions per employee, Employee satisfaction, Total hours of employee training, Employee retention rate, Labor productivity. The final factor is related to customer satisfaction. It includes Decrease in Rate of consumer complaints Total number of complaints from local community , New customer added in the year.

In total, 105 KPIs are identified for sustainability assessment of manufacturing organizations. The empirical study identifies 63 KPIs (24 social, 20 economic and 19 environmental), which are classified into 14 factors using exploratory factor analysis.

C. Determination of ranking of each indicator based on their performance within each company

A pairwise comparison matrix (Nakayama, 1986) was used to denote whether the indicators were equally significant or whether one of them was more significant than the other. A point system was used to arrive at the total score to reflect the final ranking. The more important of the two indicators was allotted one point and the other zero. The total score from each of the companies was calculated. The sum of the ranks for each sector of activities was denoted by Ri, and $\overline{Ri}$ represented the average rank of individual indicators.

The Kendall coefficient of concordance, W was used to consider the relationship among the rankings expressed by the professionals who participated in the survey. The coefficient of concordance, W is an index of the divergence of actual agreement shown in the data from the maximum possible or perfect agreement (Peng Zhang, 2013). The Kendall

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coefficient of concordance, W was found to be equal to 0.6888 designating some consensus among the respondents and that they were applying essentially the same standard in ranking the identified indicators. The value of W was tested at a 5% level of significance.

TABLE II: TOTAL SCORE (RI) OBTAINED FOR EACH INDICATOR

No	Indicators	Ri	$\overline{Ri}$ (Average per sector)	(R-$\overline{Ri}$)2
1	V83	203.75	203.75	373626.5625
2	V87	815	205	378225
3	V32	820	209	393129
4	V91	836	215.5	417962.25
5	V99	862	221.25	440564.0625
6	V68	885	221.5	441560.25
7	V72	886	224.75	454613.0625
8	V5	899	229.5	474032.25
9	V101	918	231.75	483372.5625
10	V47	927	230.25	477135.5625
11	V54	921	233.75	491751.5625
12	V79	935	235.5	499142.25
13	V11	942	236.5	503390.25
14	V69	946	238.5	511940.25
15	V10	954	239.5	516242.25
16	V94	958	240	518400
17	V65	960	240.25	519480.5625
18	V60	961	242	527076
19	V90	968	242.25	528165.5625
20	V80	969	243.5	533630.25
21	V6	974	243.75	534726.5625
22	V58	975	244.5	538022.25
23	V21	978	245.25	541328.0625
24	V18	981	248.75	556889.0625
25	V82	995	249.25	559130.0625
26	V81	997	250.25	563625.5625
27	V70	1001	250.75	565880.0625
28	V71	1003	251.5	569270.25
29	V102	1006	252	571536
30	V46	1008	252.5	573806.25
31	V43	1010	253.25	577220.0625
32	V24	1013	254.25	581787.5625
33	V53	1017	255.5	587522.25
34	V27	1022	266	636804
35	V93	1064	270.25	657315.5625
36	V36	1081	273.5	673220.25
37	V22	1094	276.25	686826.5625
38	V92	1105	284.25	727182.5625
39	V20	1137	285.25	732308.0625
40	V74	1141	285.75	734877.5625
41	V59	1143	287	741321
42	V7	1148	288.5	749090.25
43	V85	1154	288.75	750389.0625
44	V48	1155	291	762129
45	V29	1164	299	804609
46	V37	1196	304.25	833112.5625
47	V13	1217	307.25	849623.0625
48	V84	1229	309.25	860720.0625
49	V57	1237	310	864900
50	V96	1240	315.75	897282.5625
51	V49	1263	321	927369
52	V16	1284	322.25	934605.5625
53	V73	1289	331.5	989030.25
54	V33	1326	333	998001
55	V64	1332	335	1010025
56	V2	1340	335.75	1014552.563
57	V42	1343	338.5	1031240.25
58	V9	1354	340.75	1044995.063
59	V31	1363	345.25	1072778.063
60	V35	1381	348.75	1094639.063
61	V104	1395	356	1140624
62	V103	1424	363.5	1189190.25
63	V105	1454	365	1199025

.

The Kendall coefficient of concordance W: W= (12s) / ((Np^2) (Ni^3- Ni)), where Np=55 participants and Ni=63 indicators=0.68882.

D. Developing the sustainability index model using multiple regression model

Multiple linear regression was used to examine the relationship between the 63 identified indicators and the sustainability index of manufacturing companies. It was essential to understand how these variables interact with each other with a view to predict their effects on the economy, environment and society. The results led to the development of a Sustainability Index model (SIM) useful to assess manufacturing performances and rank alternatives by combining the important indicators into a single model. The hypotheses were tested for the existence of correlation between the dependent and independent variables for each of the indicators with respect to sustainability to confirm the validity of the model.

A stepwise multiple regression method was used to determine the most accurate model from the data collected. The multiple regression model is of the form:

$$y= \beta0 + \beta1X1 + \beta2X2 + \beta3X3 + ...\beta nXn + \varepsilon$$

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where:
y: sustainability index.
β0: y-intercept.
βn: slope of y with variable Xn.
X1 to Xn: environmental, economic and social indicators.
ε: random error.

All the sustainability indicators were input in the model and data obtained from the survey was input to conduct a regression analysis.

A set of 16 indicators: 5 environmental, 2 economic, and 9 social have been identified which impact directly on the sustainable performance of manufacturing companies. 55 companies were used as a sample for the research. Upon, the stepwise multiple regression analysis, a sustainability index model has been developed including 16 indicators: 5 environmental, 2 economic and 9 social indicators. The R2 value and r value were 0.997 and 0.999 respectively concluding that the variables are highly positively correlated with the dependent variable that is the sustainability index.

TABLE III : SUMMARY OF RESULTS FOR STEP BY STEP REGRESSION ANALYSIS

Indicators	Coefficients
Intercept	-0.074
V80	0.621
V47	0.218
V90	0.096
V36	0.154
V84	-0.648
V18	0.295
V42	0.349
V35	-0.341
V79	0.550
V72	-0.283
V105	-0.046
V73	0.722
V87	-0.136
V65	0.058
V93	-0.099
V70	0.749

Sustainability Index SI = 0.074 + 0.621*V80 + 0.218*V47 + 0.096*V90 + 0.154*V36 - 0.648*V84 + 0.295*V18 + 0.349*V4 - 0.341*V35 + 0.55*V79 - 0.283*V72 - 0.046*V105 + 0.722*V73 - 0.136*V87 + 0.058*V65 - 0.099*V63 + 0.749*V70

Using this model, susutainability index of each company is found out.

V.CONCLUSION

Sustainability in manufacturing is becoming increasingly important for industry and this study proposes a multi-level conceptual framework for measuring sustainability in manufacturing organizations. This work provides flexibility to managers and decision makers to their own indicators thereby encouraging the stakeholder participation. The research aimed at developing a sustainability index to eventually benchmark manufacturing companies with their peers in relation to sustainable practices. A mathematical model has been developed for the purpose. The key dimensions for the assessment of sustainability were identified using the survey method. The resulting index is a composite one which combines economic, social and environmental indicators into an indexing algorithm useful to rank companies according to their performance. In addition, this research brings forward the use of a multi-dimensional approach for the assessment of manufacturing companies in relation to economic as well as social and environmental indicators. The sustainability index model developed deviates from other evaluation methods in the sense that it provides a comparison platform to companies. In spite of having efforts worldwide on measuring sustainability, only a few of them have adopted an integral approach taking into account economic, environmental, and social aspects,

The limitation of this study is that thr research was based on a sample size of 55 companies. In the future the sustainability index can be tested on a larger sample size and through the use of other statistical techniques such as curvilinear models, two-way analysis of variance, and logistic regression.

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Design and Analysis of Sustainable Facilities

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Abstract: The aim of this paper is to design and analyse sustainable facilities. As the fossil fuels and conventional energy resources are depleting, there is a need of clean and renewable energy resources. This project focuses on two sustainable facilities and its analysis. Zero electricity air cooler and Gravity Escalator. Zero electricity air cooler is made using waste plastic bottles and work on the principle of Joule-Thomson effect. An experimental analysis and software analysis using Ansys were conducted to study the effect of cooling it can provide. A conceptual model of escalator was made. Usually we need to provide energy to escalator for moving up and down. But here we use gravity to run the escalator moving down. Gear pumps were used to reduce the speed of moving down as a damper and there by using it to pump water for other needs.

Keywords: Sustainable facilities; Zero electricity air cooler; Gravity escalator; Joule-Thomson effect

I. Introduction

The demand for energy is increasing day by day and continue to grow. Energy demand worldwide grew by 2.3% last year. Also the conventional energy resources are depleting. So it is essential to find alternate renewable sources to meet the demand. As a result of increasing temperature due to global warming it has become important to find a way to reduce room temperature for human comfort. Air conditioners are commonly used in every building for this. But a major problem related to this is that it draws a good amount of energy. Energy saving in air conditioners is a primary concern in building projects, since air conditioners consume a large proportion of energy in building service equipment [2]. A zero electricity air cooler is a method used to reduce room temperature from normal flow of air. It is a eco-friendly method as plastic bottles can be used to build it which helps to reuse waste plastic bottles as the growth of plastics in India is increasing at a remarkable rate. In India, growth rate is 17% as compared to elsewhere in the world [3]. The cooling is attained according to Joule-Thomson effect.

An escalator is a mechanized moving stairway, common in places with a lot of foot traffic or where a conventional staircase would be very long and tiring to climb. Escalators can often be seen in shopping malls, museums, multi-story parking garages, and subway stations. In all buildings using escalators both upward and downward moving escalators are power driven. A gravity escalator uses gravity force to run a downward moving escalator. There by we can eliminate the need to power the downward moving escalator. Gravity force is widely used in many application as in Gravity conveyor, heat pipes etc. But it was never used for human transport. So in this paper we analyse how an escalator can be run with the help of gravitational force. One of the major problem is the acceleration during downward movement which is reduced with use of gear pump as a damper. It helps to utilise this energy to pump water instead of dissipating it as waste.

II. EXPERIMENTAL PROCEDURE

A. Zero Electricity Air Cooler

A Zero electricity air cooler is a device which consists of grids of plastic bottles which are cut into half and its brim fixed on a cardboard sheet which is then fixed to a window in the direction of maximum wind flow with wider end of bottle face outside.

This works based on the principle of Joule-Thomson effect. It describes the temperature change of a real gas or liquid when it is forced through a valve or porous plug while keeping it insulated so that no heat is exchanged with the environment. The air enters through the wider opening of the bottle and passes through the bottleneck. The air gets compressed here. This compression increases the velocity of air. So the air undergoes a rapid expansion at the exit of bottleneck. This rapid expansion causes a reduction in temperature and also a drop in pressure which in turn draws surrounding air to the stream.

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A software model of the bottle was created using the software Ansys 15.0 and CFD analysis was conducted to analyse about the change in temperature.

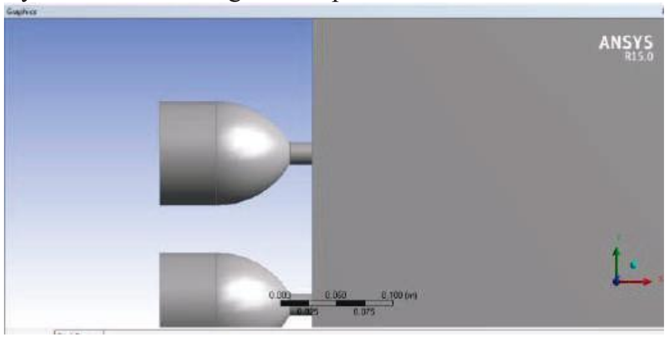

Fig. 1 Ansys model of bottle

After that a small experimental setup was arranged with three different bottle profiles. A single bottle was arranged on a cardboard box and a fan was setup in front of it to provide wind at different speed. And test was conducted for three different wind speed using the fan and change in temperature and velocity were analysed. A digital anemometer with inbuilt thermometer was used for this. For testing temperature difference of a room a cardboard of 80x35cm was cut out and holes were made in it in three rows and seven columns and bottle brim were inserted in it. It was then mounted on the window and temperature difference of inside was noted down.

B. Gravity Escalator

In this paper a conceptual model of an escalator that works with gravitational force as was modelled. This can reduce the human effort while climbing down a stairs and also can avoid the need to power an escalator that moves down. The main problem identified was high acceleration and increasing speed of moving down. So we need to damper this speed. For this many techniques can be used like mechanical dampers, eddy current dampers etc. but in all these the energy is dissipated as waste. So for this model we use gear pump as a damping method and this absorbed energy can be used to pump water for the building needs.

For experiment the gear pump used was Mahindra Assembly Oil Pump (9 cm L x 9 cm W x 33 cm H). Experiment was conducted for a smaller scale level. The gear pump was set up at three different heights, 1m, 2m, 3m with its inlet in water. On the shaft of the pump weight was attached. The weight was tied to a string and string was wound on the shaft. So that when weight moves down it rotates the shaft which rotates the gear and water is pumped. Thus it reduces the speed of weight moving down. This was conducted for four different weights of 0.5kg, 1kg, 1.5kg, 2kg. The time taken to reach down was calculated with stopwatch. The water discharged was measured and average velocity was calculated and plotted.

Based on the result it was extrapolated to a case of escalator for a height of 4m with a 35° inclination for a person of weight 60kg.

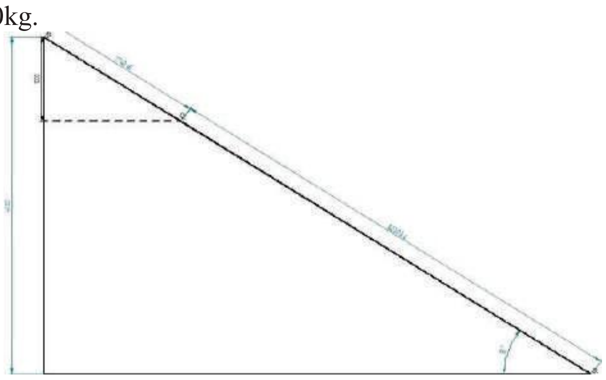

Fig. 2. Escalator analysis model

Initial point is named as P, a point Q is marked at a height 1m down from initial point and end position is named R on the inclined plane.
Distance PQ= 1.74m
Distance QR= 5.16m
Distance PQ is provided with free rollers and QR with rollers connected with gear pump through chain and sprocket method. So as the roller rotates gear pump also rotates which pump water.
Velocity at Q is $v_f=\sqrt{(2\square h\square\square 35)}$= 3.35m/s
Energy at point Q= $\frac{1}{2}\square\square^2$=336.675 J
This energy has to be absorbed during the distance QR
Safe speed of escalator= 0.5m/s
So time required to travel QR at this speed is 10.32s
Therefore, power to be given to pump during this distance is 336.6/10.32= 32.6kW

III. RESULTS

A. Zero Electricity Air Cooler

The figure 2 shows the Ansys result of bottle on CFD analysis

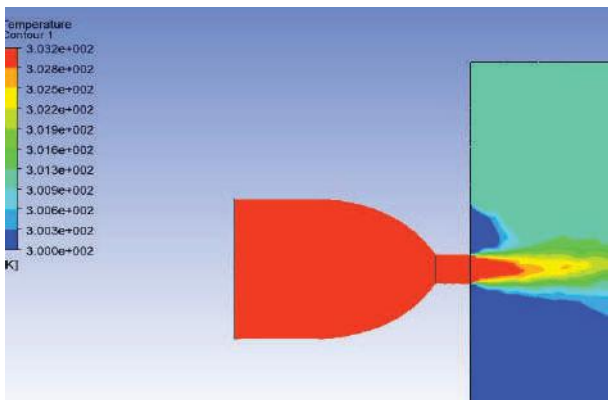

Fig. 3. CFD result of Ansys model

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The red colour represents air of high temperature (30°C) and blue colour represents air of lower temperature (27°C). So from the CFD analysis it shows a temperature difference of 3°C.

TABLE: I TEST RESULT OF BOTTLE PROFILE 1

Sl.no	Inlet velocity (kmph)	Exit velocity (kmph)	Inlet temperature (°C)	Exit temperature (°C)
1	5	5.8	34.2	33.7
2	7	8.5	34.2	33.4
3	10	12.3	34.2	33.1

TABLE II: TEST RESULT OF BOTTLE PROFILE 2

Sl.no	Inlet velocity (kmph)	Exit velocity (kmph)	Inlet temperature (°C)	Exit temperature (°C)
1	5	6.1	34.1	33.5
2	7	8.9	34.1	33.2
3	10	12.5	34.1	32.8

TABLE III: TEST RESULT OF BOTTLE PROFILE 3

Sl.no	Inlet velocity (kmph)	Exit velocity (kmph)	Inlet temperature (°C)	Exit temperature (°C)
1	5	5.9	34.1	33.6
2	7	8.6	34.1	33.2
3	10	12.7	34.1	32.9

From the test results it was found that the bottle profile doesn't have any much impact on the cooling effect. Because it can be seen that the temperature difference for a specific inlet velocity is almost similar for all three profiles. But it can be seen that the temperature difference is increasing with increase in wind velocity.

TABLE IV: TEST RESULT ON ROOM

Sl.no	Date	Inlet velocity (kmph)	Outlet velocity (kmph)	Inlet temperature (°C)	Outlet temperature (°C)
1	14/01/19	6.6	6.9	32.2	32.1
2	15/01/19	7.1	7.7	32.4	32.2
3	16/01/19	7.9	8.5	33.1	32.8
4	17/01/19	6.8	7.2	32.3	32.1
5	18/01/19	7.2	7.5	31.9	31.6

The table above shows the test results that is obtained by conducting the experiment inside a room. A cardboard sheet fixed with bottle was fixed on a window and temperature and velocity were measured. But by conducting this experiment the difference in temperature obtained was less. A maximum difference of 0.4°C was obtained. Maximum difference obtained was for the wind velocity 7.9 kmph.

B. Gravity Escalator

Test results conducted on gear pump with four different weights on heights 3m,2m,1m is tabulated

TABLE V: MASS-TIME READING FOR HEIGHT 3M

Mass (kg)	Time (s)
0.5	65
1	36
1.5	18
2	7

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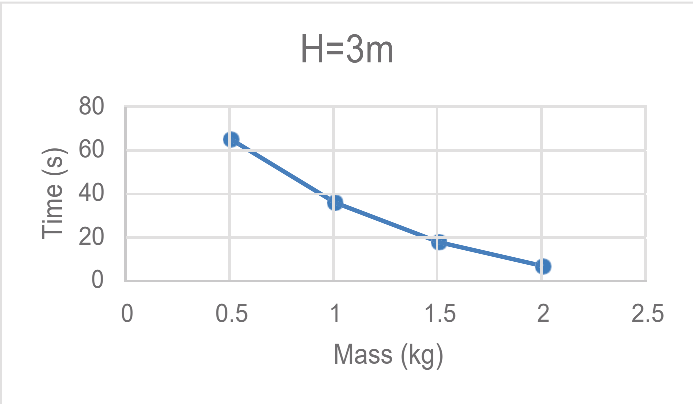

Fig 4: Graph plotting time and mass for height 3m

TABLE VI: MASS-TIME FOR HEIGHT 2M

Mass (kg)	Time (s)
0.5	44
1	25
1.5	10
2	5

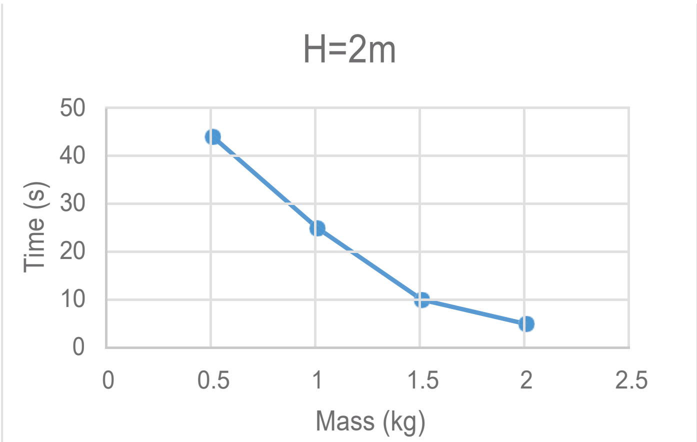

Fig 5: Graph of Time and mass for height 2m

TABLE VII: MASS-TIME FOR HEIGHT 1M

Mass (kg)	Time (s)
0.5	23
1	13
1.5	6
2	3

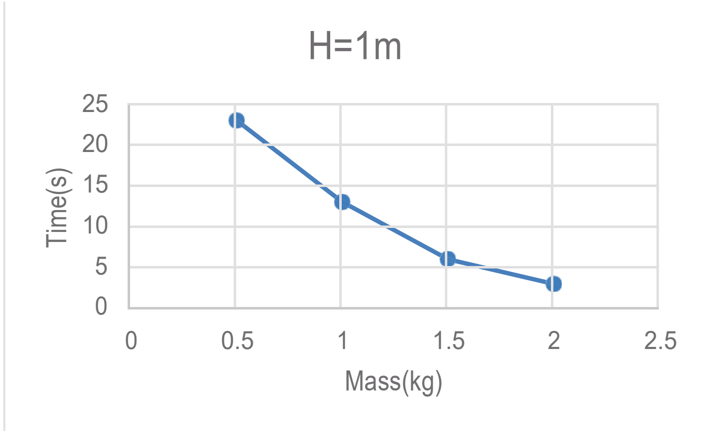

Fig 6: Graph of Time v/s mass for height 1m

From the results we can see that all three situations show similar relationship between Mass and time. As the mass increases the time required to reach the bottom is decreasing. But there is an acceleration for the mass moving down and is calculated by

$$a = \frac{mg}{m+M/2}$$

a= acceleration of mass moving down

m= mass suspended from height

M= mass of the gear shaft system

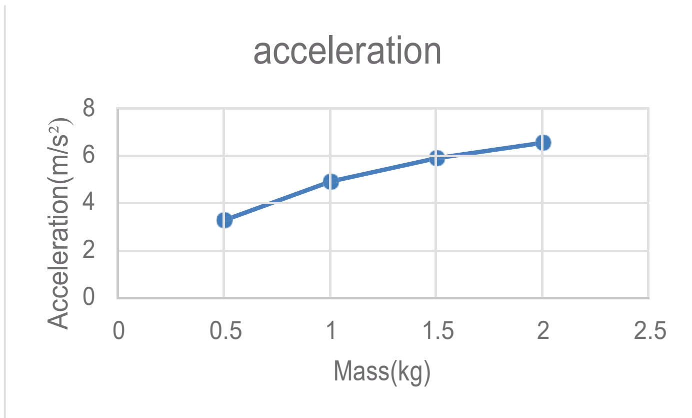

Fig 7: Acceleration with respect to masses

IV. CONCLUSION

Energy crisis is increasing day by day, so renewable and sustainable energy sources are required to be explored to meet up the demand in energy. Temperatures are getting intolerable these days, day by day the temperatures are increasing due to industrialisation, global warming, pollution etc. The zero electricity air cooler was zero pollution, low cost, easy to make, and, easy to install cooling device which will help the poor in surviving the summer heat by reducing the indoor temperature. But as observed from experiment it depends upon wind velocity. Only if there is sufficient velocity it can produce proper cooling effect

Gravity escalator was now only in conceptualization phase. But as gravity is always available we can use it to bring out productive output. It can help to reduce the total energy supplied to an escalator unit and also reduce the effort of human while climbing down stairs. The energy absorbed to reduce speed is used to pump water for the building uses. In this project we considered a single man of 60kg condition only. But there is future scope where it can be designed to carry more people as the research in sustainable energy is increasing to meet up the depleting energy resources

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Path Planning Optimisation for Field Coverage in a Limited Sensing Cleaning Robot using Divide and Conquer Approach

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Abstract: Cleaning robots are increasingly becoming popular in the home environments, but their cost, area coverage and performance has not been very impressive to their users, thus often restricting their user acceptance. Most of the current robot vacuum cleaners in the market clean the room with randomization, which will still leave some of the area of the room unclean. Many complete area coverage algorithms developed so far usually mandate the robot to have highly sophisticated navigation system for precise localization. This requires the use of high-cost sensors as well as high computational processing capacity, which in turn makes them costly and not suitable for common usage in home environments. The application of divide and conquer approach in solving the area coverage yielded fast and better results with utilizing only small computational capacity. This work proposes an efficient area division algorithm for the divide and conquer approach. This area division algorithm combined with the primitive and efficient boustrophedon algorithm can efficiently cope with hardware limitations ranging from low computational power to numerous sensing problems arising from limited range sensors also. This work aims at optimising path planning for a limited sensing cleaning robot with a novel integrated coverage strategy for low-cost cleaning and demonstrate respectable coverage performance in most known environments.

Keywords: Cleaning Robot, Coverage Path Planning (CPP), Divide and Conquer Approach, Boustrophedon Algorithm

I. INTRODUCTION

Robotics is a field which is much developed and still developing further for aiding in satisfying the specific needs of humans. Robotics field is now improving day by day. The introduction of Artificial Intelligence (AI) has changed the face of this field, hence robots are smart and becoming smarter by implementation of these cutting-edge technologies. This technology upgrade involves skilled programming levels, high sensing capabilities and higher computational power. This makes the robots costly and thus takes away its use in private households. Naturally this high cost has inspired to adopt new alternative solutions. Robots are of various types, out of which Mobile robots are the ones that mark the field with their range of applications. Wheeled Mobile Robots (WMR) are much common as they are less sophisticated in terms of other robot motions.

Robots are improving in tackling issues which are experienced by people. The use of mobile robots is increasing in modern ubiquity as well as in private family units. Thus, the difficulties for mobile robots are rising. Some present-day applications for mobile robots are vacuum cleaning, demining, garden cutting, floor cleaning and programmed reaping of crops. These days the security and energy consumption a significant job for mobile robots. In addition to that, robot's obstacle avoidance is another major criterion that needs to be discussed. In many cases, the previously mentioned robots share one common test, ie. covering a specific region, for these kinds of robots one primary research is the Coverage Path Planning (CPP). Presently, numerous robots in the market take care of the area coverage with randomization. In this methodology, the robot moves randomly inside the zone. On the off chance that the robot ventures sufficiently long, the region ought to be secured totally. This methodology is easy to implement but expends a great deal of energy.

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Genetic Algorithm is the best method when talking about path planning for obstacle avoidance, but in other hand, it is not suitable for coverage region path planning as it requires a lot of time for execution because of the number of iterations to be done. It also requires high computational power when dealing with larger number of individuals in a certain population. Path planning for coverage region in real life environments includes a larger amount of data to be processed, hence making the Genetic Algorithm not suitable for this kind of problems.

Divide and conquer is an approach which can be adopted for this situation. In this approach the problem is broken into different sub problems which are comparatively easy to solve, then solving the sub problems one by one and by combining each solution, the required final solution can be obtained. This approach requires comparatively very less time than the GA. So, in this case while considering the real-life scenario the area to be covered needs to be divided and then individually path planned. If the divided area is rectilinear then conventional to and fro motion ie. Boustrophedon Algorithm will solve the area coverage problem efficiently.

II. Development Of Path Planning Algorithm

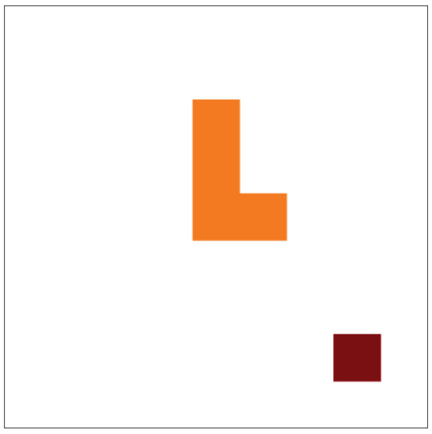
Coverage Path Planning algorithm is much more complex than the usual path planning algorithms for the obstacle avoidance. For that the prime importance is for the area coverage which is attained by the robot in motion. As this work is for limiting the sensing functions and thereby cutting the cost of the robot, we take into account that the room to be cleaned is known in prior. The plan of the room is generated with the help of graphic softwares. Then the optimised area division and path planning algorithm is designed, executed and tested using Python programming language.

2.1 Defining The Room Plan

In this work the room to be cleaned is known in prior, so the image corresponding to the room to be cleaned is created with help of graphic software Paint. Obstacles in the room are marked in colours at their respective places and the area to be cleaned is represented by the white blank space in the image.

To have a relation between the created image and actual workspace it is assumed that $50\ pixels\ (px)$ in the image corresponds to $30\ cm$ in real life environment. As the robot's actual size is proposed to be $30\ cm^2$, $50\ px^2$ will be the smallest unit in the image created. In this study we are considering a test area of $5.4m\ \times 5.4m$, so the image size to be created is $900\ px \times 900\ px$. So, we created some test environments for which corresponding images were made.

2.2 Image Processing



The images thus created are subjected to image manipulation techniques like conversion to binary image, obstacle edge detection etc. The images are shown in Fig 1. The image is converted to binary for the easy identification of obstacles. These images are converted to binary with the help of python imaging library 'pillow', binary images are as shown in Fig 2.

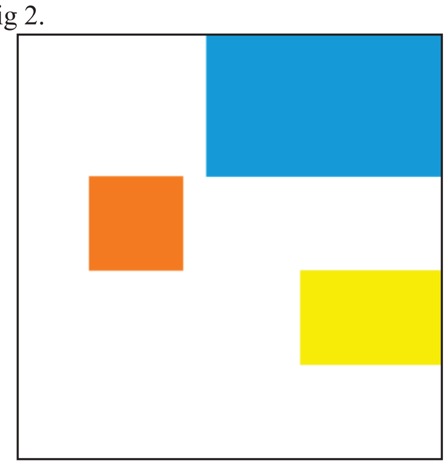


Fig 1 - Domains to be cleaned

2.3 Area Division

2.3.1 Gridding The Map

The image of the room or room map is then subjected to gridding. Gridding involves splitting the image into smallest square tiles, where each tile is having the size of the cleaner robot. The grids will be$50px \times 50px$ in the image and $30\ cm \times 30\ cm$ in real life as shown in Fig 3. After the

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gridding process each cell is analysed for black pixels. Wherever in a cell if a black pixel is encountered the cell is marked as obstacle because its unsafe for robot to visit that cell. The gridded cells are numbered for further path planning process. The final gridded map is shown in Fig 4.

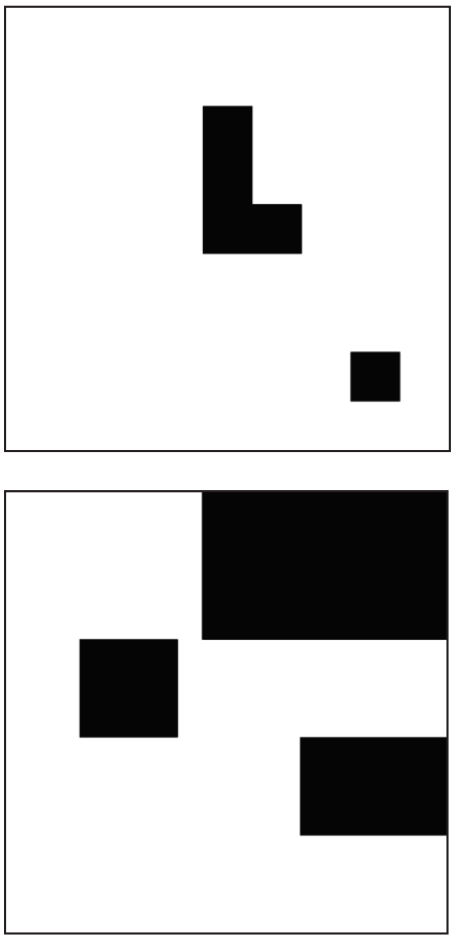


Fig 2 - Binary image of Domains

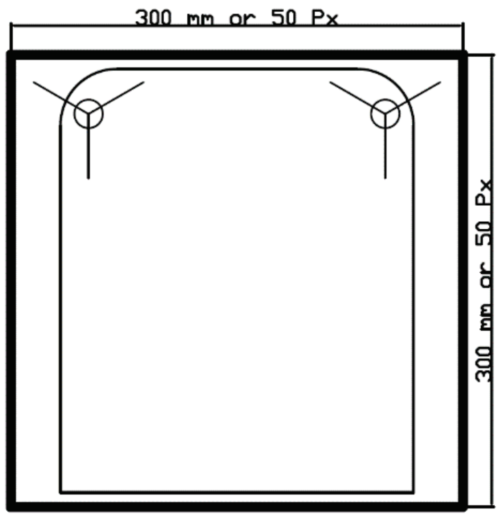
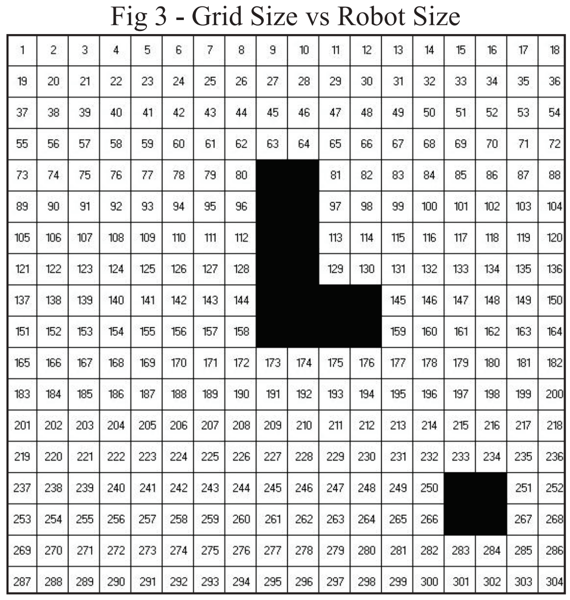


Fig 3 - Grid Size vs Robot Size



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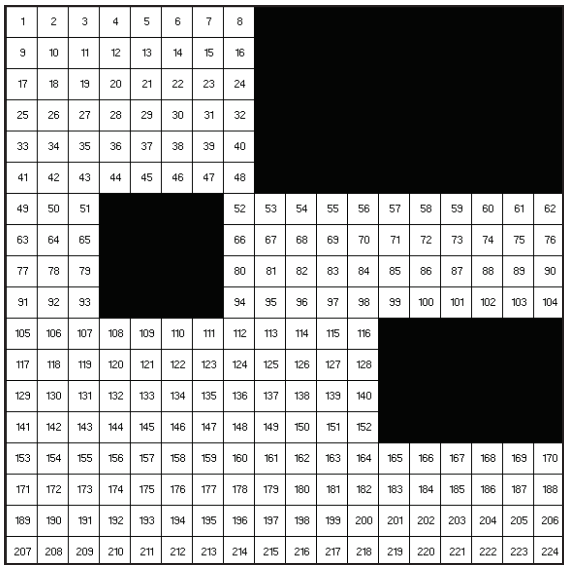

Fig. 4 - Gridded image – Domains

2.3.2 Obstacle Detection & Area Division

In binary image the area to be cleaned is white and obstacle is black in colour. Then by the help of Python libraries it is easy to identify the vertices of the obstacles marked black in colour. The coordinates of the vertices are stored in an array and will be used further for area division purposes. Then by using the proposed algorithm of Divide and Conquer approach rectilinear area division is carried out. The proposed area division method utilizes the obstacle features of the room for its efficient functioning. The Algorithm is shown in Fig. 5 & the area divided image is shown in Fig. 6.

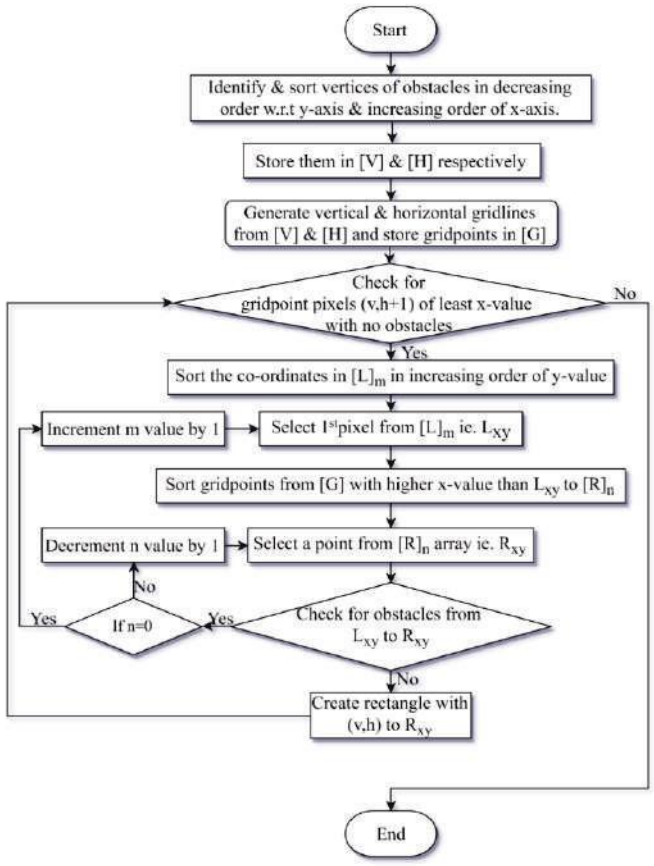

Fig. 5 - Optimised Area Division Algorithm

2.4 Path Planning

Path planning is the process of building the path for the motion of the robot. In this work we are aiming for an optimal path which has a least number of multiple visits to a single cell. As the path generated for this work is to attain coverage of a certain area, the complete path for an entire area needs to be defined. Hence, after completing the image processing, resultant image after gridding is then used for path planning using Boustrophedon algorithm. Initially the map is analysed to study which all cells lie next to each other. This is done by a precursor step known as the cell sharing.

2.4.1 Cell Sharing

Cell sharing is a precursor step in the path planning where each cell is analysed for its immediate neighbour and are found out whether they are of the same cell group. Cells in the same cell groups are stored separately and are analysed which all cells are at the four robot motion positions ie. at top, bottom, left and right. The cells data are then stored in an array and will be further used in path planning purposes.

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2.4.2 Boustrophedon Algorithm

The Boustrophedon Cell Decomposition (BCD) is a method used in artificial intelligence and robotics for configuring the space solutions. Like other cellular decomposition methods, this method transforms the configuration space into cell regions that can be used for path planning. This algorithm is the conventional to and fro motion algorithm which attains an area coverage by simple to and fro motions. The visualization of algorithm is shown in Fig. 7.

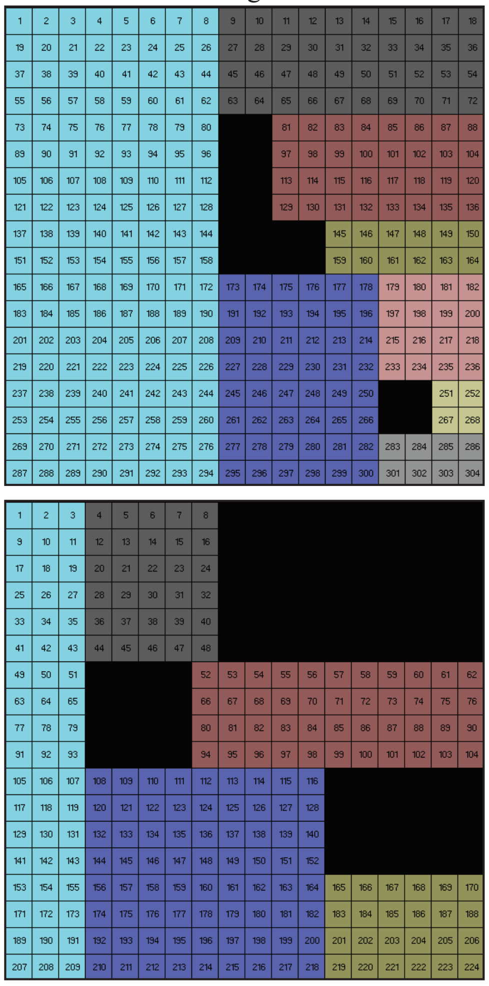

Fig. 6 - Divided area Domains

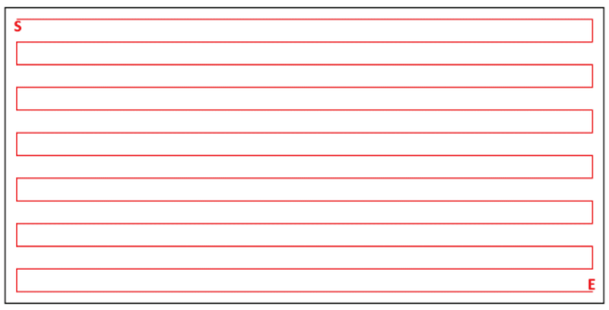

Fig 7 - Boustrophedon Algorithm

The cell data array obtained from the cell sharing step is then taken into account & by applying BCD algorithm each grid number is sorted and stored. Then path is then drawn connecting the centre point of all these square tiles. The path drawn is shown in Fig. 8. This will be used as the path for the motion of the robot. Now this path information has to be changed into a format that is easily understood by the robot for its actual motion. So, this path is then converted to numerical matrix data form ie. into the path length and the directions to turn. The numerical matrix data form is then transferred to robot controller.

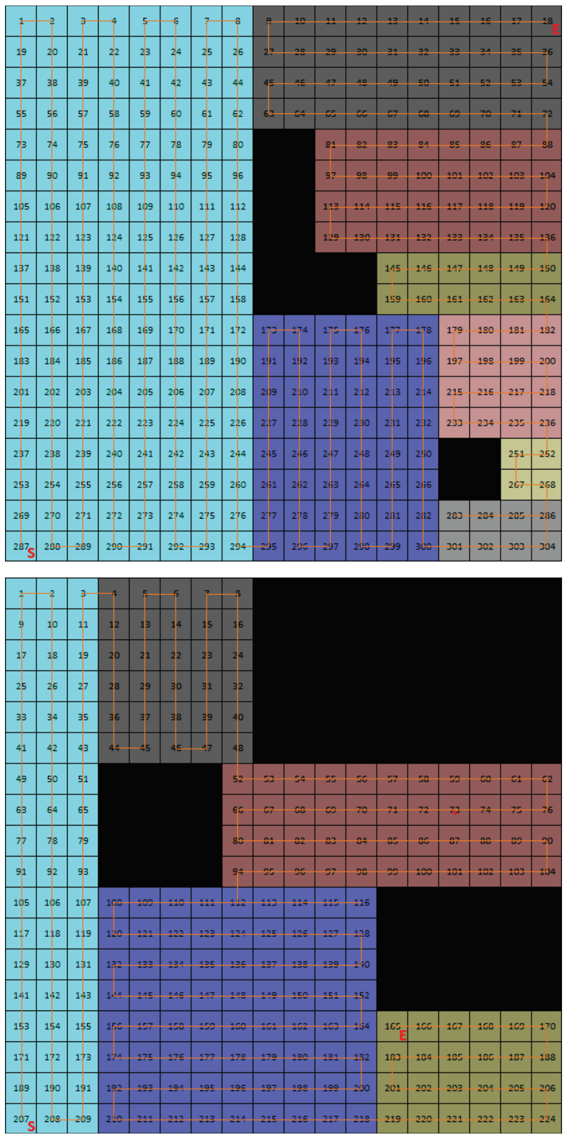

Fig. 8 – Path planned Domains

Here we can see that the path is so planned that the path does not intersect each other, but the robot has to take some retracements to implement the boustrophedon algorithm effectively. This is marked in the Path plan as 'R', in Domain

1, the robot retraces 3 cells and for Domain 2 the robot retraces 4 cells. These retracements can be accommodated to an extend as the proposed algorithm delivers an efficient optimal solution to our problem. The Path obtained is now converted into matrix data which will be of a 1 by n matrix form, [L] to denote the length & [D] to denote the directions. These matrices are then given as input to the controller reads both the matrices and identifies the path to be executed by the robot.

For Domain 1 it will be as follows:

[L] = [17, 17, 17, 17, 17, 17, 17, 17, 7, 7, 7, 7, 7, 7, 7, 4, 3, 3, 1, 1, 1, 1, 1, 3, 3, 3, 3, 5, 5, 7, 7, 7, 7, 7, 9, 9, 9, 9, 9]

[D] = [F, RU, LU, RU, LU, RU, LU, RU, LU, RU, LU, RU, LU, RU, L, F, LU, B, LU, RU, LU, RU, LU, RU, LU, RU, LU, RU, LU, RU, LU, RU, LU, RU, LU, RU, LU,]

Firstly, the direction matrix [D] is read, and for each character each program is written in the controller. For the letter 'F' Forward function is called where both the wheels move with a constant velocity. Similarly, for the letters 'RU' & 'LU' Right U turn function & Left U turn function is called respectively. For the letter 'B' Backward function is called, where the robot changes its direction and moves back or retraces the path.

These matrices may change according to each room that is taken into account. The matrices are generated by Python program by reading the red line path in the domain map. These matrices are obtained using a PC and these are fed into the controller by programming it via PC. A microprocessor will do the function of generating the matrices but, for this work it was not adapted. The computational speed of the most commonly available microprocessor 'Raspberry Pi 3' is not up to the PC for doing this function. This may be due to the complications or less experience in programming. Which indicates the need of the program to be optimised.

III TESTING & RESULTS

The robot was fabricated programmed and tested in a test environment of 1.8m x 1.8m and the robot performed well according to the map provided. The dust and paper bits which were on the floor were cleaned by the robot leaving no dust or waste particles on the floor.

Fig. 9 – Robot after fabrication

Certain complications that arouse were the time for calculating the map time using the Raspberry Pi microprocessor. This was rectified by doing the program outside the robot, using the help of a pc. The program is run and the output matrices are then extracted and loaded to the controller of the robot.

While executing the robot motion, the robot keeps on moving in its own path upto a certain limit. After which the robot shows some error in the distance. This error is mainly due to wheel slippage during turns of the robot. The encoder feedback is also affected by noise which is prone to other signal noises in the system.

IV. CONCLUSIONS

- The robot is cleaning the room as expected. The performance is much better than the robots which clean the room by randomizing.
- Robot cleans the room efficiently by avoiding multiple passes through a cleaned region.
- The errors in the system needs to be checked for their accuracy and the feedback should be free from errors in order to efficiently navigate robot through the room
- The clearance of the robot has to be kept at an optimum level to avoid collision with carpets or an additional roller has to be provided infront.

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Investigation of Mechanical Properties in 5A Grade Duplex Stainless Steel and Niobium stabilized 5A Grade Duplex Stainless Steel

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Abstract: Duplex stainless steels have enjoyed rapidly increasing popularity in recent years. Duplex stainless steel castings are often used in a variety of applications where unexpected service failures can result in significant operational problems and expense. In this study two different castings (standard and with stabilization) of same grade are considered for evaluation. Intergranular corrosion of duplex stainless steel is a major concern in high corrosive environments. Interstitial stabilization of alloy is a possible solution for susceptibility to inter- granular corrosion. In this proposed work niobium addition is made on 5A grade cast duplex stainless steel in order to achieve the stabilization. The required addition of niobium was made by considering the carbon, nitrogen content in the composition. Niobium being a stronger carbide and nitride former than chromium, it suppress the chromium depletion and thus increase the inter-granular corrosion resistance. In this present work mechanical properties of both the specimens were identified to compare standard and stabilized samples with respect to their tensile, impact and hardness characteristics.

Keywords: : Duplex stainless steel; Intergranular corrosion; Niobium; Mechanical properties

I. Introduction

Steel is an alloy of iron which contains elements such as Cr, Ni, Mo, Mn, N, C etc. Stainless steels are steel which consists of more than 10% Cr in their composition. Stainless steels are generally used where corrosion and oxidation resistance is important. In duplex stainless steel, iron is the main alloying element and Cr, Ni, Mo, N and other elements are added to maintain the ferrite–austenite ratio in the alloy. Duplex stainless steel consists of equal fraction of ferrite and austenite in their microstructure. These duplex stainless steels are highlighted by their attractive properties such as high corrosion resistance, fire and heat resistance, strength to weight advantage tough and impact resistance etc. Its field of application is wide such as refineries, shipping, automobile, textile machinery, tannery equipments, pumps, elevators and escalators etc. Based on their elemental composition duplex stainless steels are classified into different grades such as 1A, 2A, 3A, 4A, 5A, 6A, 7A grade. From these grades 5A grade is mainly used for experimental purposes. In this project niobium is stabilized with DSS to investigate variation in mechanical properties and comparing variation with the standard DSS. High level of chromium is important to stabilize duplex structure while carbon and nitrogen, precipitate on grain boundary leaving a chromium depleted zone thereby promoting intergranular corrosion. To reduce this problem specific alloying elements such as titanium, niobium, zirconium and tantalum is used. Niobium is used as an stabilizing element for duplex stainless steel, within which it forms niobium carbide and niobium nitride. These compounds improve the grain refining, and reduce secondary precipitates. These effects in turn increase the toughness, hardness, formability and weldability. Within micro alloyed steel, niobium content is small (less than 0.1%). This paper is divided into following section. Section 2 explains the previous work. Section 3 mentions about materials and casting procedure. Section 4 deals with tests and analysis. Section 5 deals with the results and discussion. Section 6 concludes the work.

II. LITERATURE SURVEY

Several studies are conducted now on application of Nb in stainless steels. Nb is added with ferritic stainless steel and austenitic stainless steel and the improvement in hardness value and toughness value are compared.

Mehmet Turker and Levon Josef Capan (2017) investigated variation in mechanical properties of Nb stabilized austenitic steel with sand casting and centrifugal casting technique. The tensile strength, hardness value of centrifugal casting and sand casting techniques are compared. SEM, EDS results shows that the sand cast samples had chromium carbides in small quantities, in addition to the niobium carbides.

Leandro Paulo de Almeida Reis Tanure and Claudio Moreira de Alcantara (2016) conducted study on comparison of microstructure and mechanical behavior of the Ferritic Stainless Steels ASTM 430 stabilized with niobium and ASTM 439 stabilized with niobium and titanium. This research shows that the volume fraction of precipitates is more for ASTM 430 Nb stabilized steel compared to ASTM 439 niobium titanium bi stabilized steel and also the yield stress and totalelongation is more for ASTM 430 Nb stabilized steel due to smaller grain size compared to ASTM 439 bi stabilized steel.

Prabhu paulraj and Rajnish Garg, (2015) presented a paper on effect of intermetallic phases on corrosion behavior and mechanical properties of duplex stainless steel and super duplex stainless steel which shows the formation of intermetallic phase formed due to precipitates and mentions all the phase formation during heating. The intermetallic phases affect impact toughness and corrosion resistance. This journal suggests us to control the phase formation with appropriate chemical composition.

Marina Knyazeva and Michael Pohl, (2013) conducted study on Duplex Steels Part I: Genesis, Formation, Structure which shows that the DSS posses better mechanical properties when compared to features completely ferritic or completely austenitic. It also shows all the chemical composition of ferritic, austenitic and duplex stainless steel. Also detailed explanation is provided about mechanical properties, merits and demerits of DSS. The same authors in 2013 conducted study on Duplex Steels. Part II: Carbides and Nitrides shows the precipitation behaviour of alloying elements. Due to these precipitates carbides and nitrides are forming which reduces the corrosion resistance and cause brittle material fracture.

K Hulka, A Kern, and Schriever, (2005) presented a paper on application of niobium in quenched and tempered high-strength steels. The change in mechanical properties are compared such as strength and toughness with the addition of Nb and without the addition of Nb. And also the field of application of Nb micro alloyed high strength steel are presented.

The work of B.I. Voronenko (1997) on Austenitic Ferritic stainless steels deals with the precipitation behaviour as well as characteristics of DSS. This is the base journal of the thesis and the topic of duplex stainless steel is evolved from here.

III. MATERIALS AND METHODS

Materials used for the present work includes 5A grade and 5A grade stabilized DSS. Ferro silicon, ferro manganese, ferro molybdenum, primary nickel, LC ferro chrome, nitrated LC ferro chrome, ferro niobium, pure iron are the various raw materials used for casting both 5A grade DSS and 5A grade niobium stabilized DSS based on charge calculation.

The procedure for casting both the specimens were done by using induction melting furnace. Ferro alloys are added inside the crucible. The power is switched on. The frequency is set around 50Hz to rise the temperature. The metal mixture will melt according to the rise in temperature in the crucible. By tilting the crucible using the provided lever the molten metal is poured into the mild steel split mold. Within 15-20 minutes molten metal solidifies. Final cast is removed from the mold.

IV. TESTS AND ANALYSIS

A. *SPECTRO ANALYSIS TEST*

This test is usually done to identify the composition of elements in the specimen. Optical spectrometry was used to identify the elements present in the specimen. For this purpose SPECTROMAX LMX07 machine is used to analyze the metals present in both the steels.

B. *TENSILE TEST*

The specimens are prepared according to ASTM (American society for testing of materials) A370 using universal testing machine of model TUECN-400 and machine number CL/ME/UT ME01. The prepared specimen were subjected to tranverse tensile test.

C. *HARDNESS TEST*

The hardness value of both the duplex stainless steel was determined as per ASTM A 370 and E 10 using Brinell hardness testing of model AKB 3000 and machine number CL/ME/BRIN03 often use a very high test load (3000 kgf) and a 10mm diameter indenter.

D. *IMPACT TEST*

The equipment used for calibrating is in accordance with ASTM E23 using charpy impact testing of model AIT-300-EN and machine number CL/ME/IMPA02. The standard test peace shall be 55mm long and of square section, with 10mm sides. In the centre of the length, there will be a V notch. Test specimen are marked with heat number for identification.

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E. MICROSTRUCTURE ANALYSIS

The microstructural analysis of the specimen prepared were carried out using optical metallurgical microscope of model MVMS I 310 and machine number CL/ME/IMAG/15 at an ambient temperature of 25.7°C. Optical microscope uses light for imaging. The magnification was carried out in 100X and 500X in order to identify the two phase structure of duplex stainless steel at different magnification power.

F. SEM, EDS ANALYSIS

Field Emission Scanning electron microscopy (SEM) was used with backscattered electron technique under magnification of 3000X, the surface of specimen is scanned with an electron beam and the reflected or scattered beam of electrons is displayed using a cathode ray tube. Mainly the surface features can be examined with SEM.

Energy dispersive X ray spectroscopy (EDS) analysis of the samples were done in order to calculate the percentage of elements in each points. This EDS system is typically equipped with SEM instrument. For these purpose Zeiss Neon 40EsB Cross beam equipment is used.

V. RESULTS AND DISCUSSION

A. SPECTROANALYSIS TEST RESULTS

Table I: Chemical composition for standard DSS

Elements	%wt
C	0.025
Si	0.838
Mn	0.882
S	0.003
P	0.017
Cr	24.68
N	0.19
Ni	7.1
Mo	3.815
V	0.059
Co	0.40
Cu	0.78
Fe	61.2

From the above table we can see that there is a major content of Fe and Cr as in case of 5A grade DSS.

TABLE III: Chemical composition for niobium stabilized DSS

Elements	%wt
C	0.039
Si	0.786
Mn	0.736
S	0.06
P	0.021
Cr	23.457
N	0.18
Ni	6.82
Mo	4.17
Nb	0.33
V	0.025
Co	0.043
Cu	0.28
Fe	63.1

From the above table we can see that there is a content of niobium in niobium stabilized DSS (0.33%). So that we can proceed with further tests.

B. TENSILE TEST RESULTS

TABLE IIIIVV: Tensile test result of standard DSS

Max load(kN)	102.0
Yield strength(MPa)	651.378
UTS (MPa)	848.518
Elongation(%)	29.50

TABLE VIV: Tensile test result of niobium stabilized DSS

Max load(kN)	98.56
Yield strength(MPa)	660.658
UTS (MPa)	895.458
Elongation(%)	29.60

FIGURE I: Broken tensile test specimen

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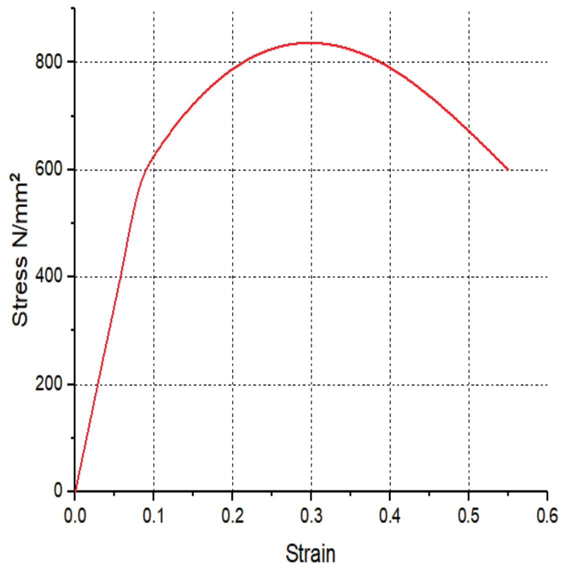

FIGURE VIIVIII: Stress vs strain of standard DSS

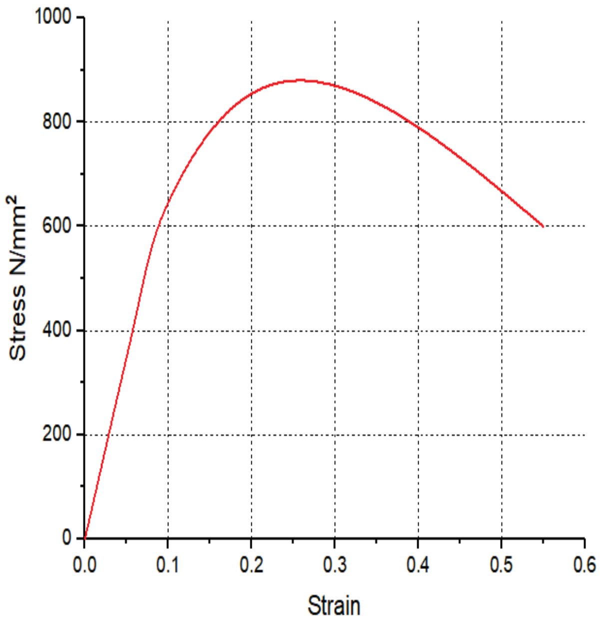

FIGURE III: Stress vs strain of niobium stabilized DSS

The yield strength and ultimate tensile strength values of standard DSS are less (651.378MPa and 848.518MPa) compared to niobium stabilized DSS (660.658MPa and 895.458MPa), the difference between percentage elongation of both the steel is 0.10. From the tensile test result we can see that the tensile strength increases to up to 45.7MPa.

C. HARDNESS TEST RESULTS

TABLE V: Hardness test result of both steels

Specimen	Observed values HBW (10/3000)			Average values (HBW)
Standard DSS	255	255	241	250
Stabilized DSS	269	255	255	260

FIGURE IXV: Hardness test specimen

From the above table it is evident that niobium stabilized DSS posses more hardness value (260HBW) which indicates on the addition of niobium has influenced the hardness of the specimen.

D. IMPACT TEST RESULTS

TABLE VX: Impact test result of both steels

Specimen	Impact energy(J)			Average value(J)
Standard DSS	192	194	193	193
Stabilized DSS	210	212	214	212

FIGURE V: Broken standard DSS specimen

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FIGURE VXI: Broken niobium stabilized DSS specimen

From the above table it is evident that niobium stabilized DSS posses better impact toughness value (212J).

E. MICROSTRUCTURE ANALYSIS

Mag:100X

Mag:500X

FIGURE VXIIXIII: Optical micrograph of standard DSS

Mag:100X

Mag:500X

FIGURE VXIVXVXVI: Optical micrograph of niobium stabilized DSS

The above micrograph represents two phase microstructure ferrite (dark) and austenite (light) region. The reagent used to identify the structure is Villela's reagent.

F. SEM, EDS ANALYSIS RESULTS

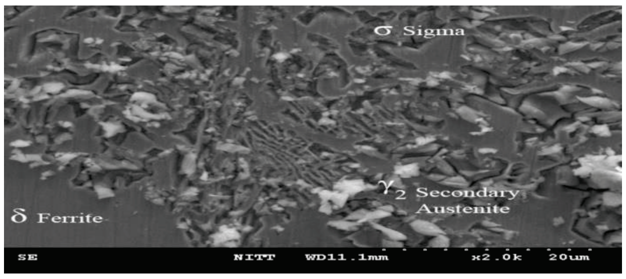

FIGURE IX: SEM image of standard DSS

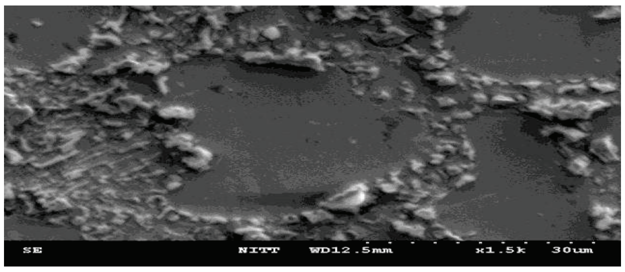

FIGURE X: SEM image of niobium stabilized DSS

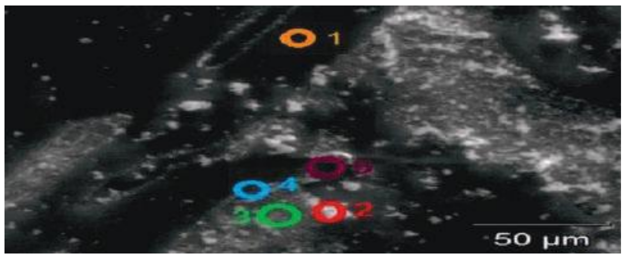

FIGURE XI: EDS image of standard DSS

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TABLE VXVIIXVIII: EDS analysis report on DSS

Details	C	N	Cr	Fe	Ni	Mo
Point 1	0.10	5.44	25.24	57.20	9.32	2.70
Point 2	1.84	7.51	9.28	66.35	12.2	2.81
Point 3	0.58	1.13	31.36	54.34	4.65	7.94
Point 4	3.34	2.32	12.30	70.41	6.80	4.83
Point 5	3.45	7.4	35.63	40.30	5.08	8.14

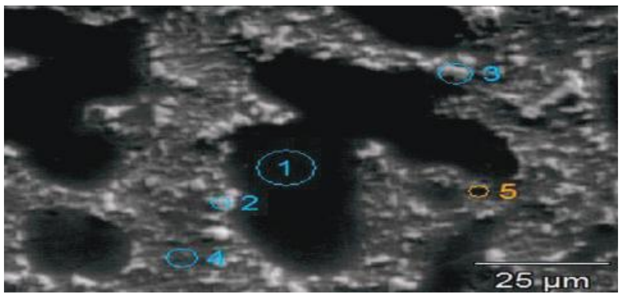

FIGURE XII: EDS image of niobium stabilized DSS

TABLE VXIXXXXXI: EDS analysis report on niobium stabilized DSS

Details	C	N	Cr	Fe	Ni	Nb	Mo
Point 1	0.35	1.17	25.95	57.52	8.53	3.35	3.13
Point 2	0.81	0.47	28.6	58.36	3.43	2.35	5.98
Point 3	2.22	0.94	23.69	59.04	5.03	5.55	3.53
Point 4	0.25	0.71	26.53	59.13	6.99	2.53	3.86
Point 5	0.87	1.22	23.27	60.41	5.94	4.67	3.62

From the EDS analysis report we can see that the chromium content in the stabilized sample is almost constant and within the specified range of 23-28 wt percentage.

VI. CONCLUSION

Both the standard 5A grade duplex stainless steel and 5A grade niobium stabilized duplex stainless steel has been casted. Further tests such as spectroscopy test, tensile test, hardness test, impact test were conducted to compare the results to evaluate the variation in the results. Also image analysis such as optical microscopy, SEM, EDS was also carried out. From the tensile test we can see that the yield strength and ultimate tensile strength is more on niobium stabilized DSS which means ability to withstand external force without breaking is more for niobium stabilized DSS compared to standard DSS. The hardness and impact test results of the stabilized DSS indicates that niobium has influenced the composition to increase both the values. The optical test result indicates the precipitation in the standard sample is more, where as precipitation is lesser in the stabilized sample which is influential in deciding the mechanical properties of the material.

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Manufacturing and Analysis of Bamboo Fiber Reinforced Epoxy Composite

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Abstract: In this work Bamboo fiber reinforced epoxy matrix composites were fabricated and its mechanical properties were analysed by considering the factors such as matrix reinforcement ratio and fiber arrangement. Bamboo fiber reinforced epoxy composite was fabricated using 6% NaOH treated bamboo fibers of different arrangements like unidirectional, cross weaved and random and in the random arrangement, different fiber lengths 10 mm, 20 mm and 25 mm were also considered. Mechanical properties like tensile strength, impact strength etc. are analysed using ASTM standard specimen. Microscopic inspection of Bamboo fiber epoxy matrix composite done through SEM (Scanning Electron Microscopy). SEM results revealed that fiber breakage, matrix cracking, fiber matrix debonding and fiber pull out are major causes of failure of composite. A hand guard for sports bike is fabricated using the optimized combinations.

Keywords: Bamboo fiber, Epoxy composites, Mechanical properties, Matrix Reinforcement ratio, Fiber arrangement, SEM.

I. Introduction

Composites are one of the most widely used materials because of their adaptability to different situations and the relative ease of combination with other materials to serve specific purposes and exhibit desirable properties. Composite materials are primarily employed as structural materials in light weighting applications due to the high strength weight and modulus weight ratios. Glass and carbon fibers have traditionally been the most commonly employed reinforcing materials. The applications of composite materials are vast and can be used in each and almost every field. They possess applications in buildings and public works (chimneys, housing cells, door panel, windows, partitions, swimming pools, furniture and bathrooms); electrical and electronics (insulation for electrical construction, armor, boxes, covers, cable tracks,antennas, tops of television towers, and wind mills); general mechanical components (gears, bearings, housing, casing, jack body, robot arms, flywheels, weaving machine rods, pipes, components of drawing table, compressed gas bottles, tubes for offshore platforms and pneumatics for radial frames); rail transports (front of power units, wagons, door, seat, interior panels and ventilation housing); road transports (body components, complete body, wheel, shields, radiator grills, transmission shaft, suspension spring, chassis, suspension arms, casing, cabin, seats, highway tankers and isothermal trucks); marine transports (hovercrafts, rescue crafts, patrol boats, trawlers, anti-mine ships, racing boats, pleasure boats and canoes); space transport (nozzles, rocket boosters, reservoirs and shields for atmosphere reentrance); air transports (all composite passenger aircrafts and gliders, helicopter blades, propellers, transmission shafts and aircraft brake discs); cable transports (telepherique cabins and telecabins); sports and recreation (poles used in jumping, tennis and squash rackets, fishing poles, bicycle frames, roller skates, skies, sails, javelins, surf boards, bows and arrows, protection helmets, golf clubs and oars) etc.

There has been tremendous interest in using natural fiber composites instead of synthetic fibers because of their low density, abundant availability, low cost and biodegradability. Bamboo fibers have significant potential in composite making due to its high strength and environmentally friendly nature. Bamboo fiber has higher ultimate tensile strength than most of natural fibers such as jowar and sisal. Bamboo fiber also has higher tensile modulus than banana, sisal, coir fibers etc.

The combination of Bamboo fiber with epoxy matrix has been used by various researchers. Bamboo fiber has higher ultimate tensile strength than most of natural fibers. Bamboo fiber reinforced epoxy composites can be used in applications where carbon fiber and glass fiber based composites are being used. Bamboo fiber is one of the most widely used natural fibers and has great potential as reinforcement in polymer composites; hence, bamboo fibers have been chosen for the current work as a reinforcement fiber.

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II. OBJECTIVE

The main goal of this study is to explore the potential of using bamboo fibers as reinforcement for epoxy composites. Specifically, the project covers the followings.

To prepare bamboo fibers to be used as reinforcement for epoxy composites and prepare the bamboo fibre reinforce epoxy composites. The influence of the matrix reinforcement ratio, fiber arrangement and fiber size on the mechanical properties of the composite will be investigated. Evaluation of mechanical properties such as tensile and impact strength of composites. To study the fracture surface morphology and investigate failures using SEM. And also fabricate the bike handle guard.

III. LITERATURE SURVEY

Ziaullah Khan, B.F. Yousif, Mainul Islam [1] presented a paper on Fracture Behavior of Bamboo Fiber Reinforced Epoxy Composites. Optimum NaOH concentration for treatment of bamboo fibers was determined through single fiber tensile test. Single fiber tensile test and Single Fiber Fragmentation test results show that fibers treated with 6% NaOH show better ultimate tensile strength and interfacial shear strength.

Darshil U. Shah, Bhavna Sharma, Michael H. Ramage [2] Processing bamboo for structural composites: Influence of preservative treatments on surface and interface properties.The wetting behaviour and adhesive bonding performance of the bamboo material with epoxy resin. Optimised industrial manufacturing and material performance of products such as epoxy bamboo composite, it is imperative to understand processing-property relations specific to bamboo.

N. Amir, Kamal Ariff Zainal Abidinb [3] presentedthe effects of Fibre Configuration on Mechanical Properties of PP/MAPP Natural Fibre Reinforced Polymer Composite. The advantages of natural fiber reinforced PMC are biodegradable, recyclable, lightweight, low production cost, and readily available. Therefore, natural fiber reinforced polymer composites have been used for many applications such as automotive components, aerospace parts, sporting goods and building industry.

Elanchezhian, Vijaya Ramanath,G.Ramakrishnan[4] investigatedon mechanical properties of natural fiber composites. The mechanical and physical properties of natural fibers varies from fiber to fiber. Natural composites like bamboo, jute, sisal are used in many engineering applications, because of its superior properties such as specific strength, low weight, low cost, fairly good mechanical properties, and nonabrasive, ecofriendly and bio degradable characteristics. The mechanical property among these material is good for bamboo.

Dirk E. Hebel, Alireza Javadian,Felix Heisel,Karsten Schlesier,Dragan Griebel [5] Evaluated the tensile strength of bamboo fiber composites for structural applications. Tensile and flexural properties of Bamboo fiber composites with different reinforcement configurations were evaluated.

Subhankar Biswas,Sweety Shahinur,Mahabub Hasan [6] investigated Physical, Mechanical and Thermal Properties of Jute and Bamboo Fiber Reinforced Unidirectional Epoxy Composites done.SEM analysis, tensile and flexural testing and thermo gravimetric analysis were performed in order to evaluate surface morphology, mechanical properties and thermal behaviour of the unidirectional composites respectively. It is observed that bamboo fiber reinforced epoxy composites showed good results in terms of tensile strength.

IV. METHODOLOGY

A. MATERIALS

In this study, bamboo fiber is used as reinforcement in the composite due to its low cost, low density, high specific strength and modulus and renewability as a natural product. Epoxy resin is used as matrix in the composite because epoxy exhibit higher mechanical properties than other resin such as polyester and vinyl-ester. It is expected the bamboo fiber can reinforce the epoxy's mechanical properties especially in impact strength. But the bamboo fiber must be chemically treated before used to reinforce epoxy according to references.

1) BAMBOO FIBER

In this work bamboo fiber selected mainly based on their arrangement. Here considered mainly three types of arrangement unidirectional, cross woven (figure1.1) and random short fibers (figure 1.2). These random short fibers are mainly in three different length 10mm, 20mm and 25mm. All fibers are treated with 6% of NaOH solution for 24 h as shown in figure 1.3. After treatment, fibers were washed with clean water and dried in air for approximately another 24 h. So this chemical treatment with NaOH gives a rougher surface of sisal fiber and is able to provide a better bonding between sisal fiber and epoxy resin, in order to acquire a better interfacial bonding natural fiber composite materials.

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Figure 1.1 Cross woven Bamboo fiber

Figure 1.2 Random Bamboo fibers

Figure1.3 Bamboo fiber soaked in 6% NaOH solution

2) EPOXY RESIN

Epoxy resins are the most versatile amongst all other polymers; it exhibits a number of highly desirable properties like Low shrinkage,Excellent chemical resistance,Outstanding mechanical strength,High adhesion to a many substrates,Good electrical insulating properties.

In this study, the Kinetix R246TX Liquid Epoxy Resin and Kinetix H160 as Hardener have been used shown in figure. Kinetix R246 is a solvent free, low viscosity epoxy resin developed by ATL Composites Pty Ltd, with hardener H160, it is able to cure at room temperature or low elevated temperatures. According to its specification, its pot life under 25 C is 120 mins, mixing viscosity 300 MPa. And the demolding time is 28 hours. So it is very suitable for laboratory to fabricate suitable composite systems. And this epoxy resin system has a variety industry application in boat and automobile industry, so we use this epoxy resin in preparing for further industry application of our bamboo fiber/epoxy composite system.Kinetix R246TX Liquid Epoxy Resin is an opaque liquid and Hardener is a clear pale brown liquid.

B. COMPOSITE FABRICATION

This experiment used a ply wood mould (200X200X4mm3) shown figure 2.1, which contains 8 specimen dimensions for impact strength testing. Similarly another ply wood mould (200X200X2mm^3) of 8 specimen dimensions used for tensile strength testing. The testing specimens are fabricated as per the ASTM e4 Standard shown in figure 2.2. The mould is coated with a releasing agent Enzo G-Star AP Grease which is commonly used in automobiles. Mould is placed over a plywood plate which is same dimensions as the mould. The epoxy resin (R246TX) and corresponding hardener (H160) is mixed in a ratio of 10:1 by weight percentage. Composites of various compositions with three different fiber loading (40wt%, 50wt% and 60wt %) and three different fiber orientation like unidirectional, cross woven, random arrangement are fabricated using simple hand lay-up technique.

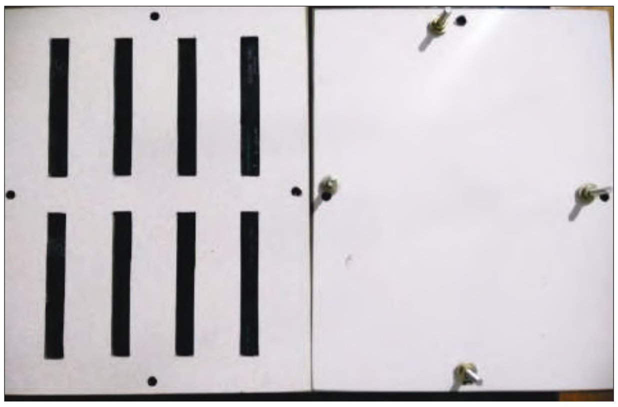

Figure 2.1: Impact test specimen mould

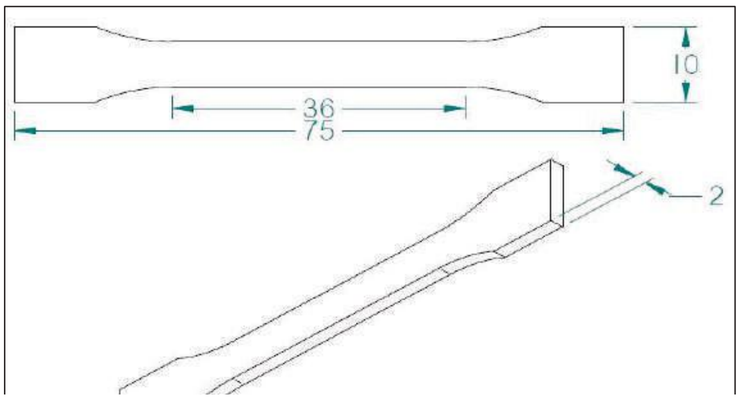

Figure 2.2: Tensile test specimen

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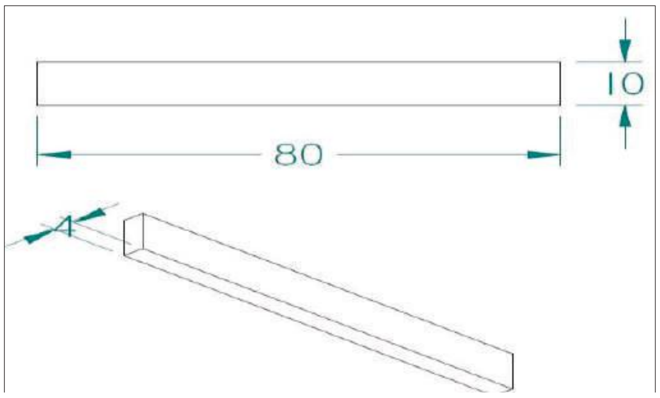

Figure 2.3: Impact test specimen

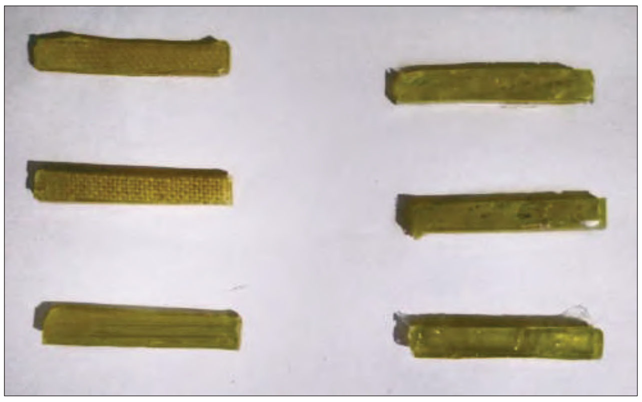

Figure 2.1.1: sample impact test specimen manufactured

D. MECHANICAL TESTING OF COMPOSITES

1) TENSILE TEST

The tensile test is generally performed on flat specimens. The most commonly used specimen geometries are dog-bone and the straight side type with end tabs. The specimen dimensions used in present case is shown in figure 2.2 .The tensile tests were conducted according to ASTM E4 standard on a computerized Universal Testing Machine. The span length of the specimen was 40 mm. the tests were performed with constant strain rate of 2 mm/min. Figure 2.1.2 shows the UTM on which tensile testing performed.

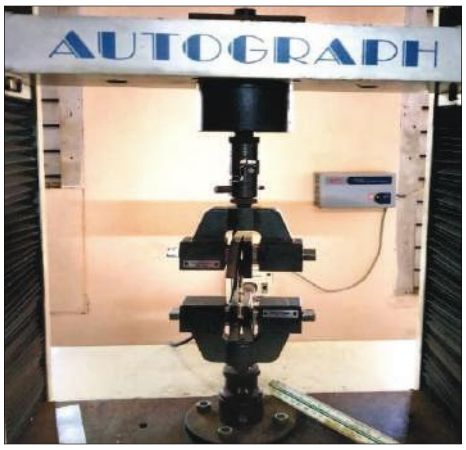

Figure 2.1.2: Tensile testing machine

2) IMPACT TEST

Unlike metals, fiber reinforced composite materials don't undergo plastic deformations after the impact. Near the impact area may appear elastic deformations (in the case of a low intensity impact) or deteriorations of the material (the separation of the fibers from the matrix, matrix cracking, and fiber breaking).The absorbed energy consequent to the impact depends, among others parameters, on the fiber – resins link resistance. If this link is strong, a continuous crack may spread along the material. In the case of a weak link, the generated crack may have an irregular form, leading to a rapid separation of the fibers from de matrix and to a considerable absorption energy. In this case izord method is used as per the ASTM E4 standard dimensions shown in figure. Figure 2.1.3 shows the machine on which impact testing performed.

Figure 2.1.3: Impact testing machin e

V. RE SULT AND DISCUSSIONS

1) DATA ANALYSIS

TAGUCHI ANALYSIS

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The Single objective optimization done by Taguchi Method. Taguchi method involves reducing the variation in a process through robust design of experiments. The overall objective of the method is to produce high quality product at low cost to the manufacturer. The parameters which has higher value represents better composite such tensile strength, impact strength are called higher is better. In this case the Signal to Noise ratios for two objectives; composition ratio (wt %) and fiber arrangement were individually analysed and optimized. For tensile strength, 'larger is better' criteria were selected. For impact strength, also 'larger is better' criteria were selected.

Table 1.1 S/N Ratios of Tensile strength and Impact strength

Table 1.2 Influence on tensile strength response table for signal to noise ratios of tensile strength (larger is better)

SL.NO	M/R Wt%	FIBER ARRANGEMENT	TENSILE STRENGTH (Mpa)	S/N RATIO OF TENSILE STRENGTH	IMPACT STRENGTH (J/m)	S/N RATIO OF IMPACT STRENGTH
C1.1	40	U	24.7632	28.1814	308.386	50.20764
C1.2	40	U	25.147		355.939	
C1.3	40	U	27.236		313.247	
C2.1	40	C	26.3639	28.2026	322.355	50.684
C2.2	40	C	25.9875		371.268	
C2.3	40	C	24.8569		338.15	
C3.1	40	R	23.899	27.3443	255.236	48.203
C3.2	40	R	24.4523		263.179	
C3.3	40	R	21.7893		253.369	
C4.1	50	U	31.4932	29.0874	432.281	53.131
C4.2	50	U	26.2563		475.398	
C4.3	50	U	28.3668		455.921	
C5.1	50	C	35.3375	30.8855	510.396	54.16
C5.2	50	C	33.4562		523.357	
C5.3	50	C	36.4563		498.879	
C6.1	50	R	27.3272	28.477	401.289	51.80
C6.2	50	R	26.369		386.902	
C6.3	50	R	25.9687		379.987	
C7.1	60	U	22.3331	27.2035	247.931	47.050
C7.2	60	U	24.365		222.389	
C7.3	60	U	22.2368		209.976	
C8.1	60	C	25.3963	28.2302	310.893	50.791
C8.2	60	C	27.1463		376.987	
C8.3	60	C	24.9865		362.328	
C9.1	60	R	24.6547	27.4082	254.368	47.707
C9.2	60	R	22.369		244.655	
C9.3	60	R	23.5367		231.254	

From the table 1.2 we can conclude that among these two parameters Composition ratio has more influence on tensile

Level	Composition Ratio wt%	Fiber arrangement
1	27.91	28.16
2	29.48	29.11
3	27.61	27.74
Delta	1.87	1.36
Rank	1	2

strength, Percentage of contribution is 59.03%

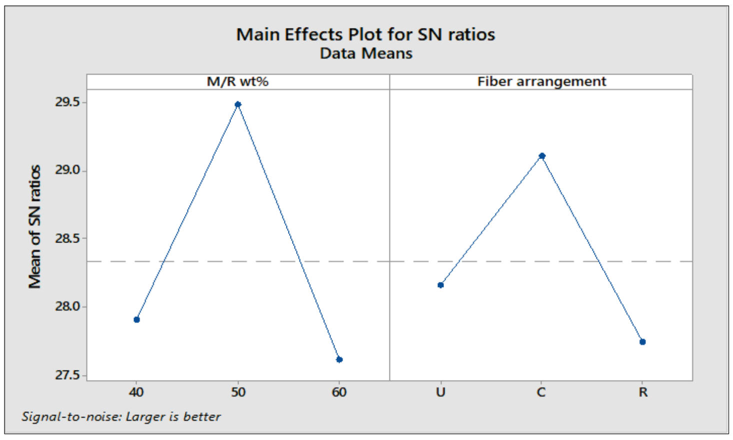

Figure 3.1: Main effects plot for Sn ratios of tensile strength.

From this we conclude that Maximum value of Tensile strength at the parameters of Bamboo fiber reinforced epoxy composite, Composition wt% 50 and fiber arrangement is cross woven. Maximum value of Tensile strength = **32.5589 mpa** is calculated.

Table 1.3 Influence on impact strengthresponse table for signal to noise ratios of impact strength (larger is better)

From the table 1.3 we can conclude that among these two parameters Composition ratio has more influence on impact strength, Percentage of contribution is 69.77%

Level	M/R wt%	Fiber arrangement
1	49.7	50.13
2	53.03	51.88
3	48.52	49.24
Delta	4.51	2.64
Rank	1	2

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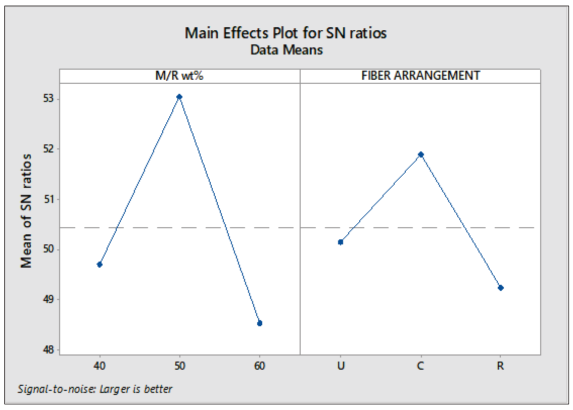

Figure 3.2 : Main effects plot for Sn ratios of impact strength.

From this we conclude that Maximum value of impact strength at the parameters of Bamboo fiber reinforced epoxy composite, Composition ratio wt% 50 and fiber arrangement is cross woven. Maximum value of impact strength = **510.5545 J/m** is calculated.

2) MORPHOLOGY STUDY ON CROSS SECTIONS OF BAMBOO FIBER EPOXY COMPOSITE'S

Scanning electron microscope of Model JEOL JSM-6480LV (Figure 3.4) was used for the morphological characterization of the composite surface. The samples are cleaned thoroughly, air-dried and are coated with 100 Å thick platinum in JEOL sputter ion coater and observed SEM at 20 kV. To enhance the conductivity of the composite samples a thin film of platinum is vacuum evaporated onto them before the micrographs are taken. The fracture morphology of the tensile fracture surface of the composites were also observed by means of SEM.

Figure 3.4. SEM Set up

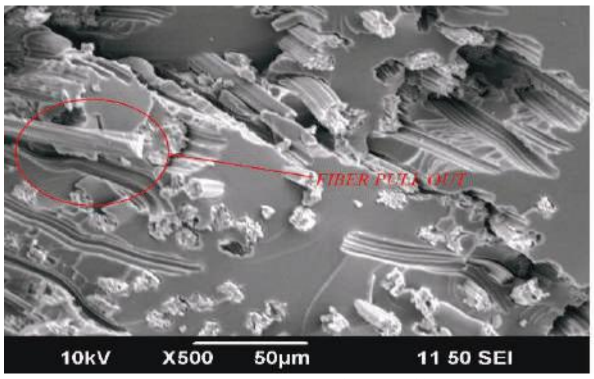

Figure 3.5 a: Fiber pull out

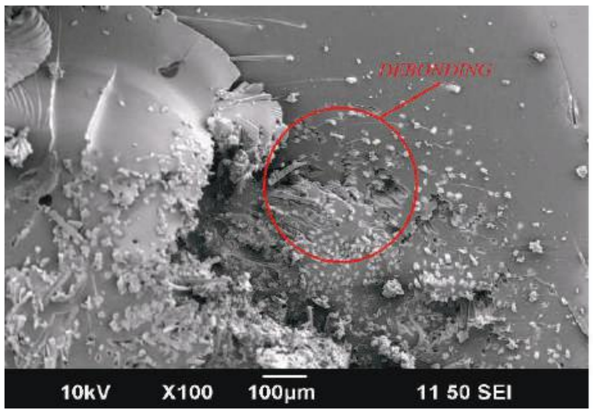

Figure 3.5 b: Debonding

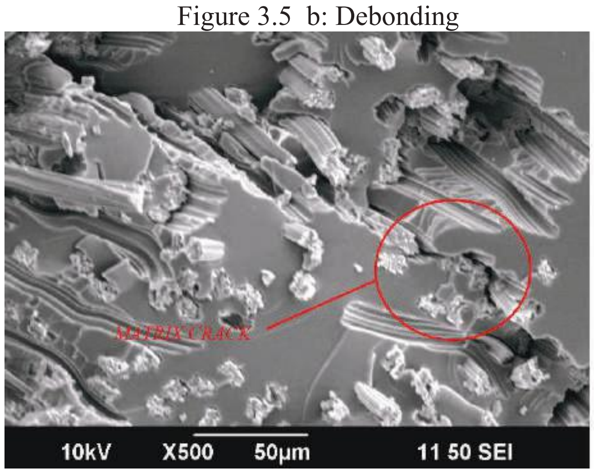

Figure 3.5 c: Matrix crack

Fig.3.5 a,b,c :Cross section morphology of Bamboo fiber epoxy composite

SEM results of tested specimen revealed that fiber breakage, matrix cracking, fiber matrix debonding and fiber pull out are the major failures of bamboo fiber epoxy composite.

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3) FABRICATION OF HAND GUARD FOR BIKE

Hand guard on any bike is to prevent your hand getting crushed during any impact or accident and when you fell on the ground. Which is used to minimize the impact on collision. Will definitely provide some wind protection when riding fast in cold weather. It helps to protect our hands and levers from direct contact during a small collision or when you fall towards a side. At present these Hand guards are fabricated using abs/plastics then thrown away and replaced with another which accumulate more plastic waste. As a possible replacement an attempt was made to make the bike Hand guard with bamboo fiber reinforced epoxy composite materials.

According with the optimum parameters obtained from research, with 50wt% of composition ratio and cross woven bamboo fiber are selected for fabrication of Hand guard. Fiber is treated with 6% of NaOH. Then mould of the Hand guard was made first using plaster of paris as shown figure 3.6. The release gel was coated over the mould. Over which the epoxy resin was first poured using hand layup technique. Further a layer of cross woven bamboo fiber was placed. Again a layer of epoxy resin was poured and then the second layer of bamboo fiber was placed in the same orientation as the first layer again the epoxy resin was poured. And a plastic coating used as a release film placed over the final layer and left it for curing. After curing demould the manufactured product and painted it as shown in figure 3.8.

Figure 3.7: product (hand guard for bikes-cross Woven bamboo fiber reinforced epoxy composite)

Figure 3.8: painted hand guard

Figure 3.6: Mould –made up of plaster of paris

Figure 3.9: Cross woven bamboo fiber reinforced epoxy composite, Hand guard installed in a bike

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VI. CONCLUSION

The experimental investigation on the effect of fiber arrangements and composition ratio of mechanical behavior of bamboo fiber reinforced epoxy composites leads to the following conclusions obtained from this study are as follows:

- Among these two parameters composition ratio has more influence on both tensile and impact strengths.
- Cross woven fiber arrangement and 50wt% of composition ratio are the optimum parameters for maximum mechanical strength.
- Maximum tensile strength obtained is **32.5589 Mpa**
- Maximum impact strength obtained is **510.5545 J/m**
- SEM results of tested specimen revealed that fiber breakage, matrix cracking, fiber matrix debonding and fiber pull out are major failures of composite.

According with the better result, using that optimum parameters a Hand guard for Motor bike is fabricated.

VII. FUTURE SCOPE

There is a very broad scope for future scholars to explore the current research area. This research work can be further extended to study other aspects of composites like use of other natural fibers and evaluation of their various properties and the experimental results can be similarly analyzed. This work can be further extended to study other tribological aspects like abrasion, wear, hardness behaviour of this composite.

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Investigation Of Mechanical Properties Of Brown And White Coir Reinforced Polymer Composites

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Abstract: Fiber reinforced polymer composites have a acquired a dominant place in variety of application because of high specific strength and modulus. In recent years, the concept of "eco materials" has gained key importance due to the need to preserve our environment. So the Abundant availability of natural fiber can be used to produce high performance materials instead of synthetic material. Coir is one of the most eligible natural fiber to use as reinforcement material. In this study, White and brown coir reinforced polymer composites are aligned in different angle with the help of thermoset resin and also the combination of thermoset resin and thermoplastic material. Treated and untreated coir fiber in two colour are used for determine the better strength material. The mechanical properties of the composites such as tensile and impact strength evaluated by using suitable apparatus to found out optimum layout configuration. Alkaline treatment is used for making treated coir fiber. Based on the result, brown coir fiber shows better mechanical properties compared to white coir fiber. Treated brown coir fibre in thirty degree shows the optimum lay -up and high strength compared to white coir fibre. These insights prove use full in the design of automotive component and found out how properties are affected the features of the part.

Keywords: Coir fibre, Mechanical properties, Fibre lay-up, polymer composite

I. INTRODUCTION

The concept 'green think green' has been introduced to raise the awareness of using environment friendly products in product development. There is increase in demand for environment friendly materials around the globe. Composite materials with natural based phases are more desirable materials and vigorously developing area in a material engineering. Bio composites belong among very prospective composites which determine a direction of future materials, such as aerogel and other composites and materials. Natural vegetable fibres have been already abundantly used in many industrial applications where just the vegetable fibres are of a dominant position.

These materials are generally cheaper than synthetic reinforcement composites. Natural fiber reinforced composites are green composites which are used in automobile industries, since these materials have good impact strength, good flexural strength low cost and low density, high toughness, reasonable specific strength. These composite materials can be produced with low cost and have good characteristics such as renewability, easy to process, low energy requirement for its manufacture. Synthetic fibers are being replaced by natural fibers because of their beneficial properties such as light weight and high strength.

The growing factors like environmental challenges, biodegradabilty,non- toxicity etc , leads the researchers to focus their studies on exploring th efeatures of natural materials like natural fibers.Alot of reasearch is going on to make use of natural fibers as a reinforcing material in the polymer matrix composites. There are a lot of challenges aced by the researchers to make the natural fiber suitable for theire needs due to its hydropholic nature, thermal and chemical instability. But nodays natural fiibers can be replace synthetic fibers to some extent by making them compatible with polymer matrixes by some surface modification techniques

II. LITERATURE REVIEW

A thorough review of the available literates was also done to understand the effect of various parameters that influence the mechanical and thermal properties of fiber reinforced polymer composites. Coconut coir is a natural fiber which has been used for many applications such as manufacturing of ropes, floor mats, thermal insulators and also as fuel due to its huge availability (10 x 10-6 tons per year) in India. Research activities in the field of natural fiber materials resulted in this material having found applications in the manufacture of composite particle boards, thermal insulators and building materials[1]. Several fiber surface treatment methods have been studied to improve the adhesion between coir fiber

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and the surrounding the matrix. Alkalization technique mainly used to remove the hemicellulose from the fiber surface and less harmful to the environment and changing the arrangement of units in the cellulose macro molecules which resulting the better mechanical inter locking. Aspect ratio enhancement helps to make better mechanical bonding between matrix and fiber [2].white coir fibers are smoother and finer, but also weaker. Coconut fibers are commercially three forms, namely bristle, mattress and decorticated .Brown coir fiber is most commonly used in engineering applications. It is abundantly available in India Matured coir fiber reinforced polymer matrix composites are used for many engineering applications like automobile industries; construction purposes; aeronautical engineering etc [3].

Rout et al. [4] studied the significance of surface treatment on the coir reinforced polyester composites. The coir fiber was subjected to alkali treatment, vinyl grafting, and bleaching before adding them with general purpose polyester resin. The mechanical charecteristics like tensile strength, bending and impact strength were increased because of surface treatment. Bleached fiber composite (at 650C) showed better flexural strength. NaOH treated fiber/polyester composite exhibited better tensile strength. Because of the chemical treatments of fibers the water absorption tendency of composite was reduced.

Nam et al. [5] studied the significance of alkali treatment on interfacial bonding and mechanical properties of coir fiber filled poly (butylene succinate) biodegradable composites. Composites with fiber concentration of 10-30 % were prepared using 5 % NaOH treated fibers. On comparing with untreated fiber composites authors found a remarkable improvement in the interfacial shear strength (IFSS) and mechanical properties of treated coir fiber/ polybutylene succinate (PBS) composites. The treated composites with 25 % fiber content exhibits higher mechanical properties. Samal et al. [6] prepared bamboo as well as glass fiber filled polypropylene hybrid composites and examined their mechanical, thermal and morphological properties. They also added maleic anhydride grafted polypropylene (MAPP) to the composite in order to enhance the interfacial bonding between the fibers and matrix. It was reported that the hybrid composite shows improved mechanical properties like tensile, impact and flexural strength as compared with virgin polypropylene. SEM micrograph of the composites showed a reduction in the interfacial gap between fiber and matrix. TGA showed the improved thermal stability of hybrid composite compared to the polymer.

Mir et al. [7] performed surface treatment on coir fiber, after that a systematic investigation on the mechanical and physical properties of coir-polypropylene bio composites had conducted. For improving the compatibility with polypropylene matrix, the coir fiber was reacted with basic chromium sulfate and sodium bicarbonate salt in acidic solution. Composites with fiber percentage of 10, 15 and 20 were prepared. The study reveals that the chemically treated fiber based composite showed good mechanical charecters than untreated. The composite with 20% fiber weight concentration exhibited optimum mechanical property compared to other. During surface treatment, the OH groups of untreated coir cellulose which were hydrophilic in nature had been changed to hydrophobic –OH-Cr groups. Because of this, the water absorption amount of composite was also lowered. Monteiro et al. [8] conducted a study on the mechanical characteristics of coir fiber reinforced polyester composites. The coir fiber percentage was increased up to 80 % and found that up to 50% fiber loading, composites were become rigid, and after that composites behaves like agglomerates.

The use of coir fibre reinforced polypropylene composite for the panel of automotive interior applications was studied by Ayrilmis et al. [9]. This study proved that the coir fibre would be a vital component in the production of thermoplastic composites, especially for the effective replacement of comparatively highly expensive and dense glass fibres. When the coir fiber quantity increased up to 60 wt %, the flexural and tensile properties of the composites improved by 26% and 35%, respectively. Even if the further increase in fibre quantity caused to decreases the flexural and tensile properties because of the inadequate coverage of all the surfaces of the coir fibre in polymer matrix.

III. MATERIALS AND METHODS

A. Materials

Coir fiber were supplied from coir board ,*alapuza.* Fibers were extracted from husk shell of premature and mature coconuts as shown in fig 1,(10-12 months on the plant)with purely mechanical extraction process. Matrix used in the composites was obtained by mixing epoxy resin of type Araldite XIN 100 and hardener Araldite XIN100.Sodium

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hydroxide (NaOH,99%) was used to treat the fibers. Polyester sheet supplied from Indian mart.

Fig 1(a)Brown and white Fibers removed from the coconut (b) Fibers prepared for experiment

B. Coir fiber

Coir fiber is a lingo-cellulosic natural fiber. coir fiber obtained from the husk of cocos-nucifera. The coir fiber is relatively waterproof and is the only natural fibers to resistant to damage by salt water.The density of the brown coir fiber 1.29± 0.07 g.cm^{-3} and white coir fiber 1.01± 0.05 g.cm$^{-3.}$ Microstructure of coir fiber is shown in fig 2 for understanding the behavior of the fiber and interactions with the composite matrices and table 1 shows the chemical composition of the fiber.[11]

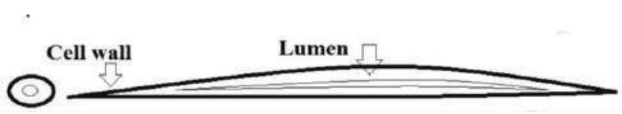

Fig 2 Structure of coir

Table 1: chemical composition of coir fibre

Cellulose (%)	Hemicellulose s(%)	Pectin(%)	lignin(%)	Density(g.c m^3)
46	0.3	4	45	1.15-1.46

Table 2: Properties of coir fiber

Property	Untreated fiber		Treated fiber
	Measurem ent	literature	Measuremen t
Diameter(µm)	125-295	100-400(6,7)	136-315
Tensile strength(g/cm^3)	75-117	59-593(9,10)	114-170
Modulus of elasticity(GPa)	0.85-1.71	2.7-6(2,5)	2.44-4.77
Elongation at beak (%)	15-29	15.50(3,4)	19-34

C. Epoxy Resin

Araldite XIN 100 epoxy resin is used as a resin with hardener is Araldite XIN 900 shown in Fig 3b. It's the world 's largest adhesives .XIN100 have following outstanding properties

- Excellent adhesion to many different materials
- Great strength, toughness and resilience
- Excellent resistance to chemical attack and to moisture
- Outstanding electrical insulating properties.

D. Polyester

Table 3: mechanical properties of polyester

Property	Polyester Resin
Density(g/cm^3)	1.2-1.5
Youngs modulus(GP)	2-4.5
Tensile strength (MPa)	40-90
Compressive strength (MPa)	90-250

Polyester sheet(Fig 3c) helps to increase the stability of the desired composites polyester fibers are sometimes spun together with natural fiber to produce blended properties. Polyester composites are strong and chemical resistance substance formed by the reaction of diabasic organic acids and polyhydric alcohols.

E. coir fiber treatment

The hydrophilic nature of coconut coir is act as undesirable characteristics which makes it is unsuitable for many industrial applications. Some of the ill effects of hydrophilic nature of coconut coir includes the growth of pathogens and enlargement of coir fiber by absorption of moisture from surrounding air. The coconut coir was chemically treated to

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remove the lignin from the fiber surface under the influence of moisture.

Brown coir fibers and white coir fibers are collected from the firm in pristine condition and manually cleaned for removing the plant debris coarse residues from the fiber surface. The brown coir fibers and white coir fibers are immersed in 10wt% of sodium hydroxide solution at room temperature. After that washed in fresh water for several times to removes the excess sodium hydroxide from the fiber. Finally, fibers are oven dried at 60°C and sealed in plastic bag to avoid the moisture absorption. Properties of treated and untreated coir fiber is discussed in the table 3 and brown and white coi fibers are treated in NaOH solution shown in fig4a.

F. Manufacturing process

The composite material were manufactured using hand lay–up technique (fig1) because of capability of making large sized composite material at relatively low cost. Specimen were manufactured to evaluate the variation of mechanical properties and compare the same with existing material to desired compliance .Brown and white coir fibers are collected and weighted in a required gramage,ranging from 20 mm to 50mm length. Metallic mould(Fig 3a) is used to compact the specimen with a dimension of 75 *20*10 mm .Brown and white coir fiber reinforced composites are made by three categories such as coir fiber untreated, coir fiber treated, coir fiber treated with polyester and the coir fibers are aligned in four different angles such as 0 0 , 0 30 , 0 60, 0 90 . An aluminum plate is placed inside the mould to provide good surface finish.

The polymeric matrix obtained by combining firstly resin and the hardener and mixed thoroughly to ensure equal percentage of hardener and resin .Then the coir fibers aligned in specific lay- up and the hardener and the resin is mixed with the coir fiber. The first layer of coir fiber arranged inside the mould and the polymeric matrix is spread on the coir fiber. Then the next layer is aligned and the process ids repeated upto the thickness of the specimen(Fig b and c). After 22 h , the material is removed from the metallic mould and placed in a plastic container to avoid moisture absorption during 28 curing days. After that specimens were tested in ASTM standards. Mainly 24 experiment is carried out.12 experiment for brown coir reinforced polymer composites and 12 for white reinforced polymer composites. Statistical Minitab software is used to performing the design of experiment of the research.

Fig 3(a) metallic mould 3(b) epoxy resin and hardener 3(c) Polyester sheet

Fig 4(a): Brown and white coir fiber after sodium hydroxide treatement

Fig 4(b) and 4(c) brown and white coir treated reinforced polymer composites with 90,30,60,0 respectively

G. Characterization of composites

Mechanical properties of treated and untreated brown and white coir fibers were determined through mechanical testing such as tensile testing carried out by ASTM E4.A shown in fig 5 ,constant cross section was assumed to estimate the tensile properties and cross head speed of 5 mm/ min was considered during the test.12 samples of each group(treated , untreated and treated with polyester of

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brown and coir reinforced polymer composites) were tested. Impact test carried out by mechanical stability tester such as resil impactor shown in fig 6.Specimens with 80*40*10 mm were used to testing the impact ofsample

Fig5:universal testing machine

IV. RESULTS AND DISCUSSION

Type of resin	Fiber angle	Tensile strength	Impact strength
EBUTC	0	14.32107	150.78963
EBUTC	30	22.78913	240.34781
EBUTC	60	17.30124	172.34972
EBUTC	90	12.85423	133.07136
EBTC	0	18.12753	310.15723
EBTC	30	26.79862	393.75102
EBTC	60	21.74021	352.60763
EBTC	90	15.73201	307.14731
EBTCP	0	23.32098	377.37414
EBTCP	30	30.76321	507.81743
EBTCP	60	26.79613	452.60723
EBTCP	90	20.85234	286.20731
EWUTC	0	6.56214	130.55923
EWUTC	30	12.3679	200.52492
EWUTC	60	10.478635	163.80176
EWUTC	90	4.32148	107.72937
EWTC	0	8.763254	166.14901
EWTC	30	17.963125	306.77231
EWTC	60	13.82013	195.57302
EWTC	90	11.750346	119.01782
EWTCP	0	10.84302	146.61789
EWTCP	30	19.78621	244.27013
EWTCP	60	12.05782368	162.76013
EWTCP	90	13.78635	109.37542

Table 4: Tensile strength and impact strength of brown and white coir reinforced polymer composites.

EBTC-Epoxy treated brown coir reinforced polymer composites
EBTCP- Epoxy treated brown coir reinforced polymer composites with polyester.
EWUTC- Epoxy untreated white coir reinforced polymer

A. Effect of alkaline treatment on coir fiber surface

Coir is a lignocellulostic fiber which extracts from the seed of the coconut palm. Coir has high microfibriar angle due to which posses low cellulose and high lignin contents. Percentage of elongation of break and toughness of coir fiber is higher than other natural fiber. Coir exhibit high resistance to fungal and bacterial because of high lignin content[12]. Morphological investigations carried out by the researchers on coir fiber reveals the external sheath of lignin obstruct the cellulose to make interfacial bond with the polymer. Removal of the peripheral layer of lignin helps to make more stable bond. Alkali treatment improves the fiber-matrix adhesion and resulting better mechanical interlocking and enhancing the mechanical properties of the coir reinforced polymer composites.

B. Effect of alkaline treatment on mechanical properties of coir fiber

Mechanical and physical properties of treated and untreated coir fiber were found out and compare with the literature in Table 4 . Some researchers reported that after the alkaline treatment an increase in tensile strength ,modulus of elasticity were observed and also leads to better load distribution and higher ultimate stress achieved[13]. Alkali treatment increases the tensile strength of 47% of brown coir fiber and the modulus of 74%.Where as the white fiber increased the tensile modulus of 20% and tensile strength of 31%. Alkaline treatment enhances the tensile strength of both fibers. During

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the experiments, brown coir fiber shows high tensile strength compared to white coir fiber.

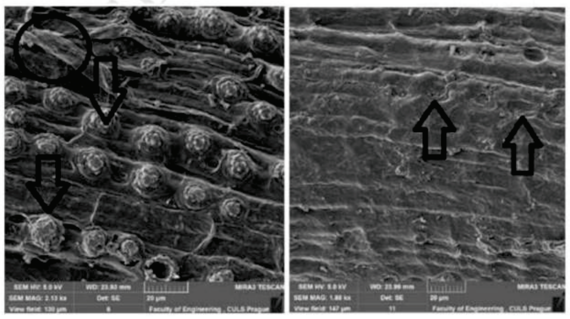

Fig6:Brown coir fiber before(a) and after (b) alkaline treatement

C. Effect of fiber orientation of coir fiber

Tensile strength and tensile moduli were found to be higher in longitudinal compared to transverse direction. When the fibers are aligned longitudinally, the maximum stress transfer occurs between fiber and matrix. The maximum strength is achieved along the direction of fiber alignment. Orientation of fiber results the significant effects on the mechanical properties of the fiber.30 degree shows the optimum lay- up resulting better tensile properties and also observed that 30 degree lay-up increases the impact resistance also. Ninety degree shows less tensile strength compared to other lay- up orientation. Sixty degree shows better tensile strength and impact strength than zero degree orientation. This results gives an idea about the orientation of fiber played the important role in the mechanical stability of the fiber. Tensile strength and tensile moduli were found to be higher in longitudinal compared to transverse direction.the fibers are alligned in longitudinally,the max stress transfer occurred between the fiber and matrix. fibers are aligned across the direction of applied force(transverse direction),crack progression in the direction of fibre alignment. So the fiber experiencing less resistance and also holes are developed in matrix due to the pull out of fiber. In the case ofLongitudinal direction fibers are oriented perpendicular to the applied force.fibers are more resistance and they withstand high loads. Epoxy resin and polyester particle adhered to the fiber surface due to extensive interfacial bond between them.

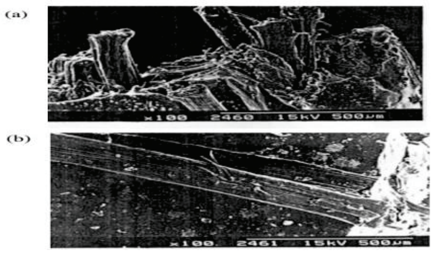

Fig7:Different orientation of coir fibre

D. Tensile properties of the composites

The obtained results for all 12 experiment were summarized in table 3. For the 24 hour curing time setting ,tensile strength is increase in treated coir fiber compared to untreated coir fiber due to the removal of impurities from the fiber surface. Brown coir reinforced polymer composites shows better tensile strength compared to white coir reinforced polymer composites. Due to the inclusion of the coir fiber, the tensile strength of epoxy resin is increases . The tensile strength of the brown fiber was increased of 22.7913MPa (untreated) and 30.7321MPa (treated).similarly the tensile strength of white fiber increased of 19.78621MPa (treated) and 12.3679MPa(untreated).Brown treated coir fiber reinforced polymer composites with epoxy resin and polyester combination gives the maximum tensile strength of the composites with 30 degree lay -up. The maximum strength can be achieved by interfacial bon between fiber, polyester and matrix. White untreated coir fiber reinforced polymer composites with epoxy resin gives the least tensile strength(4.32148) of the composites, where as composites are aligned in ninety degree.

E. Impact strength of the composites

Energy absorption capability of the composite and experimental studied. Resil impactor is used for the determined the stability of the specimen. Specimens were kept in a cantilever position and covering were provided for the safety of the operator. Then pendulum swings around to break the specimen. The impact energy obtained from the dial gauge that fitted on the machine. Specimens prepared with the dimension of 80*40*10 mm. Table 3 shows the variation of impact energy of the specimen with respect to the lay-up orientation of the coir reinforced polymer composites. From the result, brown coir fiber reinforced polymer composites having high impact strength compared to white coir reinforced polymer composites.

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Fig:6 Resil Impactor

.Similarly treated brown cir fiber with polyester composite shows the max impact strength (507N-m) compared to other brown coir fiber reinforced Potential of using coconut shell particle fillers in eco-composite material polymer composites .Thirty Degree lay- up gives the maximum impact strength compared to other lay-up orientation. Ninety degree lay-up with white untreated coir reinforced polymer composites gives the least impact resistance (107.729) of the composites.

V.CONCLUSIONS

The mechanical properties of brown and white coir reinforced composites were evaluated successfully. Brown reinforced polymer composites shows better tensile properties and impact resistance compared to untreated coir fiber. The addition of polyester improves the strength and energy absorption of the composite. Treated coir fiber improves the fiber-matrix adhesion and resulting better mechanical interlocking and enhancing the mechanical properties of the coir reinforced polymer composites. Thirty degree lay-up orientation with treated brown coir fiber gives the maximum tensile properties and impact resistance compared to other layup orientation. Similarly Ninety degree with untreated white coir fiber shows the amount of least of both value.

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An Exploratory Study of Factors Influencing Lean Production in Manufacturing SME's in Kerala

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Abstract: The present research work is an attempt to conduct an exploratory study of the factors influencing Lean production in the manufacturing Small and Medium Enterprises (SME's) in Kerala. Implementation of lean manufacturing in any type of organizations can bring many benefits, such as reducing waste and improving operating efficiency etc., to name a few. The research is combined with an industrial survey in SME's to analyse the difficulties in the implementation stage and to identify the critical success factors. Small and Medium sized enterprises are the backbone of many economies in terms of employment and industrial output. Especially, in the last years many lean methods and approaches were introduced successfully also in SME's. After a successful introduction in manufacturing the lean approach swapped also on other indirect areas such as engineering and product development.

KEY WORDS: Lean manufacturing, SMEs, Exploratory study.

I. INTRODUCTION

In today's increasing dynamic world a lean and efficient organisation has become more important for the enterprise development. The companies have begun initiatives to introduce lean methods to the company production to increase the productivity and minimize the non-value added processes while aligning the value stream with the customer. Lean Thinking was developed by Taiichi Ohno in the Toyota production lines as a philosophy to concentrate on waste reduction and value adding processes. The successful implementation of the Lean manufacturing principles were used around the world. Today the multinational companies are also using Lean methods in their production process. More than, production process the Lean methods are used in other sectors to increase the efficiency and to minimize the waste.

The lean methods are applied in other areas other than production in an enterprise. The lean manufacturing methods can be used for reducing production cost, production time and reducing the wastage in the production process. It is more important to design the production process as sufficient as possible to improve the productivity and satisfies the customer requirements. The companies are looking for methods and tools mainly to reduce costs, wastes and improving productivity. Lean management philosophy proposes a set of tools which can be used in company development. Those enterprises which adopt lean methods achieve improvements in their performance when compared to the others yet to follow this philosophy.

II. DATA COLLECTION AND CHARACTERISTICS OF THE SURVEYED ENTERPRISES

The data in the survey refers to a representative sample of companies. An interview was conducted with the entrepreneurs of the company with a questionnaire prepared with questions to capture lean implementation. The questionnaire was to a total of 60 SME's. SME's were selected as per the MSED act, 2006. As per the act SME's are defined as follows as the enterprises where the investment in plant and machinery or equipments is between Rs. 25 lakhs to Rs. 5 crores, then it is small scale and the investment is between 5 crore to 10 crore it is defined as medium scale. And enterprises where the investment in plant and machinery or equipments is above 10 cr is considerd as large scale industries.

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Majority of the surveyed companies were small scale (39%) enterprises followed by medium scale enterprises with 33% and then large scale enterprises (28%).

The number of industries in each category is shown in table I. In the surveyed enterprises mechanical companies are dominating. The surveyed enterprises are classified based on their investment, products, turnover, no of employees inventory turnover ratio (ITR) and value added. The values are collected from the survey. The characteristics of the surveyed enterprises are discussed in this section.

Most of the companies surveyed are steal and casting companies. Around 30% surveyed are steel industry. 14% of the companies are engineering industries such as gear cutting, valves, bearings etc.11% of companies are polymer industry such as plastics PVC pipes, gloves polythene bags etc. 7% of rubber produce industries and 7% of construction material producing companies are the other type of industries were surveyed. The chemical and pharmaceutical companies are the other type of companies which having 6% of the surveyed companies. Other type of companies such as food industry mattress industry furniture making etc. contributes 23% of the companies. Majority of the Majority of the enterprises comes under manufacturing sector.

Type of company	No of company
Steels	22
Polymers	6
Chemicals & detergents	3
Rubber product	4
Construction materials	4
Other Engineering	13
Others	8

Table:I Type of industry sector

2.1 LEAN IMPLEMENTATION

From the table 2 it is clear that 39% of companies that surveyed are implemented lean manufacturing technolog partially or fully implemented. 61% companies were not implemented lean manufacturing. Many companies are companies are looking for methods and tools mainly in order to reduce costs, wastes and improving productivity. From the table it is understood that the lean manufacturing is not widely used or they are not fully aware of about the lean manufacturing. Most of the small industries are not aware about the lean manufacturing. The companies have different grounds to implement the idea. Many of them use the Lean manufacturing idea, wanted to improve the enterprise's operation, enterprises wanted to increase their competitive advantage, to increase the turnover of the company, to reduce the wastages and improved transportation. The positive experience of other companies was also a reason for the lean implementation

Table II. lean implementation

LEAN IMPLEMENTED	NOT IMPLEMENTED
22	39

2.2 TYPE OF THE INDUSTRY

Table 3 shows the nature of the company. As per the MSME development Act,2006 in India, have been defined as enterprises where (The MSME Development Act, 2006, GOI)- Small and medium scale enterprises (SMEs) are understood in India as enterprises where the investment in plant and machinery or equipments is between Rs. 25 lakhs (≈ US $ 0.04 million) to Rs. 10 crores (≈ US$1.6 million) in case of a manufacturing industry and between Rs. 10 lakh (≈ US $ 0.02 million) to Rs. 5 Crore (≈US $ 0.8 million) in case of a service sector enterprise. And enterprises where the investment in plant and machinery or equipments is above 25 lakhs is considerd as large scale industries. Around 28% of the surveyed companies are large scale industries and 33% companies are medium scaled companies. 39% of companies surveyed are small scale industries. Among the analysed enterprises most of them are small and medium scaled enterprises. Large scaled enterprises are comparatively less than SME. This is because for the large scale enterprises more investments and large industrial area is needed.

Table. III Type of the industry

TYPE	No Of Companies
Small	24
Medium	21
Large	15

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2.3 TURNOVER OF THE COMPANY

In this table 4 the turnover of the companies are classified. From the figure it is understood that the 50% of the companies have the turnover more than 5 cr. And the 25 % of companies having a turnover between 1cr and 5 cr. And the rest 25% of companies are having less than 1 cr turnover. Almost half of the surveyed companies are having a turnover more than 5cr. The lean implemented companies has more turnover compared to non-lean implemented companies. The turnover of the company can be increased by implementing lean manufacturing. Most of the enterprises are not aware about the lean manufacturing techniques. The lean implemented companies have more growth percentage than the non-implemented companies. The lean implemented companies has a significant increase in the net company's profit, no of orders, sales return etc.

Table IV. Turnover of the company

Turnover	No of enterprises
Less than 1cr	28
1-2 cr	14
Above 5cr	14

2.4 NUMBER OF EMPLOYEES

Figure 1 shows the number of employees. The number of employees are classified into four groups. First group having employees less than 25, second group having employees between 25 to 50, third group is having employees between 50 to 75 and the last group having employees more than 75. 24 companies are in first group that the number of employees are less than 25. In the second group there are 12 companies have the employees between 25 to 50, in third group there are 13 companies and the last group have 13 companies were the employees are more than 75.

By the implementation of LM we can increase the efficiency of the enterprise. In the LM implemented enterprises the number of employees are less. Most of the LM implemented enterprises are automated and less labours are needed. In the small and medium scaled enterprises the efficiency of the employees can increased by implementing lean manufacturing.

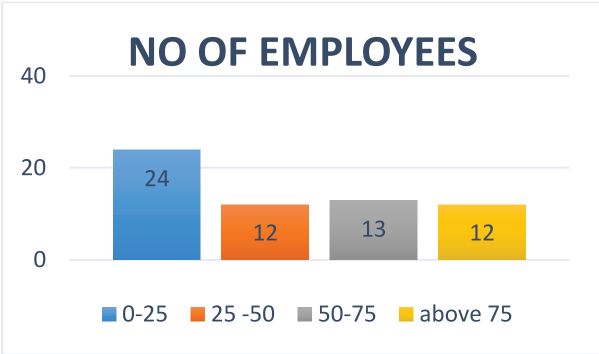

Fig 1. No of employees

2.5 ITR VALUE

The inventory turnover ratio is an efficiency ratio that shows how effectively inventory is managed by comparing cost of goods sold with average inventory for a period. In other words, it measures how many times a company sold its total average inventory dollar amount during the year. ITR is defined as the ratio between total cost of goods sold and the cost on material.
Majority of the company surveyed have ITR value between 0-2, 17 % of companies have a ITR value between 2-4 and 12% companies have ITR value more than 4.it is thinking be due to lean implementation. The LM implemented enterprises has the good ITR value. The inventory of the enterprises are controlled.

Table V. ITR value

ITR VALUE	No of companies
0-2	42
2-4	10
4-6	7

2.6 VALUE ADDED

Value Added is the extra value created over and above the original value of the product. It can apply to products, services, companies, management, and other areas of business. In other words, value-added is the enhancement made by a company/individual to a product or service before offering it to the end customer.
From the figure it is understood that most of the companies surveyed has value added are less than 2 cr. About 78 % companies have value added value less than 2 cr. About 14%

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companies have value added between 3 and 5 crore. 8% companies have value added more than 5 crore.

Table VI. Value added

Value added	No of companies
0-2	46
2-5	8
Above 5	6

From the tables it is clear that the ITR value and value added is more for lean implemented enterprises compared to non-lean implemented enterprises. The systematic implementation of LM in SMEs will yield huge benefits such as quality improvement, reduction production time, good customer responsiveness etc.

The lean implemented companies have more growth percentage than the non-implemented companies. The lean implemented companies has a significant increase in the net company's profit, no of orders, sales return etc.

III. METHODOLOGY

A questionnaire was designed to collect data for this study. An interview was conducted with the entrepreneurs of the company with the questionnaire. The questionnaire was a total of 60 SME's. The data in the survey refers to a representative sample of companies.The surveyed enterprises are classified based on their investment, type of company, turnover, no of employees,inventory turnover ratio (ITR) and value added.The data were analysed using statistical method (corealtion, regression , factor analysis) using the SPSS version 23.

3.5 CRONBACH'S ALPHA

Cronbach's alpha is the most common measure of internal consistency ("reliability"). It is most commonly used when you have multiple choice questions in a survey/questionnaire that form a scale and you wish to determine if the scale is reliable.

Cronbach's alpha is the most common measure of internal consistency ("reliability"). It is most commonly used when you have multiple choice questions in a survey/questionnaire that form a scale and you wish to determine if the scale is reliable.

Theoretically, Cronbach's alpha results should give you a number from 0 to 1, but you can get negative numbers as well. A negative number indicates that something is wrong with your data perhaps you forgot to reverse score some items. The general rule of thumb is that a Cronbach's alpha of .70 and above is good, .80 and above is better, and .90 and above is best.

Table VII. Cronbach's Alpha

Variables	Cronbach's Alpha
VA	.750
No of employees	.739
Lean	.762
ITR	.763
Turnover	.710
Investment	.700
Raw materials	.721
Wages	.730
Energy	.759
Training	.762

In this project the questionnaire made is checked its reliability by using the software SPSS. We got a cronbach's alpha of .7 which means the questionnaire is good.

3.1 CORRELATION RELATION

The correlation coefficient is a statistical measure that calculates the strength of the relationship between the relative movements of two variables. The values range between -1.0 and 1.0. A calculated number greater than 1.0 or less than -1.0 means that there was an error in the correlation measurement. A correlation of -1.0 shows a perfect negative correlation, while a correlation of 1.0 shows a perfect positive correlation. A correlation of 0.0 shows no relationship between the movements of the two variables. The first variable is value added and the other variables are investment, turnover, ITR, lean, wages, no of employees, energy and raw materials. Details are shown in table

From the table viii it is clear that all the variables shows a strong relation to the value added to the company.

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Table VIII. Correlation coefficient

3.2 REGRESSION ANALYSIS

In statistical modelling, regression analysis is a set of statistical processes for estimating the relationships among variables. It includes many techniques for modelling and analysing several variables, when the focus is on the relationship between a dependent variable and one or more independent variables (or 'predictors'). More specifically, regression analysis helps one understand how the typical value.

Multiple Regression is a statistical method for estimating the relationship between a dependent variable and two or more independent (or predictor) variables. The regression analysis is done with VA as depended variable and investment, turnover, ITR, wean, wages, no of employees', energy and raw materials as independent variable and the result are given in table IX

Regression analysis was done to attain high-accuracy results. The *R* value represents the simple correlation and is 0.687 (the "**R**" Column), which indicates a high degree of correlation.

The R^2 value (the **"R Square"** column) indicates how much of the total variation in the dependent variable VA, can be explained by the independent variable. In this case, 68.7 % can be explained, which is very large.

The R^2 value found to be 0.472 and Adjusted r^2 found to be 0.421 meaning that the independent variables named above are positively linked to VA.

Table IX. Regression analysis

Model	Unstandardized Coefficients		Standardized Coefficients		
	B	Std. Error	Beta	T	Sig.
(Constant)	.673	.242		2.785	.007
Investment	.113	.0.35	.301	3.238	.002
Energy	-1.189	.535	.353	-2.221	.031
Materials	.050	.032	.301	1.530	.132
Labour	.073	.085	.147	.865	.391
Lean	.54	.166	.044	.329	.743

3.3 FACTOR ANALYSIS

Factor analysis is a technique that is used to reduce a large number of variables into fewer numbers of factors. This technique extracts maximum common variance from all variables and puts them into a common score. As an index of all variables, we can use this score for further analysis. Factor analysis is part of general linear model (GLM) and this method also assumes several assumptions: there is linear relationship, there is no multi collinearity, it includes relevant variables into analysis, and there is true correlation between variables and factors. Several methods are available, but principle component analysis is used most commonly.

	Component		
	1	2	3
RAWMATERIALS	.919	.181	
TURNOVER	.904	.168	
WAGES	.875	.105	
NOOFEMP	.797	.101	.276
ENERGY	.774	.331	
INVESTMENT	.735	.329	.289
TRAINING	.170	.818	
LEAN	.196	.802	
ITR			.928
VA	.563	.153	.674

Table X. Factor analysis

Principal component analysis: This is the most common method used by researchers. PCA starts extracting the maximum variance and puts them into the first factor. After that, it removes that variance explained by the first factors and then starts extracting maximum variance for the second factor. This process goes to the last factor.

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Factor analysis conducted showed that 10 variables get loaded into three factors. The variables which are loaded as factor one are raw materials, turnover, wages, number of employees energy and investment which are found to be coming under production and operations. The variables which are loaded as factor 2 are training and lean implantation which can be named which are related to human resources. Finally the variables which are loaded as factor 3 ITR and value added, these are supply chain related.

IV. RESULTS FROM THE SURVEY

This section describes the results from the survey. It is noticeable that many of the enterprises have not yet dealt with Lean methods. Others know the methods, but they have never used them. Those companies that already use Lean do this above all in the productive sector. Only 39 % of respondents already use Lean methods in product development.

39%, had experience with Lean manufacturing in product development, are very optimistic about the success. The lean implemented companies have a significant increase in their net profit. 15 Lean methods were selected, based on the findings of a previous literature review analysis, and importance of selected methods. Respondents should make a statement about whether or not they already use the methods in the company in product development (evaluation criteria: Application), whether the effort to implement the method is associated with a low or high effort (evaluation criteria: Effort) and their opinion of the estimated potential or the usefulness expected from the method (evaluation criteria: Potential).

From the responds Continuous Improvement, 5S, QC circle, Total productive maintenance, and Machine reliability are the methods most applied in product development. Just in time, line balancing, value stream mapping are the another type of lean methods used for production process. Automation is the another type of lean method used in the production The methods Continuous Improvement and 5S can be introduced with little effort, while the methods Product and Process Standardization, Automation Concurrent/Simultaneous Engineering, group technology involve a high introduction effort. The methods Automation, Just-in-Time, Product and Process Standardization, Supplier Integration promise a high potential according to the respondents.

Regression analysis showed the importance of implementing automated machines and modern manufacturing process which is as per the one of the requirement of lean manufacturing. The analysis shows that the investment followed by the energy are the most significant input. This is because implementing lean may require automated machines which require more power to operate.

V. CONCLUSION AND OUTLOOK

The results of this study show SME's experience with Lean methods. Interesting results were also analysed with regard to LPD's synergy with Industry technologies. Finally, the present work concludes with the derivation of some factors affecting implementation and factors influencing lean production in the manufacturing SME's in Kerala, Limitations for research can be found in the selection of Lean methods to design the survey. To keep the survey as simple as possible for SME management the researcher selected 15 Lean methods. Eventually an extended survey with a higher number of Lean methods would bring new insights also regarding additional methods. Another limiting factor is the geographical focus of the survey on SME`s in Kerala, as well as the limited number of questionnaires received.

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Effect of Motivational Factors on Organizational Performance in Industries of Manufacturing Sector in Kerala

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Abstract: The presence of motivational factors and co-relation of various motivational factors and organizational performance still remains unclear in Kerala's manufacturing industry scenario. Organizations, especially in the manufacturing sector, work towards targets and goal accomplishments, seeking to expand their units and thereby increase profits. This study focuses on investigating the existence of various employee motivational factors across different types of organizations and understanding the influence of these motivational factors on employee performance. Subsequently the study also investigates the influence of these motivational factors on organizational performance, by examining different organizations which employ various motivational techniques. To collect data for the research, a questionnaire was developed based on the various motivational factors identified through thorough literature review. The questionnaire was employed to large and medium enterprises in the manufacturing sector. The collected data was first divided into 8 factors and thereafter Factor Analysis (FA) was performed to validate it. Multiple Regression was employed to realize the relationship between motivational factors and organizational performance. Independent Samples T Test was also used to check the difference in motivational factors and motivational levels in both the sectors. The findings suggest that there is no perceivable effect of motivational factors on organizational performance in both large and medium scale manufacturing organizations. The Independent Samples T Test revealed that there is no significant difference between the motivational factors adopted by both the sectors. The motivational level of the employees is also found to be the same in both the sectors.

Keywords: Motivational Factors, Factor Analysis, Multiple Regression, Independent Samples T Test

I. Introduction

All firms have the desire to increase profits as best they can. Brian Becker et al. (2017) studies the possible effects human resource management have on organizational performance. A part of human resource management is motivation; fueling the employees to perform better and better each passing day. It can also be considered as a part of continuous process improvement. How can an employee be motivated? What effects do motivation have on an employee's performance and in turn on the organizational performance as a whole. In Kerala, the relationship between motivational factors and organizational performance still remain unclear, especially in the manufacturing sector. This particular research focuses on exploring the effects of motivational factors on organizational performance in the large and medium sector manufacturing industries of Kerala, through a questionnaire based survey and analysis.

II. Objective

The objective of this research is to

1. To identify the various motivational factors which could possibly have a positive impact on employee performance, which could translate to organizational performance
2. To develop an instrument to assess how far these motivational factors are prevalent within the organizations and are motivating the employee
3. To assess in general the presence of these motivational factors and its motivational effect across all organizations
4. To investigate the variation of these factors across large & medium scale manufacturing organizations
5. To investigate the relationship of organizational performance with motivational factors adopted by the organizations
6. Identify the gaps existing and suggest suitable measures to bridge the gap and enhance organizational performance

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III. LITERATURE SURVEY

Roman Zámečník (2014) aims to measure the employee motivational with multivariate statistical techniques. Cluster analysis is the primary method used. Various motivational factors have also been identified by this researcher.

Mudhafar Alefari et al. (2018) conveys a new approach called System Dynamic Modeling. Performance improvement measures are also considered in part to assess and modulate employee performance.

Lina Xiong et al. (2015) focuses on motivational drivers and their effect on hospitality brand. They have identified various motivational drivers as a part of their study and have tried to link the importance of these drivers on achieving hospitality brand image.

Muhammad Ali et al (2018) studies the effect of relationship among employees as the driver for performance. They have identified key motivational factors under relationship climate and have focused their research to its influence on industrial performance.

Noor Awanis Muslim et al (2016) investigates the importance of job security and its influence on employee performance. They have listed out various job related parameters to assess its impact on employee motivation and performance.

Hooman Khoshnevis et al (2016) studies the motivational system in a governmental organization. The relationship between hygiene and motivational factors and the motivational influence among employees and chief officers is also investigated.

IV. RESEARCH FRAMEWORK

In accordance with the objectives of the study, a practical research framework has been developed.

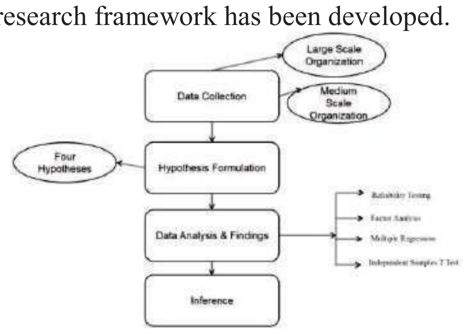

Figure 1: Research Framework

A. Data Collection

The sectors chosen for this particular study are the Large and Medium scale manufacturing organizations in Kerala.

A questionnaire with 108 constructs was developed with the various motivational factors & organizational performance measures identified through literature survey. A 5 point likert scale ranging from 1- Strongly Disagree to 5- Strongly Agree was used in the questionnaire. The constructs were grouped into a total of 8 factors; Skill & Knowledge, Reward, Work Environment Related Factor, Organizational Values & Policies, Relationship & Peer Associated Factor, Leisure, Freedom & Physiology Associated Factor, External Environment & Society and Organizational Performance Measures. The constructs were grouped mainly because of their similarities.

A total of 75 responses were obtained from both large and medium sectors combined, with 40 responses from the large sector and 35 responses from the medium sector.

B. Hypothesis Formulation

Based on the objectives mentioned, a series of hypotheses were formulated.

1) Hypothesis 1:

H_0: There is no co-relation between motivational factors & organizational performance in the case of large scale organizations
H_1: There is a significant co-relation between motivational factors & organizational performance in the case of large scale organizations

2) Hypothesis 2:

H_0: There is no co-relation between motivational factors & organizational performance in the case of medium scale organizations
H_1: There is a significant co-relation between motivational factors & organizational performance in the case of medium scale organizations

3) Hypothesis 3:

H_0: There are no differences between motivational factors adopted by large and medium scale organizations
H_1: There is a significant difference between motivational factors adopted by large and medium scale organizations

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4) Hypothesis 4:

H_0: There are no differences between motivational level of employees in large and medium scale organizations
H_1: There is a significant difference between motivational level of employees in large and medium scale organizations

C. Data Analysis & Findings

A series of analysis techniques were performed on the data obtained with the help SPSS software.

1) Reliability Analysis:

Reliability Testing is done to ensure that the constructs in the questionnaire are reliable. Using the SPSS software, the reliability of the constructs can be evaluated very easily. Some of the commonly used techniques used to test reliability are inter rater reliability, test-retest reliability, parallel forms reliability, internal consistency reliability. Cronbach's coefficient is the standard criteria used by many researchers as a measure of reliability. One could compute Cronbach"s Coefficient Alpha, Kuder Richardson (KR) Formula, or Spilt-half Reliability Coefficient to examine internal consistency within a single test. Cronbach"s Alpha is recommended over the other two for the following reasons:

a. Cronbach"s Alpha can be used for both binary-type and large-scale data. On the other hand, Kuder Richardson (KR) Formula can be applied to dichotomously scored data only.
b. Spilt-half can be viewed as a one-test equivalent to alternate form and test-retest, which use two tests. In spilt-half, you treat one single test as two tests by dividing the items into two subsets. It is a rule of thumb that Cronbach's alpha value greater than 0.7 is generally acceptable and a value lesser than 0.5 is generally poor. Reliability of each of the factors were measured separately and tabulated

Table I: Reliability Analysis

Factor	**Cronbach's Alpha**
Skill & Knowledge	0.917
Reward	0.955
Work Environment Related	0.896
Organizational Values & Policies	0.947
Relationship & Peer	0.929
Leisure, Freedom & Physiology Associated	0.930
External Environment & Society	0.937

2) Factor Analysis:

Factor Analysis(FA) is usually employed to categorize a given number of constructs in to factors based on their factor loading. Factor analysis can also be used to test whether a group of preformed factor constructs are consistent with their factor loading, that is, when the constructs have already been grouped into factors by the researcher and to test its accuracy or consistency. In this research, FA is performed to check whether the preformed 8 factors show factor loading consistency. Constructs with factor loading greater than or equal to 0.5 have been accepted.

Kaiser-Meyer-Olkin test is used to check the adequacy of the sample. It indicates the proportion of variance in the sample taken. High values (greater than 0.6) indicates that the factor analysis might be useful with the data. In addition, Bartlett's Test of Sphericity is used to check whether the variables are related or not. Small values (less than 0.05) indicate that the factor analysis might be useful.

Table II: Factor Analysis

Factor	Number of constructs considered after CFA
Skill & Knowledge	9
Reward	20
Work Environment Related	15
Organizational Values & Policies	15
Relationship & Peer Associated	16
Leisure, Environment & Physiology Associated	10
External Environment & Society	9
Organizational Performance	8

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3) Multiple Regression Analysis:

Multiple Regression Analysis (MRA) is usually used to assess the interaction or relationship of a dependent variable with two or more independent variables. It is more commonly done as a part of hypothesis testing. Both Hypothesis 1 and Hypothesis 2 were tested using Multiple Regression Analysis as both of them attempt to measure the link between motivational factors and organizational performance. The seven motivational factors were taken as the independent variables and organizational performance was taken as the dependent variable.

For hypothesis 1, the Durbin Watson test gave a value of 1.725. The R square value was obtained as 0.736, which denotes that 73.6% of the factors which affect the dependent variable have been considered. The ANOVA table showed a significance of 0.000. The significance level for each of the factors, except "External Environment & Society" was greater than 0.05. For "External Environment & Society" factor, the p value obtained is 0.011. Standardized coefficient is obtained as 0.649.

For hypothesis 2, the Durbin Watson test gave a value of 1.653. The R square value was obtained as 0.926, which denotes that 92.6% of the factors which affect the dependent variable have been considered. The ANOVA table showed a significance of 0.000. The significance level for each of the factors is greater than 0.05. The significance level for each of the factors was greater than 0.05.

4) Independent Samples T Test:

Independent Samples T Test is used to compare the means of two unrelated samples. This test was used for hypotheses 3 & 4 as they compare the means of two unrelated samples.

For hypothesis 3, Levene's test for equality of variance produced a value of 0.022, which suggests the variances are not equal. The T test gave a value of 0.766 with a significance of 0.446.

For hypothesis 4, Levene's test for equality of variance produced a value of 0.174, which suggests the variances are equal. The T test gave a value of 1.417 with a significance of 0.161.

D. Inference

Table 1 shows the Cronbach's coefficient of each factors considered. The values of Cronbach's coefficient are all greater than 0.7 which indicates a very good reliability of the questionnaire as well as the data. Most of the values are close to 1, which promises a nearly ideal reliability.

Kaiser-Meyer-Olkin test gave a value greater than 0.6 for all the factors, which indicates sampling adequacy. In addition, Bartlett's Test of Sphericity gave a significance of .000 for all the factors, which indicates that the factor analysis with the data in hand will be useful. As a result of the Factor Analysis, 6 constructs whose factor loadings were lower than 0.5 were omitted. The rest of the constructs showed promising loadings to the factors it pertains to.

For Hypothesis 1, the Durbin Watson coefficient is within 1.5 to 2.5, which indicates that there is no significant auto co-relation between the data. The R square value is obtained as 0.736, which denotes that 73.6% of the factors which affect the dependent variable have been considered. A significance of .000 in ANOVA indicates that there is goodness of fit in the data.

The p value of the last factor "External Environment & Society" is less than 0.05, which indicates that there is a significant relation of that factor with organizational performance, which suggests that external factors such as government policies, share prices and other market related schemes are big motivators and they deeply affect the performance. Also the way society views the service or product also seems to be a big motivator and proves to have an impact on performance. The rest of the factors seem to have no effect on organizational performance even though they motivate the employees.

For Hypothesis 2, the Durbin Watson coefficient is within 1.5 to 2.5, which indicates that there is no significant auto co-relation between the data. The R square value is obtained as 0.926, which denotes that 92.6% of the factors which affect the dependent variable have been considered. A significance of .000 in ANOVA indicates that there is goodness of fit in the data. The p value of all the factors are higher than 0.05, which compels the acceptance of null hypothesis.

In both large & medium sector manufacturing industries of Kerala, motivational factors seem to have no strong effect on organizational performance. This suggests that even though the employees are motivated to perform, it is not being translated to performance as a whole. This could be due to the motivational factors reaching a level of saturation. It might be lacking the push to drive performance, even though it acts as a motivator.

For Hypothesis 3, the T test revealed a significance of 0.446, which is greater than 0.05. This is in favour of the null hypothesis. It suggests that there are no differences between motivational factors adopted by large and medium scale organizations. This could be the result of a rigid management system or the inability to identify new motivational techniques

For Hypothesis 4, the T test revealed a significance of 0.161, which is greater than 0.05. This is in favour of the null hypothesis. It suggests that there are no differences between motivational level of employees in large and medium scale organizations. This could be the direct effect of hypothesis 3 or could be the generalized mind set of the people.

V. Conclusion

Various motivational factors were identified and their effectiveness in accelerating organizational performance was tested. The study revealed the current motivational setup in Kerala as far as the large and medium scale manufacturing organizations are concerned. This study also revealed that, contrary to the common notion, motivational factors seem to have very little impact on increasing organizational performance, in both large and medium manufacturing organizations in Kerala. It also revealed that organizations do promote implementation of motivational factors and that there are no differences between the motivational factors adopted as well as the motivational level, comparing both large and medium sectors.

This study may be used as a preliminary research into the motivational set up in Kerala and may also be used to discover more effective motivational factors, which could fuel organizational performance.

VI. Limitations & Future Scope

A. Limitations

This study was conducted only in industries of Kerala. Also only large & Medium sectors have been considered. The sample size obtained is small (75) which needs to be expanded for more accurate predictions. It is assumed that the presence of motivational factors are uniform across all organizations belonging to one scale (large/medium). It is also assumed that all the motivational factors are having similar effect on all employees belonging to one organization. The relation between customer satisfaction, organizational performance & employee motivation has not been dealt with in this study.

B. Future Scope

The study can be extended to include Small scale organizations and then the results can be compared. This study can also be extended to include organizations outside Kerala. This gives a more general idea of the influence of motivation on organizational performance. The sample size can be expanded and the study can be conducted again. Each organization can be considered separately and then compared. As a continuation, the relationship between customer satisfaction and employee motivation can also be investigated.

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c. Project Guide- Dr. Satish K. P.
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e. Fellow Classmates

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Experimental Investigation of Trim Cut Machining on AISI 321 Stainless Steel Using Wire EDM

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Abstract: This work deals with the trim cut machining of AISI 321stainless steel using WEDM in terms of machining parameters such as pulse on time, pulse off time, peak current and wire tension to investigate the material removal rate (MRR) and surface roughness (Ra). Trim cut is performed after rough cut to remove the rough layer deposited after machining due to melting and re-solidification of the eroded metal from work piece as well as from wire electrode. Rough cut is performed with high power of the wire electrode, together with high pressure dielectric fluid. In the semi-finished and finished stages, the processes are conducted with lower power, together with laminar flow of dielectric fluid and higher wire tension. Trim cut in WEDM is done to remove the recast layer and surface irregularities formed on the machined surface after the rough cut. Taguchi's design of experiments was used for planning and designing the experiments. Optimisation of the process parameters has been done using response surface methodology and the relative significance of various factors are evaluated.

Keywords: WEDM, Trim Cut Machining, Material Removal Rate, Surface Roughness, Response Surface Methodology

I. INTRODUCTION

Wire EDM is a special form of the traditional EDM process in which the electrode is a continuously moving wire. Material is eroded from the workpiece by a series of discrete sparks between the workpiece (anode) and the wire tool electrode (cathode) separated by deionised water which acts as dielectric fluid and continuously flushes away the machining debris, i.e. eroded particles. The movement of the wire is controlled by CNC technology. Wire electrical discharge machining is growing at highly accelerated rate owing to its capability of achieving great dimensional accuracy, surface finish and contour generation features. Wire EDM provides the best alternative, or sometimes the only alternative, for machining conductive, exotic and hard to machine material with the scope of generating intricate shape and profile. Due to its widespread applicability in industry, manufacturing engineers require a reliable model for the prediction of output performances of this process

Achieving high accuracy, surface finish and tighter tolerances during machining of materials is essential for many industries. Wire Electrical Discharge Machining (WEDM) allows us to produce parts that could not be made traditionally. WEDM can cut any conductive material regardless of their hardness and strength. WEDM process is generally used in aerospace, automobile, tool and dies industry where accuracy and surface finish is having great importance. It can produce parts with complicated geometrical shapes, a quality edge and close tolerances and has the ability to cut production time and cost. To exploit the full potential of the WEDM machine tool, the machine should run at optimum conditions.

A. Trim Cut Machining

The purpose of trim cutting operation is to improve surface finish, job accuracies and to reduce the inaccuracies produced by minor job deformations after first cut. It also reduces bow effect on cut job surface produced in first cut due to adverse flushing conditions. Beside this, it also improves the die life by reducing the thickness of thermally affected layer formed, in the first cut, on the machined surface. The trim cutting or finish cutting is an operation where the wire electrode traces back the same path with certain amount of offset with respect to the path of the first cut. The number of trim cutting operations followed by first cut may vary from 1 to 3 with varying amount of offset values. This total operation, i.e. trim cutting operation followed by first cut or rough cut is commonly termed as "multi-pass cutting" or sometimes simply "trim or finish cutting" operation. At the first cutting stage, it is shaped with the highest power of the wire electrode, together with high-pressure dielectric fluid and lower wire tension. In the semi-finished and finished stages, the processes are conducted with lower power, together with laminar flow of dielectric fluid and higher wire tension

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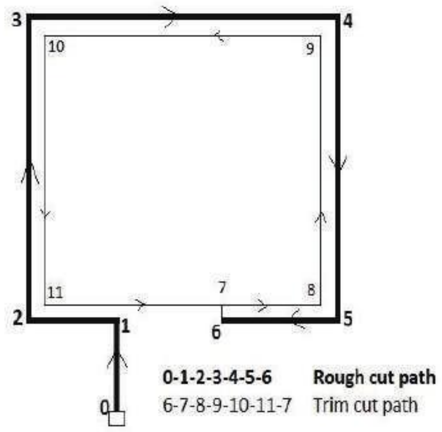

Figure 1 – Work path profile during trim cut machining

II. Literature Survey

Mehul M. Prajapati et.al (2018) [1] conducted research work on AISI 304L Stainless steel for machining using wire electrical discharge machining to evaluate the surface roughness from high to low discharge energy modes during main cut and trim cuts.Input process parameter which are taken into consideration are pulse on time (Ton), pulse off time (Toff), input power (IP), servo voltage (V) and servo feed (SF). The surface roughness is selected as a response variable. The experimental results reveal that the average surface roughness significantly reduced from 3.029 µm to 2.1303 µm for the test I from main/rough cut to trim cuts. For test II, Surface roughness reduced from 3.1243 µm to 1.854 µm from main/rough cut to trim cuts. And for test III, Surface roughness reduced from 3.196 µm to 1.9756 from main/rough cut to trim cuts. Also it is observed that from higher to lower discharge energy the surface roughness is decreases. Based on the experimental results it is concluded that surface roughness decreases from main/rough cut to trim cuts.

AmiteshGoswami et.al (2017)[2] investigated the features of trim cut wire EDM machining of Nimonic 80A in terms of machining parameters, to predict material removal rate (MRR), surface roughness (Ra), wire wear ratio(WWR) and microstructure analysis is carried. In this work, L27 orthogonal array with four control factors viz., Ton, Toff, IP, WO and three interactions viz., Ton * Toff, Ton * IP, and Ton * WO have been studied. Trim cut is performed after rough cut to remove the rough layer deposited after machining due to melting and re-solidification of the eroded metal from work piece as well as from wire electrode. In trim cut, wire electrode traces back the original path followed during rough cut with some wire offset values. In trim cut machining, pulse-on time (Ton) has been found to be the major factor affecting the MRR (52.31%) and SR (74.69%). The experimental work shows that the wire wear ratio has been mainly affected by wire off-set with a percentage contribution of 45.34. Highly significant interaction (for WWR) has been found between Ton * Toff. (14.90%) and Ton * wire off-set (14.71%). High value of surface finish can be obtained by trim cut machining. Highest MRR and SR were obtained at pulse-on time: 0.6 µs, pulse-off time: 14 µs, peak current: 90A, wire off-set: 0.10 mm and pulse-on time: 0.45 µs, pulse-off time: 14 µs, peak current: 120A, wire off-set: 0.12 mm respectively

Siva Prasad Arikatla et.al (2017)[3]Investigated multi cutting pass i.e. rough/main cut and trim/finish cut approach was adopted to improve the quality of surface characteristics of WEDM surface of Titanium alloy. The process parameters such as pulse on time, pulse off time, input power and servo voltage has taken at different levels as shown in Table 2. And the water pressure, wire feed rate and wire tension are taken as 10 kg/cm2, 8 m/min and 1.1 kgf respectively at constant. The influence of main cut and trim cuts on kerf width, cutting rate, MRR, overcut, surface roughness, surface topography and micro structural changes have been studies with reference to the experimental results. The results show that the WEDM ed surface topography shows dominant micro voids, thick white layer and heat affected zone and even micro cracks at high pulse on time and pulse current and these are low at low pulse on time and pulse current during trim cuts.

G. Selvakumar et.al (2015)[4] in the work studied die corner accuracy achievable through trim cutting operation has been analysed in the presence of a higher wire lag arising due to the higher workpiece thickness, acute corner angle, and higher flushing nozzle height. The influence of the corner error (uncut area left between the actual profile and the desired profile) generated in the first cut (rough cut) on the considered responses, namely volume removal rate, corner accuracy, surface roughness, and dimensional shift, has been analyzed by setting three different parameters during the first cut of the trim cutting operation.The effective wire offset in trim cutting (Ze), workpiece thickness (h), pulse on time, and peak current were the main influencing factors in determining the volume removal rate. The surface roughness (Ra) was predominantly influenced by the pulse on time, peak current, and the effective wire offset in trim cutting (Ze). The corner angle (θ) was the most important factor in determining the corner error (CE) followed by the flushing nozzle height (a), pulse on time, rough cutting parameters, and peak current. The dimensional shift (DS) was primarily influenced by the effective wire offset in trim cutting (Ze). The trim cutting

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operation is a superior strategy in improving the die corner accuracy than the pulse parameter modification strategy

S. Sarkar et.al (2008)[5]conducted experiments for investigating the features of trim cutting operation of wire electrical discharge machining of Ɣ-titanium aluminide. A second-order mathematical model,in terms of machining parameters, was developed for surface roughness, dimensional shift and cutting speed using response surface methodology (RSM). The experimental plan was based on the face centered, central composite design (CCD).The residual analysis and experimental results indicate that the proposed models could adequately describe the performance indicators within the limits of the factors that are being investigated. Finally the trim cutting operation has been optimized for a given machining condition by desirability function approach and Pareto optimization algorithm. It was observed that performance of the developed Pareto optimization algorithm is superior compared to desirability function approach.

.

III.EXPERIMENTATION

Experiments were performed randomly on ELECRONICA ULTRACUT S1 CNC wire electrical discharge machine (figure 2). From the available literature on trim cut WEDM, total four number of input parameters namely; pulse-on time(T_{on}),pulse-off time(T_{off}),peak current(IP) and wire tension(WT) were selected to study the material removal rate and surface roughness at different settings of the machine. In this work L_{27} orthogonal array with four control factors viz., T_{on} , T_{off}, IP and WT have been studied. Tables 2 and 3 shows the various process parameters with their levels for trim cut machining and L27 orthogonal array with four input variables assigned to different columns respectively. AISI 321 stainless steel of (12%Ni, 19% Cr, 0.7%Ti,65.295%Fe,2%Mn,0.75%Si,0.030%S,0.08%C,0.10% N) block of thickness 10mm was used as work material. Cubical block of size 10mm were machined. Firstly, rough cut was performed at the parametric condition corresponding to optimal MRR, with zero offset value and machining was stopped 2 mm before the wire electrode completed the rough cut. This was done to keep the punch in its position for trim cut. Then the machining path was reversed for trim cut by selecting trim cut parameters as per designed orthogonal array. Fig. 1 shows the work path profile during trim cut machining. Zn coated Brass wire electrode of diameter 0.25 mm (Soft) was used for performing the experiments. De-ionized water was used as the dielectric fluid. For more precise measurement, digital stopwatch was used for calculating the time taken for each experiment. Material removal rate was calculated by using the formula

$$MRR=(W_b – W_a) /\rho \times t$$

Where,
W_b – weight of the specimen before machining
W_a – weight of the specimen after machining
ρ – density of the material (8.027 g/cm^3)
t – machining time

Surface roughness is measured using taylor/hobson precision tester (Figure 3). An electronic balance with 0.001g accuracy is used to measure the weight of the workpiece.

Figure 2: ELECTRONICA ULTRACUT S1 CNC wire EDM

Figure 3: Taylor/Hobson precision roughness tester

Table 1: process parameter with their levels

Parameters	Units	Levels		
		1	2	3
Pulse on time(Ton)	µs	110	115	120
Pulse off time(Toff)	µs	50	55	60
Peak current(IP)	A	10	11	12
Wire tension(WT)	Kgf	8	9	10

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A. DATA COLLECTION

AISI 321 stainless steel specimen of size 10mm*15mm*20m are used for conducting experiment. The specimen have been prepared first with the help of conventional milling machine. Twenty seven numbers of samples of same material and same dimension have been made. After that the weight of each sample has been measured accurately with the help of electronic weighing balance machine. The specimens are machined using different levels of process parameters with the help of CNC Wire EDM accordingly. After machining the weight of the samples are measured accurately with the help of weighing machine. After machining the surface roughness have been measured with the help of Taylor/Hobson precision tester.

Table 2: Experimental observation

Exp no	Ton	Toff	IP	WT	R_a	MRR
1	110	50	10	8	1.96	9.175
2	110	50	11	9	2.53	10.631
3	110	50	12	10	2.97	13.548
4	110	55	10	9	2.67	9.358
5	110	55	11	10	3.06	13.291
6	110	55	12	8	3.12	14.027
7	110	60	10	10	2.64	7.861
8	110	60	11	8	2.91	12.914
9	110	60	12	9	3.04	14.292
10	115	50	10	8	2.82	10.864
11	115	50	11	9	3.12	11.844
12	115	50	12	10	3.96	13.206
13	115	55	10	9	2.76	8.642
14	115	55	11	10	3.01	10.927
15	115	55	12	8	3.42	13.468
16	115	60	10	10	2.37	8.003
17	115	60	11	8	2.98	10.561
18	115	60	12	9	3.07	13.072
19	120	50	10	8	2.89	11.014
20	120	50	11	9	3.37	13.125
21	120	50	12	10	4.32	14.694
22	120	55	10	9	2.48	10.836
23	120	55	11	10	2.87	11.947
24	120	55	12	8	3.53	13.378
25	120	60	10	10	2.72	10.546
26	120	60	11	8	3.16	11.754
27	120	60	12	9	3.68	13.363

B. DATA ANALYSIS

1) Taguchi Parametric Analysis

1.1) Effect of Process Parameters on Surface Roughness (SR)

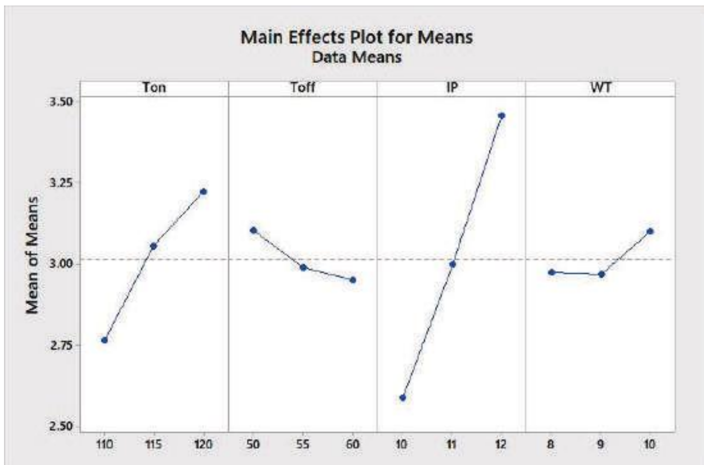

Figure 4: Main effects plot for means of R_a

Surface roughness is ‘smaller the better’ type characteristic. Surface roughness was measured using Taylor/Hobson roughness tester. Fig. 4 shows the main effects plot for means (SR).According to Fig. 4, the SR is lowest at the first level of pulse-on time (Ton1), third level of pulse-off time (Toff3), first level of peak current (IP1) and second level of wire

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tension (WT2). SR increases with increase in pulse-on time and peak current, while decreases with increase in pulse-off time. Peak current and pulse on time are the most influencing parameter that affects surface roughness with a percentage contribution of 54.62 and 15.58

1.2) Effect of Process Parameters on Material Removal Rate (MRR)

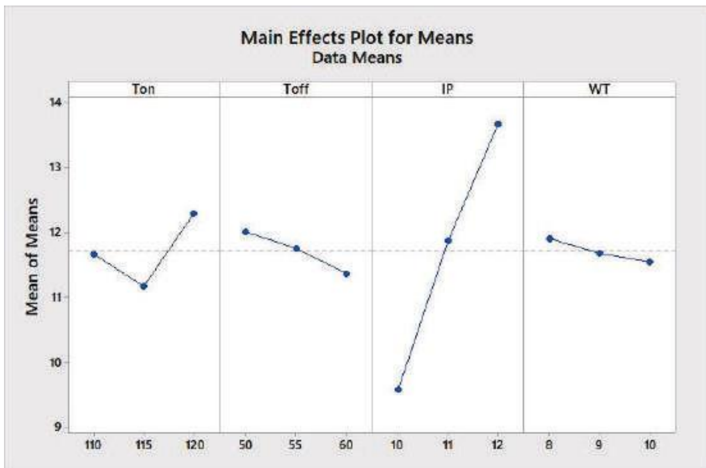

Figure 5: Main effects plot for means of MRR

Material removal rate is 'the larger the better' type characteristic. Fig. 5 shows the main effects plot for means (MRR). According to Fig. 5, the MRR is highest at the third level of pulse-on time(Ton3), first level of pulse-off time (Toff1), third level of peak current(IP3) and first level of wire tension (WT1). The MRR increased when the pulse-on time (Ton) and peak current were increased. Peak current is the most influencing parameters that affect material removal rate with a percentage contribution of 75.89

2) Multiple Regression Analysis

The relationship between a set of independent variables and the response *y* is determined by a mathematical model called regression model. When there are more than two independent variables the regression model is called multiple-regression model. In general, a multiple-regression model with *q* independent variable takes the form of
For second degree model

$$y = \beta_0 + \sum_{i=1}^{k} \beta_i x_i + \sum_{i<j} \sum \beta_{ij} x_i x_j + \sum_{i=1}^{k} \beta_{ii} x_i^2 + \epsilon$$

Where y is the corresponding response

Mathematical relationship between the input parameters and surface roughness
For second degree
Ra = -56.7 + 0.765 Ton + 1.026 Toff - 4.35 IP + 1.56 WT - 0.00244 Ton*Ton + 0.00149 Toff*Toff + 0.099 IP*IP + 0.047 WT*WT - 0.00717 Ton*Toff + 0.0263 Ton*IP - 0.0058 Ton*WT- 0.0093 Toff*IP - 0.0309 Toff*WT

Table 3: Fitted value compared with experimental value for R_a

Exp no	T_{on}	T_{off}	IP	WT	R_a	R_a predicted	% error
1	110	50	10	8	1.96	2.231	-13.8
2	110	50	11	9	2.53	2.578	-1.91
3	110	50	12	10	2.97	3.219	-8.39
4	110	55	10	9	2.67	2.519	5.65
5	110	55	11	10	3.06	2.76	9.8
6	110	55	12	8	3.12	2.947	5.56
7	110	60	10	10	2.64	2.667	-1.04
8	110	60	11	8	2.91	2.917	-0.25
9	110	60	12	9	3.04	3.062	-0.71
10	115	50	10	8	2.82	2.597	7.893
11	115	50	11	9	3.12	3.047	2.327
12	115	50	12	10	3.96	3.791	4.274
13	115	55	10	9	2.76	2.677	2.992
14	115	55	11	10	3.01	3.021	-0.36
15	115	55	12	8	3.42	3.397	0.661
16	115	60	10	10	2.37	2.617	-10.4
17	115	60	11	8	2.98	3.057	-2.6
18	115	60	12	9	3.07	3.304	-7.62
19	120	50	10	8	2.89	2.842	1.66
20	120	50	11	9	3.37	3.394	-0.72

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21	120	50	12	10	4.32	4.24	1.848
22	120	55	10	9	2.48	2.714	-9.42
23	120	55	11	10	2.87	3.159	-10.1
24	120	55	12	8	3.53	3.726	-5.55
25	120	60	10	10	2.72	2.445	10.1
26	120	60	11	8	3.16	3.075	2.68
27	120	60	12	9	3.68	3.424	6.95

2.1) Normal Probability Plot for R_a

The normal probability plot as shown below represents clear pattern indicating that all the factors and their interaction given in are affecting the Ra

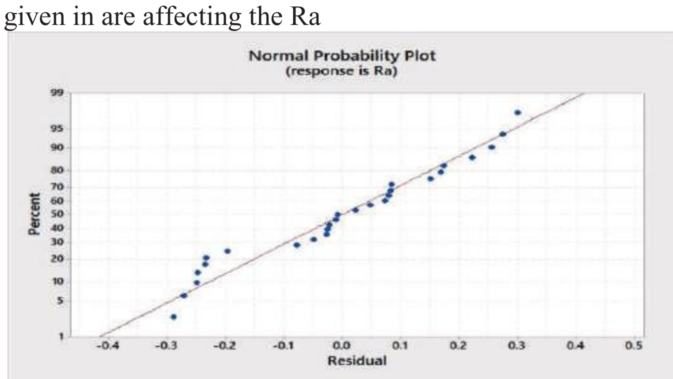

Figure 6: *Normal Probability Plot for R_a*

2.2) Contour Plots of R_a

The below figure shows the contour plots of R_a. colour in this figure gives us a clear idea about the regions where surface roughness is minimum while considering the interaction effect

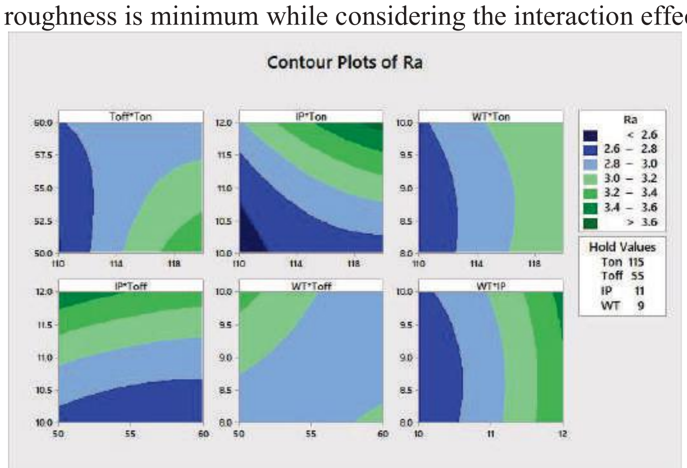

Figure 7: *Contour Plots of R_a*

Mathematical relationship between the input parameters and surface roughness

For second degree

MRR = 262 - 5.68 Ton + 1.41 Toff + 10.5 IP -7.30 WT + 0.0324 Ton*Ton- 0.0028 Toff*Toff- 0.112 IP*IP + 0.329 WT*WT - 0.01628 Ton*Toff - 0.1072 Ton*IP + 0.0410 Ton*WT+ 0.1125 Toff*IP - 0.0584 Toff*WT

Table 4: Fitted value compared with experimental value for MRR

Exp no	T_{on}	T_{off}	IP	WT	MRR	MRR predicted	% error
1	110	50	10	8	9.175	9.587	-4.49
2	110	50	11	9	10.63	11.43	-7.48
3	110	50	12	10	13.55	13.7	-1.11
4	110	55	10	9	9.358	9.042	3.379
5	110	55	11	10	13.29	11.81	11.16
6	110	55	12	8	14.03	14.31	-2.04
7	110	60	10	10	7.861	8.417	-7.19
8	110	60	11	8	12.91	12.3	4.73
9	110	60	12	9	14.29	14.49	-1.41
10	115	50	10	8	10.86	9.807	9.728
11	115	50	11	9	11.84	11.32	4.401
12	115	50	12	10	13.21	13.27	-0.5
13	115	55	10	9	8.642	9.068	-4.93
14	115	55	11	10	10.93	11.51	-5.35
15	115	55	12	8	13.47	13.08	2.878
16	115	60	10	10	8.003	8.259	-3.2
17	115	60	11	8	10.56	11.2	-6.04
18	115	60	12	9	13.07	13.07	0.04
19	120	50	10	8	11.01	11.66	-5.85
20	120	50	11	9	13.13	12.85	2.084

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21	120	50	12	10	14.69	14.48	1.469
22	120	55	10	9	10.84	10.73	1.014
23	120	55	11	10	11.95	12.85	-7.53
24	120	55	12	8	13.38	13.48	-0.75
25	120	60	10	10	10.55	9.724	7.794
26	120	60	11	8	11.75	11.73	0.232
27	120	60	12	9	13.36	13.27	0.683

2.3) Normal Probability Plot for MRR

The normal probability plot as shown below represents clear pattern indicating that all the factors and their interaction given in are affecting the MRR

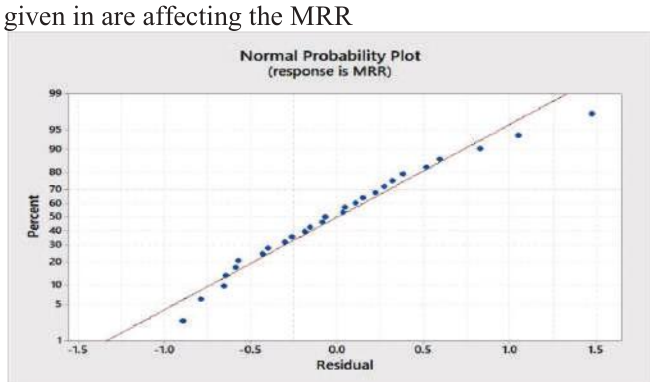

Figure 8: *Normal Probability Plot for MRR*

2.4) Contour Plots of MRR

The below figure shows the contour plots of MRR. Colour in this figure gives us a clear idea about the regions where material removal rate is maximum while considering the interaction effect

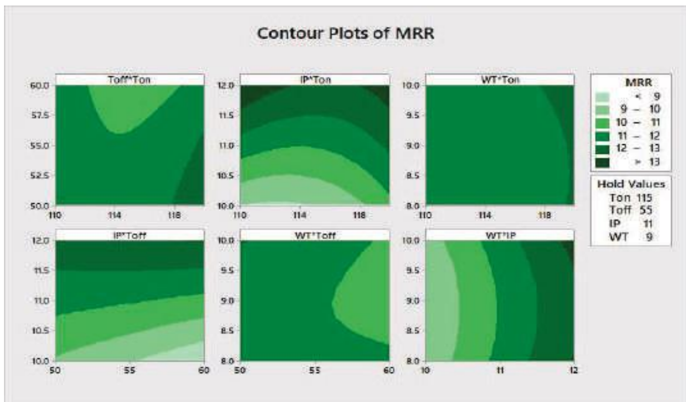

Figure 9: *Contour Plots of MRR*

IV. RESULTS & CONCLUSIONS

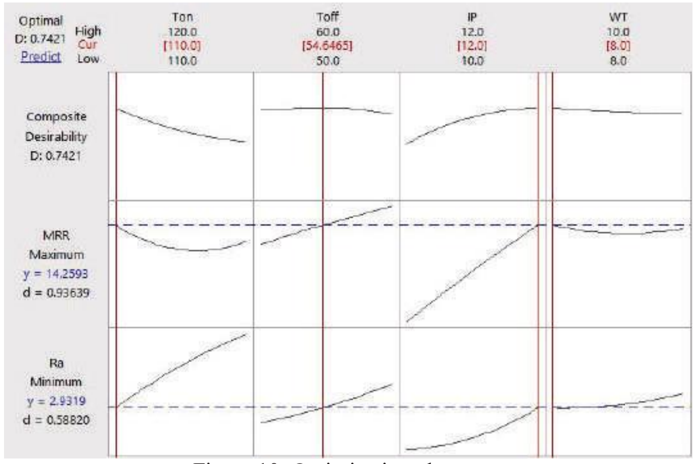

Figure 10: Optimization plot

- The optimization plot signifies the affect of each factor on the responses or composite desirability.
- The vertical red lines on the graph represent the current factor setting.
- The number displayed at the top of column shows the current factor level.
- The horizontal blue lines and numbers represent the responses for the current factor level.
- Minitab calculates the maximum material removal rate and minimum surface roughness
- From the optimization plot
  Maximum MRR=14.25973 mm^3/min
  MinimumSR(Ra)=2.9319microns
  obtained when
  T_{on} = 110 µs , T_{off} = 54.5465 µs, IP =12 A, WT = 8 kgf
  Composite desirability = 0.7421
- The effect of machining parameters such as T_{on} ,T_{off}, IP and WT on surface roughness and material removal rate are studied with the help of ANOVA
- Peak current and pulse on time are the most influencing parameter that affect surface roughness with a percentage contribution of 54.62 and 15.58
- Peak current is the most influencing parameters that affect material removal rate with a percentage contribution of 75.89
- In this work, multi response optimization problem has been solved by using an optimal parametric combination of input parameters such as T_{on}, T_{off} ,IP and WT using MINITAB 17 software.
- Mathematical equation have been developed showing the relation between input parameters and responses with the help of Regression analysis

- Response surface methodology has been successfully implemented for optimizing the input parameters.
- The optimum condition was successfully predicted by using the mathematical equation.

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d. Research Scholars of Dept. of Mechanical Engineering, NSS College of Engineering Palakkad
e. Fellow Classmates

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An Empirical Study on Classification of Automotive Spare Parts Based on Demand Pattern

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Abstract: Spare parts are very essential in most industrial companies. They are characterized by their large number and their high impact on the company's operations whenever needed. Spare parts demands are very particulate. In the majority of cases it takes place with irregular time intervals and very variable quantities. A classification of spare parts therefore, is helpful to determine service requirements for different spare parts classes, and for forecasting and stock control decisions. In this paper, an empirical study was conducted on spare parts classification at Popular Vehicles & Services Ltd, Trissur. The experimental database consists of the individual demand histories of almost 12500 spare parts. The classification was done based on demand pattern. Four quadrants were identified based on two dimensions; Demand size variability and Average inter demand interval. The empirical results from this study demonstrate considerable scope for applying forecasting methods.

Keywords: Spare Parts, Classification, Demand size variability and Average inter demand interval.

I. INTRODUCTION

A spare part is a corresponding part that is kept in an inventory and used for the repair or replacement of failed parts. Spare material has special characteristics that distinguish it from all the other materials used in a productive or service system. The principle feature resides in the consumption profile: the demand of spare parts are intermittent (an intermittent demand is a demand which takes place with irregular time intervals and concerns reduced and above all, very variable quantities).

Spare parts forecasting poses a large challenge for all forecasters. The accuracy of a forecasting method for a particular product depends on characteristics exhibited by the product's demand history. The reason is that the demand is stochastic and a big proportion of the demand data is zero for several periods of time resulting on having inaccurate results. Consequently, demand time series are sometimes divided into several discrete categories in order to assign the best forecasting method. So classifications of spare parts based on demand can serve for accurate forecasts. This study focuses on the classification of automotive spare parts based on demand pattern.

II. LITERATURE SURVEY

Literature has many contributions on spare parts classification. Williams (1984) was the first to propose demand variation partition in basic components towards item categorization.

Eaves and Kingsman (2004) developed over Williams (1984) ideas and proposed new categorization scheme focused on demand forecast models selection.

The classification of Syntetos et al. (2005) is as Four quadrants, which are determined based on two dimensions: demand size variability and average demand inter-arrival interval.

III. SPARE PARTS DEMAND CATEGORIZATION

The spare parts demand is very uneven. Infrequent demand occurrences or irregular demand sizes, when demand occurs, do not allow lead time demand to be represented by the

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normal distribution. In these cases, demand will be called as non-normal. In the majority of the cases, it takes place with irregular time intervals and concerns reduced and, above all, very variable quantities as shown in figure.

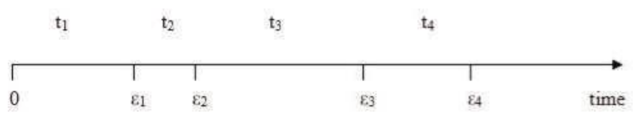

Figure.1 example of the non-normal (intermittent) consumption of a spare part

€i = consumption of spare part (pieces)
ti = interval between two consecutive demands

For a valuation of this double characterization of spare parts demand, two parameters
recognized in international field are utilized:

ADI - Average inter-demand interval: average interval between two demand of the spare part. It is usually expressed in periods, where the period is the referential time interval which the business utilizes for the purchases;

CV – Coefficient of variation: standard deviation of the demand divided by the average demand.

$$\mathrm{ADI} = \frac{\sum_{i=1}^{N} t_i}{N}$$

$$\mathrm{CV} = \frac{\sqrt{\frac{\sum_{i=1}^{N} (\varepsilon_i - \varepsilon)^2}{N}}}{\varepsilon}$$

$$\text{where } \varepsilon = \frac{\sum_{i=1}^{N} \varepsilon_i}{N}$$

For ADI, N is the number of periods with non-zero demand, while for CV it is the number of all periods.

Four quadrants are determined based on this; considering cutoff values of 0.49 for CVand 1.32 for ADI. These cutoff limits were mathematically determined by comparing Mean Square Error (MSE) of different forecasting models. The cutoff limits derived by Syntetos et al. (2005) are expected to have general validity for a wide range of realistic control parameters. The Figure2 presents the four categories of the spare parts demand patterns.

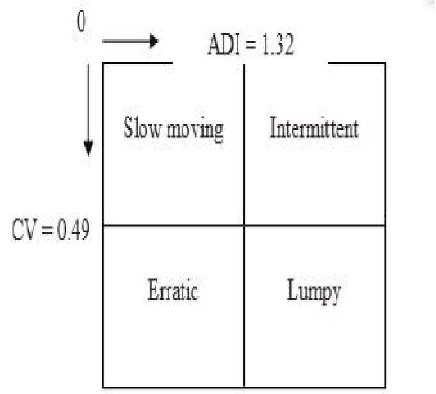

Figure.2 Principal patterns for the characterization of the spare parts demand

Four quadrants can be recognized:

1. Slow Moving (or Smooth): This items have a behaviour which is similar to that of the traditional articles, whose average demand per period is low. This may be due to infrequent demand occurrences, low average demand sizes or both

2. Strictly Intermittent: Item with infrequent demand occurrences. They are characterized by extremely sporadic demand (therefore a lot of a period with no demand) with a not accent variability in the quantity of the single demand.

3. Erratic: This item's demand size is highly variable. The fundamental characteristic is the great variance in the requested quantity, but the demand is approximately constant as distribution in the time.

4. Lumpy: It is the most difficult to control category. Its demand, when it occurs, is highly variable because it is characterized by a lot of intervals with zero-demand and a great variability in the quantity.

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IV. EMPIRICAL RESULTS

The data set contains information on ordered spare parts at the Popular vehicles and services during the period from April 2017 to February 2019. Each spare part data includes the item code, item description, order date and the issued quantity. The total number of spare parts items used is 12517. Using this demand pattern based on two dimensions namely Average inter-demand interval and Coefficient of variation. Spare part items were classified into four categories; Erratic, Lumpy, Intermittent and Slow Moving. The classification was conducted based on the monthly demand of spare part. Table 1 and figure.3 shows the results of the classification.

Table.1 Results of classification

Classification	Number of Spare Parts
Erratic	617
Lumpy	9760
Slow Moving	676
Intermittent	1464

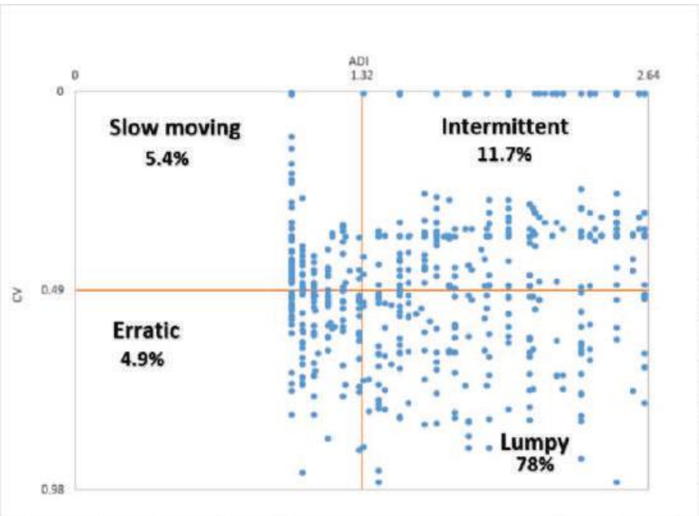

Figure.3 Four Quadrant Categorization.

This study may be used as a preliminary research into the motivational set up in Kerala and may also be used to discover more effective motivational factors, which could fuel organizational performance.

V. CONCLUSION

The automotive spare parts are classified into four as Erratic, Lumpy, Slow Moving and Intermittent based on two Demand size variability and Average inter demand interval. It is found that the more number of products comes under the category of Lumpy which have 78% of total and the least number of products comes under Erratic, which is 4.9%.

This study is used as the preliminary step for the demand forecasting of automotive spare parts.

VI. LIMITATIONS AND FUTURE SCOPE

A. Limitations

The data collected was from April 2017 to Feb 2019, since the company was established 3years ago, which needs to be expanded for more accurate results.

B. Future Scope

The study can be extended to find out the demand forecasting methods for the categorized spare parts.

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Designing and Investigation of Static and Dynamic Behaviour of Non-Pneumatic Tyre with Polyurethane Spokes For Fabrication

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Abstract: Non-pneumatic tires (NPTs) have wide application prospects due to their advantages of no run flat, no need of air pressure maintenance, and low rolling resistance. The common non-pneumatic spoke structure is honeycomb. The objective is to create another spoke structure and to investigate the dynamic and static analysis to evaluate the properties. NPT parts and structure is studied. Individual part modeling and assembly is done. The load and other parameters are to be applied on the assembled structure. Stress concentrations, deformation, rolling resistance are some of the important factors in the project. Manufacturing of spoke is planned to be carried out through 3D printing technology. The analysis is a series of simulation procedures which includes many parameters such as designing, material selection, geometric modeling and numerical methods. The numerical methods include defining constraints and force direction along with the other parameter like meshing.

Keywords: NPT, Static analysis, Dynamic analysis, 3D printing

I. Introduction

Non-pneumatic tires (NPTs) have wide application prospects due to their advantages of no run flat, no need of air pressure maintenance, and low rolling resistance. The common non-pneumatic spoke structure is honeycomb. The possibility for another structure replacing the existing structure is a budding field. The objective is to create another spoke structure and to investigate the dynamic and static analysis to evaluate the properties. NPT parts and structure is studied. Individual part modeling and assembly is done. The load and other parameters are applied on the assembled structure. Stress concentrations, deformation, rolling resistance are some of the important factors in the project. These factors have a higher rate in influencing the behavior of the non-pneumatic tyre performance. Manufacturing of spoke is planned to be carried out through 3D printing technology. The analysis is a series of simulation procedures which includes many parameters such as designing, material selection, geometric modeling and numerical methods. The numerical methods include defining constraints and force direction along with the other parameter like meshing. The final objective of the project is to find out the closeness of the behavior of a new structure properties with that of the existing. The project goes through a series of operations such as computer aided modeling, property analysis through the collected data using mechanical software and also an advanced manufacturing technique familiarization and the relation between the actual and simulated parameters.

II. Objective

The objective of this research is to

1. To design a Non-pneumatic tyre design using the standard nomenclature and the polyurethane material.
2. To carry out the static analysis on the new model using Ansys workbench software.
3. To analyse the behaviours and compare with the trends of the existing design.
4. To investigate dynamic conditions on the analysis software and compare with the traditional trend.
5. To check the rolling resistance behaviour of the whole model.
6. Manufacture the prototype using any one advanced manufacturing technique.

III. Literature Survey

Detailed investigation reports on the analysis regarding the static and dynamic properties have been notified in the journal of composite materials which is published on 2018. The authors Xiaochao Jin, Cheng Hou details about the behaviour variations in the wheel simulation with respect to the variation of load applied on the structure [1].

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Rhyne T, Cron SM [2] in their journal details about the development of a non-pneumatic tyre and this also describes the advantages of such a wheel over the traditional tyre and also other features.

Cho JR, Kim KW, Yoo WS, Hong SI [3] also is a similar journal which has the above mentioned details but also ex0plains about the components of a non-pneumatic wheel and the peculiarity each of the component insist to adapt to the design. A typical NPT usually consists of a hub, a number of flexible spokes, a shear ring and a tread.

Honeycombs possess high stiffness and strength in out-of-plane directions, and relatively lower mechanical resistance and higher resilience in in-plane directions. This was an important data required for the design and this was formulated of identified by Gibson LJ, Ashby MF [4].

Therefore, the in-plane configuration of honeycombs is usually utilized in NPTs. In addition, the cell structures of honeycombs are tunable to optimize in-plane properties, e.g. by changing the cell angle, wall thickness, and length to produce tailored stiffness and strength. This property analysis was formulated in a journal of composite material published on 2016[5, 6].

Recently, an attempt has been made to use honeycomb spokes in constructing NPTs in trucks [7]. Zhang QC, Yang XH, Li P, Huang GY, Feng SS, Shen C, Han B, Zhang XH, Jin F, Xu F, Lu TJ who were the authors of this journal done a detailed work report on the practical application of the tyre by adapting it into the trucks.

IV. CONSTRUCTIONAL DETAILS

Unlike the traditional tyre the non-pneumatic tyre does not have an inflated sidewall and this design is entirely different from that of the previous one. Here the tyre have a number of components that the pneumatic tyre does not have and this is the important characteristic which have to be taken care of in manufacturing a non-pneumatic tyre. The main component is a flexible polyurethane material which is used as a spoke in place of the inflated air column inside a traditional tyre. This flexible polyurethane spoke is transformed into required structure and this is used to absorb the cyclic tensile compressive action occurring due to the contact of the tyre with the road. The wheel hub/rim is same as that of the normal hub used in the ordinary wheel structure and this does not require any modification. Upon the wheel rim the polyurethane material is mounted and this is created as per the standard geometrical dimensions. On the periphery of the polyurethane spoke the shear band is assembled. A shear band is a composite structure constructed with the combination of the polyurethane shear ring sandwiched in between the two inner and outer ring made out of the standard AISI 4340 stainless steel. This again is mounted over by a tread structure on the outermost periphery which is made out of the synthetic rubber. These are the most common components used in the construction of a non-pneumatic tyre.

A. *Geometric details*

The geometric dimensioning of each component has been done using the standard format. Normally the geometric aspects mainly based on the dimension of the wheel hub/rim dimension because as per the Indian tyre design standards IS 15363(2012) the sidewall height can be determined through the available dimension of the wheel rim. And the corresponding height and the dimension for each component are determined. The important parameter in the tyre design field is the tyre representation code where each code representation is for peculiar data regarding the component details. From the dimension we come to know the cross sectional width, then the aspect ratio and the constructional nature of the ply. In this case the ply construction must be in radial nature. But the relevance of the ply construction in the non-pneumatic tyre is not so important. In some cases the load capacity of the tyre will also be represented and this is known as load index. The standard geometric sizes and the tyre representation are detailed as:

WHEEL REPRESENTATION=145/80/R13

- No of holes=4 or 8
- 80% width of the sidewall height is the aspect ratio
- R= Radial construction
- Cross sectional width of NPT=145mm
- Diameter of NPT=562.2mm
- Sidewall height=116mm
- Diameter of rim=330.2mm
- Thickness of rim=5mm
- Thickness of shear band=9mm
- Thickness of rings=0.5+0.5mm
- Thickness of tread=5mm
- Inner radii of rim=100mm

B. *Material properties*

The suitable materials for the manufacturing of each component are selected as per the standard nomenclature and Indian standards. The properties which each component requires for fulfilling the purpose vary with respect to the design also. So the compatibility and the easiness in availability of material along with the affordability were some parameters taken into consideration. The materials properties of materials were tabulated.

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Table.1. Material Properties

Material	Density Kg/m^3	Poisson's ratio	Shear modulus Gpa	Bulk modulus Gpa
Aluminium Alloy(7075-t6)	2800	0.33	26	68
High strength steel	7830	0.27	84	14
Concrete	2300	0.18	12	15
Polyurethane	1265	0.40	10	5
Rubber	$2.3*10^{-6}$	0.47	34	55

C. Structure and software selection

The selection of the structure for the sidewall is selected from a number of possible structures and this is done normally from the auxetic structures. The property of the auxetic structure is that they become thicker when stretched. This is in the perpendicular direction of the applied force. Normally the hexagonal honeycomb structures are most commonly used as their properties are suitable for the purpose. This occurs due to the internal structure of the material structure and the auxetic can be single crystals, molecules or even particular structure. These structures usually possess high mechanical properties high energy absorption and high fracture resistance. Hexagonal structure is replaced with another auxetic structure and the investigation was done on the design compatibility and the behaviour of structure under variable condition of static and dynamic parameters.

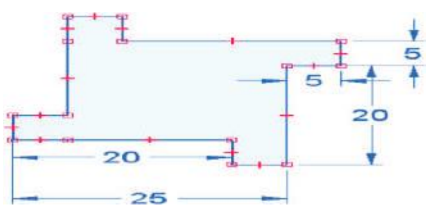

Fig. 1 Basic structure geometry

V. DESIGNING

The designing was carried out in different phases. Each component was 2D drafted at first and then the assembly was done. The standard geometrical calculations were done for each component. After the compatibility check on the dimensions through the 2d drafts 3D projections for each component were designed and they were assembled.

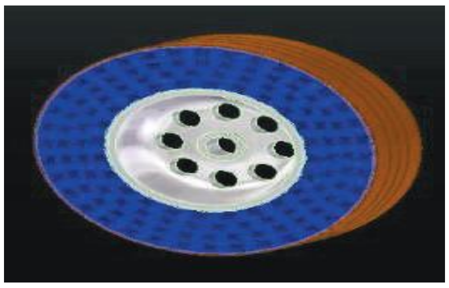

Fig. 2 Assembled view of components.

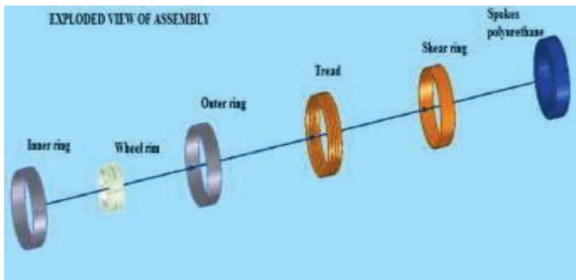

Fig. 3 Exploded view of components

VI. STATIC ANALYSIS

Only the static parameters are considered here. Once the model is transferred from the designing software to the analysis software there are certain factors or some numerical data to be collected. Static analysis is mainly done using the condition of varying load application. Once load is applied the corresponding deformation and the stress distribution is calculated and from this the behaviour can be founded out.The collected engineering data has been transferred in to the designing software and also modal validation is done for carrying out the meshing operation and the parameters for static conditions are applied. The deformation in spokes as well as in whole assembly along with the stress distribution is founded out and the corresponding graphs are plotted. Forces ranging from 100N to 3000N were applied.

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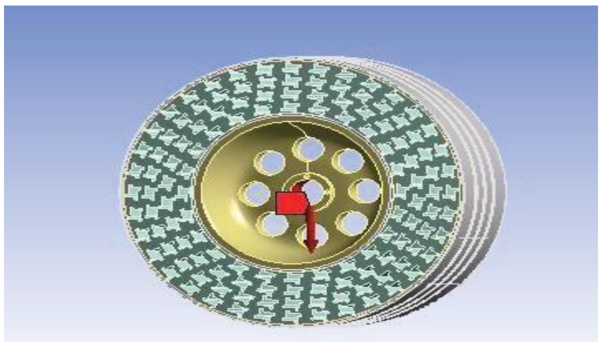

Fig. 4 Static forces applied

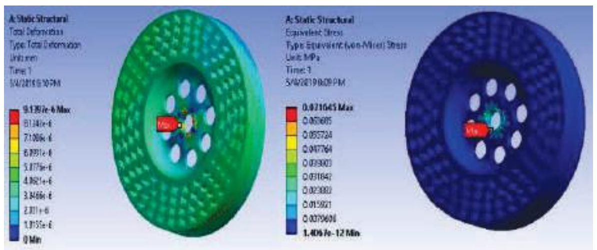

Fig.5: Stress and deformation in assembly

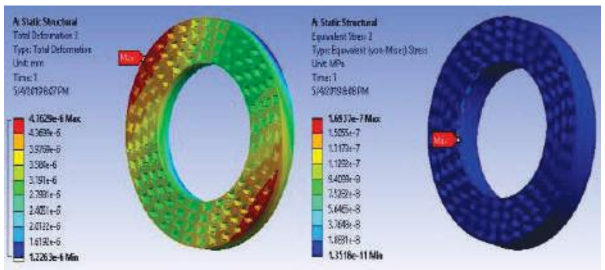

Fig.6: Stress and deformation in spoke

VII. DYNAMIC ANALYSIS

The same procedure as of static condition is followed except the variable parameters as that required for the dynamic conditions are applied.

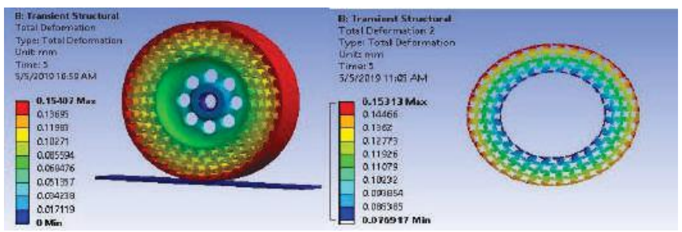

Fig.7: Deformations in spoke and wheel

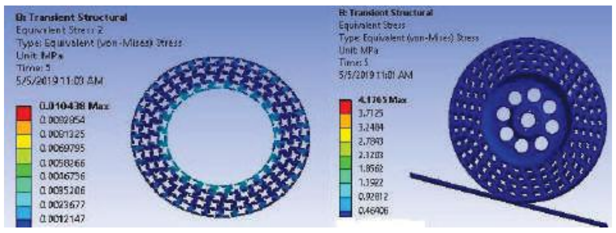

Fig.8: Stress in wheel and spoke

A. Behavioural Analysis through graphs

Graphs were plotted for the stress distribution and the deformation of the wheel under the conditions applied on the simulation. The stress distribution behaviour and the deformation individually for whole assembly as well as the spokes were analysed and were compared with the trend for a pneumatic tyre. The non-pneumatic tyre showed exactly the same trend as that of the traditional tyre. Thus the next step was to analyse the trend of rolling resistance.

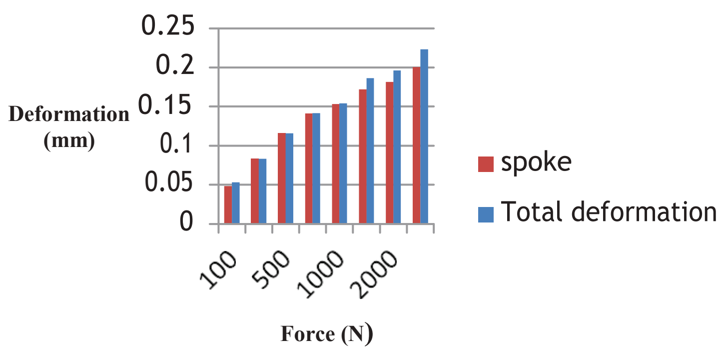

Fig.9: Deforamtion graph under dynamic condition

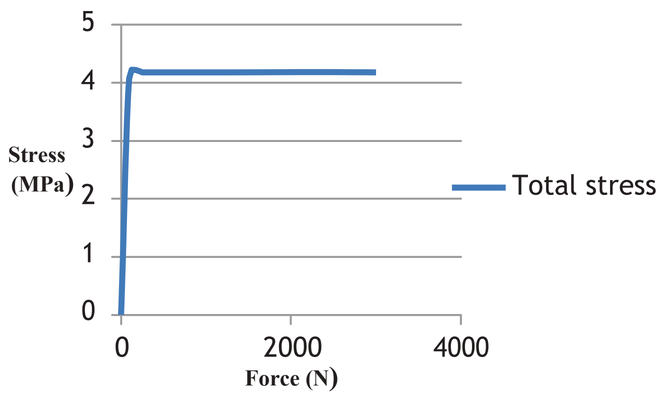

Fig.10: Total stress

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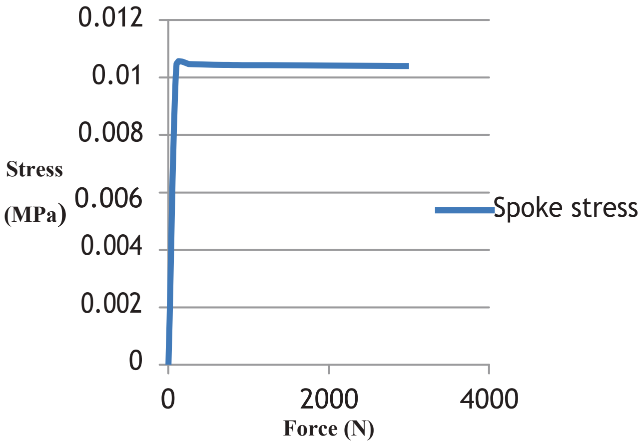

Fig.11: Spoke stress

B. Rolling resistance

Rolling resistance is calculated when tyre is rolled at steady and maximum speed of 10rad/sec.Normally rolling resistance is found to be low for spokes with small mass and smallest deformation. Dynamic friction coefficient is considered as 0.15 in the dynamic analysis calculations.
Mathematical equation for calculating rolling resistance is:
$F_{RR} = C_{RR} * \text{Weight/ Radius of wheel}$
F_{RR} = Rolling resistance force to be calculated
C_{RR} = Coefficient of rolling resistance
Weight = Force due to gravity being exerted on each tyre (mass of tyre in kilograms*9.81)
We can understand that the role of speed in calculating the rolling resistance is insignificant.
And also the coefficient of rolling resistance for the polyurethane material is 0.030-0.057 .The loads were converted to lbs. and the diameter to inches as MKS system and the results once obtained was converted to SI system. Thus the rolling resistance under variable loads were calculated and tabulated for generating the graphs and verifying the behaviour.

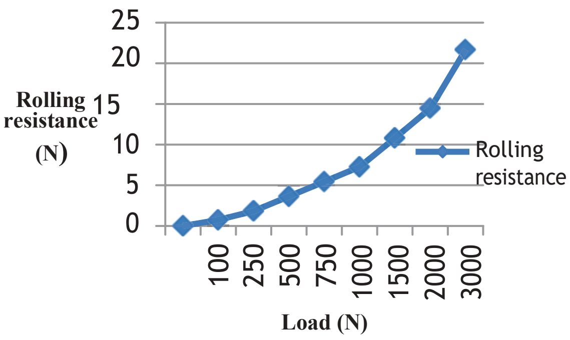

Fig.12: Rolling resistance

C. Manufacturing of prototype

To check the possibility of designed structure compatibility in the real life application on the polyurethane material a prototype was manufactured using the same materials.
Advanced manufacturing technique of 3D printing was opted for the process to get familiarized with the modern manufacturing method and also this was an optimal solution in case of the cost when the tyre is manufactured in small numbers.

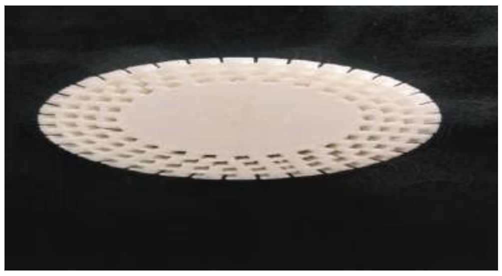

Fig.13: Spoke prototype

VIII. CONCLUSION

In conclusion, the goal of this project work is to analyse the behaviour of the non-pneumatic tyre design under varying load conditions in case of static and dynamic environment. The static analysis results were studies and the gradual increase of the stress and deformation was similar to that of in the pneumatic tyre. But the values obtained here was too low. The reduction in values may be due to the change in structure and also the material used. Thus the next step is to analyse the dynamic conditions which includes rolling resistance also. While analysing the result the rolling resistance shows the same trend as that of in traditional tyre where the force increases rapidly after a slow increase till 1000N. Both the static and dynamic condition of the tyre shows the same behaviour when graphs were plotted as that of the traditional pneumatic tyre. There is a reduction in the values range and it is assumed because of the change in load application and also due to the variable conditions of simulation.

IX. LIMITATIONS & FUTURE SCOPE

A. Limitations

The study is done only in the consideration of flat road. The contact problem parameters are not taken in to consideration. Also the work can be done using varying parameter of speed and other designs or auxetic structures.

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B. Future Scope

The scope of the work has a lot of depth and scope as the optimality of the design in the simulation analysis is acceptable and live experimentation can be done. The adaptation of new manufacturing techniques can be studied and validated. The existing structure can be replaced and the analysis can be done using other possible auxetic structures under the same format.

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b. NSS College of Engineering Digital Library
c. Project Guide- Dr. Suresh K. S.
d. Fellow Classmates

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An Experimental Investigation of Texturing On Cutting Performance of Tungsten Carbide Cutting Tool

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Abstract: Dry Machining, the process of machining without the use of coolants/cutting fluids is the need of the hour, as the environmental pollution and the manufacturing costs are at their highest. With every second, the manufacturing costs are increasing causing global inflation, and also the pollution has been increasing, reducing the human life span and the quality of life. The coolants represent 15- 20% of the manufacturing cost, and this cost can be easily avoided by avoiding the excessive use of cutting fluids. Although cutting fluids cannot be restricted completely, dry machining can be practiced where the quality and machining time are equal to or better than wet machining. Several methods adopted for the tool wear reduction but the effective one is texturing on rake face of a cutting tool .It has recently emerged as a promising and environment friendly method enhancing removal of heat from the machining zone. In this study tungsten Carbide used as cutting tool because it is the most suitable materials for dry cutting and high- speed machining of high hardness work piece EN9 steel due to their unique intrinsic properties, such as: high melting point, high hardness, and good chemical inertness. This paper reports study on the influence of dot, parallel line and vertical line textures by electrical discharge machining on rake face of the Tungsten Carbide cutting tools. The texturing on the carbide tool is done by Electrical discharge machining (EDM). Dot-textured, parallel line-textured, vertical line-textured and non-textured carbide tools were used in turning of EN9 steel and their performance was compared in terms of machining forces, tool temperature, and surface roughness of the turned work piece. Use of dot-textured carbide tool resulted in least values of cutting forces, tool temperature, and surface roughness of the turned work piece than the textured carbide tools at different cutting speeds, depth of cuts and feed rate. Dot also act as fins which enhance heat loss to the machining environment and helping in reduction of tool temperature. By using grey relational analysis and mini-tab software the results were analyzed and optimum points are obtained. This study proves that dot-texturing of rake face of tungsten carbide tool by Electrical discharge machining process is an economical, effective and environment friendly method to improve cutting Performance. Thus, an improvement in machining output parameters have resulted in the increase in tool life.

Keywords: Dry machining, texturing, EDM, dot-textured, parallel line-textured, vertical line-textured, grey relational analysis.

I. Introduction

Dry machining (without the use of any cutting fluid) is an important objective in industry to reduce environmental pollution and production costs, and it is becoming more and more popular in the world. However, in dry machining, there will be more friction and adhesion between the tool and work piece since they will be subjected to a higher temperature caused by severe friction between the tool and work piece during the machining process. Surface structuring can be used to alter the surface topography in order to improve tribological behavior. This will result in increasing tool wear and hence a reduction in tool life. Tungsten Carbide cutting tools are generally the most suitable materials for dry cutting and high-speed machining of high hardness work piece materials compared to high-speed steel and carbide tools due to their unique intrinsic proper- ties, such as: high melting point, high hardness, and good chemical inertness.

This improvement is linked with effective lubrication, debris entrapment, reduced contact stresses and/or hydrodynamic lift. Recently, this methodology has been applied to cutting tools. Thirteen percent reduction in cutting force and 30 % reduction in feed force was reported when steel was used as work piece while 50 % reduction in cutting forces and 75 % in feed forces were reported when aluminum were used as a work piece. In recent years, surface texturing has been introduced to improve the tribological properties of contact surfaces, many researchers found substantial improvement of tribological performance when applied with a

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textured surface compared with a non-textured surface under different conditions. During metal cutting process, severe friction exists when the tool is in contact with the workpiece, i.e., on the rake face, resulting in a series of phenomenon such as cutting deformation, cutting forces, cutting heat, adhesions, and tool wear . To alleviate the severe friction and wear condition, the cutting fluids are usually used. . Moreover, lubricating action of cutting fluids requires that the cutting fluids absolutely penetrate the capillaries of cutting zone and have the time available for it to chemically react with the chip to reduce the interfacial shear strength. With its lubricating and cooling functions, the cutting fluids can help in reducing the cutting temperatures and friction forces and hence improves the tool life.

In recent years, surface texturing has been introduced to improve the tribological properties of contact surfaces, many researchers found sub- stantial improvement of tribological performance when applied with a textured surface compared with a non-textured surface under different conditions.

II. MATERIALS AND PROPERTIES

A. *Properties of work piece*

EN9 used as a work piece in this experimental procedure. EN9 is a medium carbon steel grade commonly supplied in the as rolled condition. It can be flame or induction hardened to produce a high surface hardness with excellent wear resistance for a carbon steel grade. It is used commonly for many general engineering applications. Typical applications include, shafts, axes, knives, bushes, crankshafts, screws, sickles, wood working drills and hammers.

TABLE I : EN9 ALLOY STEEL ROUND BAR CHEMICAL COMPOSITION

Carbon	Phosphorus	Manganese	Sulphur	Silicon
0.50-0.60%	0.06% max	0.50-0.80%	0.06% max	0.05-0.35%

TABLE II: EN9 ALLOY STEEL ROUND BAR PHYSICAL PROPERTIES

DENSITY (G/CM²)	8.08
DENSITY (LB/IN³)	0.292
MELTING POINT (°C)	1425
MELTING POINT (°F)	2600

TABLE III: EN9 ALLOY STEEL ROUND BAR MECHANICAL PROPERTIES

TENSILE STRENGTH (MPa)	551
YEILD STRENGTH (MPa)	241
ELOGNATION(%)	30

B. *Properties of cutting tool*

Tungsten carbide cutting tools are generally the most suitable materials for dry cutting and high- speed machining of high hardness work piece materials compared to high-speed steel and carbide tools due to their unique intrinsic proper-ties, such as: high melting point, high hardness, and good chemical inertness.

Tungsten carbide (chemical formula: WC) is a chemical compound containing equal parts of tungsten and carbon atoms. In its most basic form, tungsten carbide is a fine grey powder, but it can be pressed and formed into shapes through a process called sintering for use in industrial machinery, cutting tools, abrasives, armour-piercing rounds, other tools and instruments, and jewellery.

TABLE IV : TUNGSTEN CARBIDE PROPERTIES

Property	Minimum Value (S.I.)	Maximum Value (S.I.)
Poisson's Ratio	0.2	0.22
Shear Modulus	243	283
Tensile Strength	370	530
Young's Modulus	600	686

III. DETAILS OF EXPERIMENTATION

A. *texturing design*

There are four different types of texturing are done by electric discharge machining and the designs are created in creo parametric software. The four types of texturing designs are dot texturing (fig 2) ,vertical line texturing (fig 3) and parallel line texturing(fig 4). These texturing are done by EDM. Electrical Discharge Machining (EDM) is a controlled metal-removal process that is used to remove metal by means

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of electric spark erosion. In this process an electric spark is used as the cutting tool to cut (erode) the work piece to produce the finished part to the desired shape. In EDM the input voltage is 40v-80v ,pulse on time 50-130 micro seconds and pulse of time is 50-130 micro seconds.

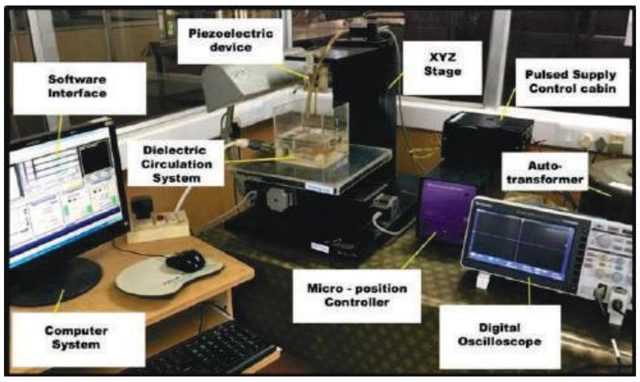

Figure 1 : EDM experimental setup

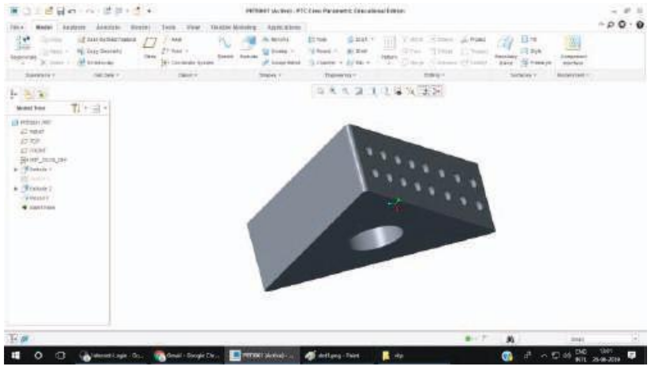
Figure 2: Dot textured tool design.

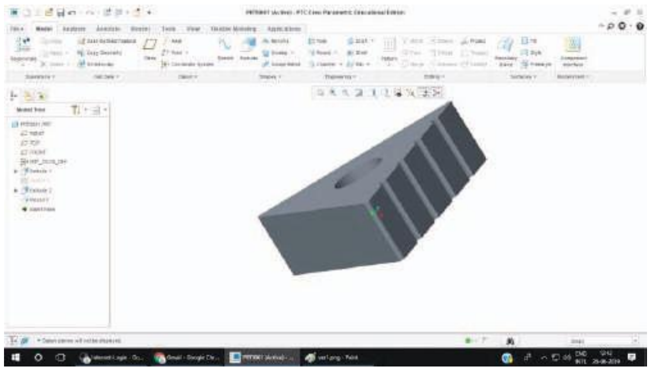
Figure 3:vertical line textured tool design.

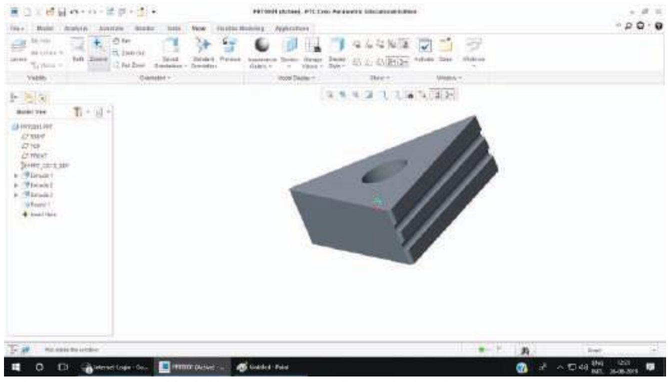
Figure 4: Parallel line textured tool design.

B. Cutting experiments

Using textured and non-textured cutting tool the cutting experiments were carried out in lathe machine. In these experiments the input parameters are cutting speed, feed, and depth of cut .The 9 combination of the cutting parameters are used in this testing procedure and from these experiments cutting temperature, cutting force and surface roughness are observed. The tested results are given below;

Table V: Testing of non-textured tool.

CUTTING SPEED (m/min)	FEED RATE (mm/rev)	DEPTH OF CUT (mm)	CUTTING FORCE (N)	CUTTING TEMPERATURE (°C)	SURFACE ROUGHNESS(microns)
70.6	0.026	1	389	77.5	2.462
70.6	0.019	0.75	267	66	2.377
70.6	0.016	0.5	218	50.5	1.834
108.3	0.026	0.75	261	119.7	1.915
108.3	0.019	0.5	252	108.7	1.739
108.3	0.016	1	264	112.3	1.441
164.9	0.026	0.5	194	117.4	1.041
164.9	0.019	1	191	133.6	1.26
164.9	0.016	0.75	169	128.6	1.128

Table VI: Testing of dot-textured tool.

CUTTING SPEED (m/min)	FEED RATE (mm/rev)	DEPTH OF CUT (mm)	CUTTING FORCE (N)	CUTTING TEMPERATURE (°C)	SURFACE ROUGHNESS (microns)
70.6	0.026	1	366	64.5	2.452
70.6	0.019	0.75	257	65.2	2.312
70.6	0.016	0.5	195	52.6	1.533
108.3	0.026	0.75	271	105	1.671
108.3	0.019	0.5	229	90.7	0.927
108.3	0.016	1	231	96.1	1.321
164.9	0.026	0.5	167	107.2	0.887
164.9	0.019	1	130	109.6	1.511
164.9	0.016	0.75	163	106.1	0.814

Table VI: Testing of vertical line-textured tool.

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CUTTING SPEED (m/min)	FEED RATE (mm/rev)	DEPTH OF CUT (mm)	CUTTING FORCE (N)	CUTTING TEMPERATURE (°C)	SURFACE ROUGHNESS(microns)
70.6	0.026	1	377	68.5	2.762
70.6	0.019	0.75	263	61.2	2.177
70.6	0.016	0.5	214	58.1	1.734
108.3	0.026	0.75	260	110.6	1.515
108.3	0.019	0.5	244	95.1	1.439
108.3	0.016	1	258	105.2	1.241
164.9	0.026	0.5	188	109.3	1.041
164.9	0.019	1	176	111.6	0.96
164.9	0.016	0.75	164	110.6	0.991

Table VII: Testing of parallel line-textured tool

CUTTING SPEED (m/min)	FEED RATE (mm/rev)	DEPTH OF CUT (mm)	CUTTING FORCE (N)	CUTTING TEMPERATURE (°C)	SURFACE ROUGHNESS(microns)
70.6	0.026	1	371	71.6	2.854
70.6	0.019	0.75	264	65.2	2.261
70.6	0.016	0.5	207	59.6	1.786
108.3	0.026	0.75	274	115.4	1.662
108.3	0.019	0.5	236	98.4	1.524
108.3	0.016	1	255	93.3	1.374
164.9	0.026	0.5	173	110.5	1.022
164.9	0.019	1	153	125.7	1.112
164.9	0.016	0.75	160	118.1	1.034

IV. RESULTS AND DISCUSSIONS

A. *Analysis of cutting experiment results*

From these observations to know about the best textured pattern the graphs were plotted. By analysing the graph (fig 5) the cutting force of textured machining is reduced to 8.8%(dot textured machining),6.78%(vertical line textured machining),5%(parallel line textured machining) than that of plain machining.

By analysing the values of cutting temperature from the graph (fig 6) cutting temperature of textured machining is reduced 12.8 %(dot textured machining),9.1%(vertical line textured machining),6.1%(parallel line textured machining) than that of plain machining.

Finally by observing the graph(fig 7) showing surface roughness of plain and textured machining surface roughness of textured machining is reduced 11.3 %(dot textured machining),8.3%(vertical line textured machining),3.5%(parallel line textured machining) than that of plain machining.

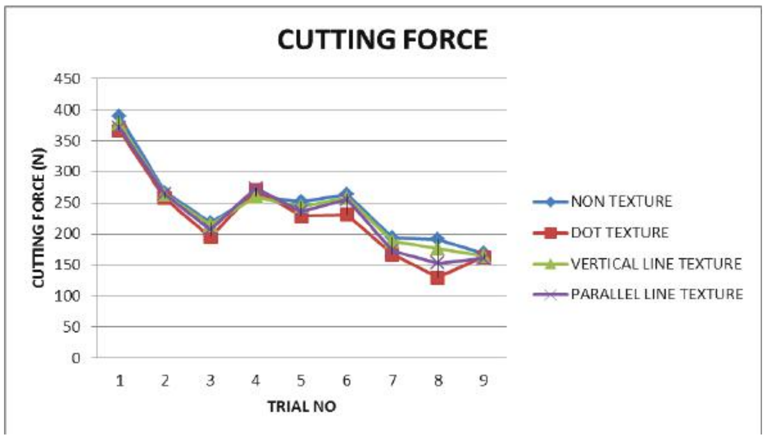

Fig 5: Cutting force of plain and textured machining

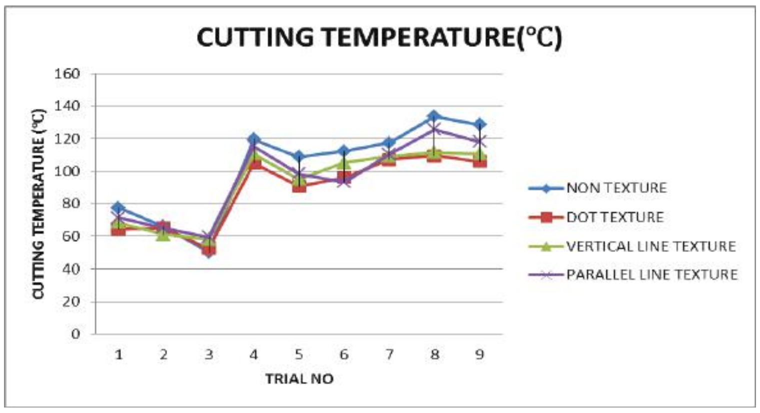

Fig 6: Cutting temperature of plain and textured machining

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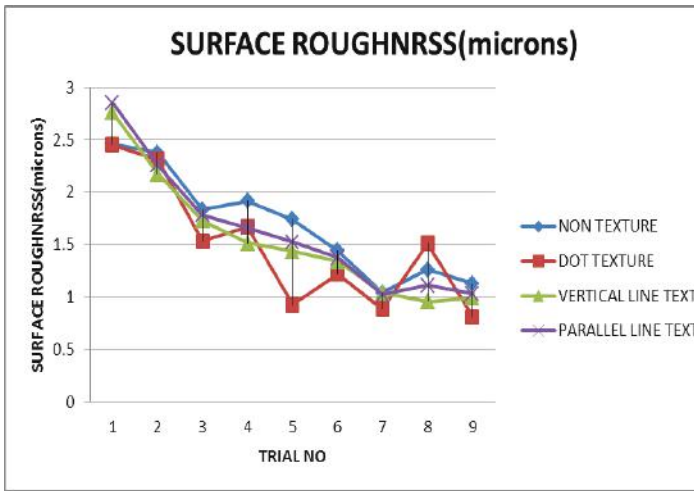

Fig 7: Surface roughness of plain and textured machining

B. Optimization methodology using grey relational analysis for dot textured tool cutting parameters

In multi-response problem, the influence and relationship between different parameters are complex and not clear. This is termed as grey which signifies poor and uncertain information. This proposed methodology (grey relational analysis) analyses this complicated uncertainty among the multi responses in a given system and optimize it with the help of grey relational grade. Therefore a multi response optimization problem is reduced to a single response optimization problem called single relational grade.

Step-1

The data is first to be normalized because of avoiding different units and to reduce the variability. It is essentially required since the variation of one data differs from other data. A suitable value is derived from the original value to make the array between 0 to 1 . In general, it is a method of converting the original data to a comparable data. If the response is to be minimized, then smaller-the-better characteristics is intended for normalization to scale it into an acceptable range by the following formula.

$$x^*_i(k) = \frac{\max\ x_i(k) - x_i(k)}{\max\ x_i(k) - \min\ x_i(k)} \quad (1)$$

where, i = 1,…, m; k = 1,…,n., m is the number of experimental data and n is the number of responses. xi(k) denotes the original sequence, xi*(k) denotes the sequence after the data pre-processing, max xi(k) denotes the largest value of xi(k), min xi(k) denotes the smallest value of xi(k), and x is the desired value.

Step-2

Next step is to calculate grey relational coefficient, ξi(k) from the normalized values by the following formula as follows

$$\xi_i(k) = \frac{\Delta_{min} + \xi\Delta_{max}}{\Delta_{0i}(k) + \xi\Delta_{max}}, \quad (2)$$

where, Δ0i is the deviation sequence of the reference sequence and the comparability sequence and $\Delta_{0i} = \|x_0(k) - x_i(k)\|$ where x0 (k) implies the reference sequence and xi (k) termed as comparability sequence. Delta min and delta max are the minimum and maximum values of the absolute differences (delta 0i) of all comparing sequences. ζ is distinguishing or identification coefficient and the range is between 0 to 1. Usually, the value of ζ is taken as 0.5.

Step-3

To find out the grey relational grade (GRG) as follows

$$\gamma_i = \frac{1}{n}\sum_{k=1}^{n}\xi_i(k) \quad (3)$$

Where, ᵞi is the required grey relational grade for ith experiment and n = number of response characteristics. The grey relational grade represents the level of correlation between the reference sequence and the comparability sequence and is the overall representative of all the quality Characteristics. Thus the multi-response optimization problem is converted into single response optimization problem through grey relational analysis coupled with Taguchi approach.

Step-4

Then an optimal level of process parameters is determined using higher grey relational grade that indicates the better product quality. To obtain this, average grade values for each level of process parameter is to be find out which can be shown as mean response table. From, mean response table, Higher values of average grade values is chosen as optimal parametric combination for multi-responses.

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Step-5

After optimal combination is find out, the next step is to perform the analysis of variance (ANOVA) for judging the significant parameters affecting the multi-responses at 95% confidence level and thus giving important information on the experimental data. As the effect of each parameter on multi response cannot be assessed by Taguchi method, thus the ANOVA analysis will be helpful to find out the percentage of contribution to identify the effects. The procedure of ANOVA is to separate out the total variability of the response (sum of squared deviations about the grand mean) into each parameter Contributions and error. The P-value (probability of significance) is generally calculated based on F value or Fisher's F- ratio to get the information of significance on the selected response if its value is less than 0.05. The degrees of freedom (DF) are required to evaluate the mean square (MS) and measure the availability of independent information to evaluate sum of squares (SS). In an ANOVA analysis, mean square deviation and F-value is calculated by MS = SS/DF and F = MS for a source parameter/MS for the error.

C. *Implementation of methodology to find multi-response parametric optimization*

Step-1

The experimental data have been normalized for cutting force, cutting temperature and surface roughness using Eq. (1) and presented in Table VIII called grey relational generations.

Table VIII : Grey relational generation values

TRIAL NO:	CUTTING FORCE ,F(N)	CUTTING TEMPERATURE, T (°C)	SURFACE ROUGHNESS,Ra(microns)
1	389	77.5	2.462
2	267	66	2.377
3	218	50.5	1.834
4	261	119.7	1.915
5	252	108.7	1.739
6	264	112.3	1.441
7	194	117.4	1.041
8	191	133.6	1.26
9	169	128.6	1.128

Step-2

From the normalized data set of Table 2, grey relational coefficients have been computed using equation 2. The value of distinguishing coefficient is taken as 0.5 as equal weighting has been given to both quality characteristics. The results are shown in Table IX.

Step-3

Next, grey relational grade (GRG) has been found out using Equation 3 from the results of grey relational coefficients. The result of GRG is presented in Table IX. This result is utilized for optimizing the multi-responses as it is converted to a single grade.

Table IX:Grey relational coefficient and grey relational grade values

DEVIATION SEQUENCE			GREY RELATION COEFFICIENT			GREY RELATION GRADE	RANK
F	T	Ra	F	T	Ra	GRG	
1.000	0.209	1.000	0.333	0.705	0.333	0.457	8
0.538	0.221	0.915	0.482	0.693	0.353	0.510	7
0.275	0.000	0.439	0.645	1.000	0.533	0.726	1
0.597	0.919	0.523	0.456	0.352	0.489	0.432	9
0.419	0.668	0.069	0.544	0.428	0.879	0.617	5
0.428	0.763	0.310	0.539	0.396	0.618	0.517	6
0.157	0.958	0.045	0.761	0.343	0.918	0.674	3
0.000	1.000	0.426	1.000	0.333	0.540	0.625	4
0.140	0.939	0.000	0.781	0.348	1.000	0.710	2

Step-4

From the value of GRG, the effects of each process parameters at different levels are observed and mean grey relational grade is presented in Table 4. The optimal parametric combination

is chosen based on higher mean grey relational grade values from Table X. The higher value of grey relational grade implies a stronger correlation to the reference sequence and better performance. Thus,the optimal settings for multi-responses becomes A3-B3-C3 i.e. cutting speed of 164.9 m/min, feed of 0.016 mm/rev and depth of cut of 0.5 mm, respectively. This result(table x) indicates that the cutting speed has the most influencing effect on multi-responses compared to depth of cut and cutting speed in hard turning operation.

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Table X: Main effects on mean grey relational grade

Level	A	B	C
1	-5.145	-5.835	-5.536
2	-5.735	-4.714	-5.374
3	-3.498	-3.829	-3.469
Delta	2.238	2.007	2.067
Rank	1	3	2

A- Cutting speed
B- Feed rate
C- Depth of cut

Step-5

Next, analysis of variance (ANOVA) table is formulated considering grey relational grade value which has been shown in Table XI. This table gives the significance of process parameters on multi-responses. From the ANOVA table, it is revealed that cutting speed and depth of cut are significant process parameters affecting multi responses as its p-value is less than 0.05 at 95% confidence level. Feed rate does not show any significance on both responses simultaneously.

Source	DF	Adj SS	Adj MS	F-Value	P-Value	
A	2	0.03454	0.01727	23.06	0.042	Significant
B	2	0.02526	0.012628	16.86	0.056	Insignificant
C	2	0.034492	0.017246	23.03	0.042	Significant
Error	2	0.001498	0.000749			
Total	8	0.095786				

V. CONCLUSIONS

Machining was done on the EN9 steel. The textured cutting tools were assessed in terms of, cutting force, cutting temperature, surface roughness the following conclusions were obtained:

- Among the textured design dot textured cutting tool shows the best result.
- Cutting force of textured machining is reduced to 8.8%(dot textured machining),6.78%(vertical line textured machining),5%(parallel line textured machining) than that of plain machining.
- cutting temperature of textured machining is reduced 12.8 %(dot textured machining),9.1%(vertical line textured machining),6.1%(parallel line textured machining) than that of plain machining.
- surface roughness of plain and textured machining surface roughness of textured machining is reduced 11.3 %(dot textured machining),8.3%(vertical line textured machining),3.5%(parallel line textured machining) than that of plain machining.
- The optimal setting for multi-responses becomes A3-B3-C3 i.e. cutting speed of 164.9 m/min, feed of 0.016 mm/rev and depth of cut of 0.5 mm, respectively.
- From the ANOVA table, cutting speed and depth of cut are the most significant controlled process parameter influencing multi-responses at 95% confidence level in hard turning operation as a case study when minimization of cutting force, cutting temperature and surface roughness are concerned. Other parameter such as feed rate does not show any significance on responses.

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A Study On Psychosocial Issues Of Labourers In Manufacturing Industry

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Abstract: Labour is one of the primary factors of production. The aggregate of all human physical and mental efforts are used as part of creation of goods and services. The psychosocial approach looks at individuals in the context of the combined influence of psychological factors and the social environment on the employee's physical and mental wellness. Adverse workplace factors can increase the risk of ill-health in workers, so more comprehensive measures of the psychosocial work environment are needed. A psychologically effective workplace is the place where every acceptable effort for promoting psychological health of workers without reducing the productivity. Psychosocial hazards will contribute to ill health of workers definitely effects negatively to economy. Study of psychosocial issues includes categorising psychosocial into 3 domains and analysing them separately by using SPSS (statistical package for social sciences), and it pinpoints which among the particular age range, experience range and job category suffers the most.

Keywords: psychosocial issues**,** SPSS, psychologically effective workplace, mental efforts

I. Introduction

The economy of the entire nation depends on secondary sector mainly manufacturing industries. Labour, one of the primary factors of production is the heart of a production firm. Psychosocial risk factors are important since if they are present in the work environment they can be sources of stress. The presence of psychosocial risk factors in the workplace influences the risk of individuals developing musculoskeletal problems. This, in turn, has an impact on injury related costs, absenteeism and productivity. The psychosocial problems of workers reflect the productivity in turn reflects the economy of the firm itself. In fact cooperation among workers turn to be worse, if the management doesn't interact with the worker properly. Psychosocial factors are recognized to be critical in both the causation and the prevention of disease and in the promotion of health. This is so for the health sciences in general and for occupational health in particular, since psychosocial factors are among the most important of those that influence the total health of a working population. Careful consideration of the nature of health impairment said to be work-related has resulted in more attention being given to the psychosocial factors. The main purpose of this paper is to investigate the psychosocial issues of labourers using a standardised method that covers the entire spectrum of above issues, thereby finding out which among the workers experiences psychosocial issues the most based on age factor, experience factor and job category.

II. OBJECTIVES

- To examine the psychosocial issues of labourers using a standardised method that covers the entire spectrum of above issues.
- To analyse the psychosocial issues of labourers based on age factor of workers.
- To analyse the psychosocial issues of labourers based on experience factor of workers.
- To analyse the psychosocial issues of labourers based on occupational group of workers.
- To analyse the relationship between psychosocial environment and psychosocial issues.

III. METHODOLOGY

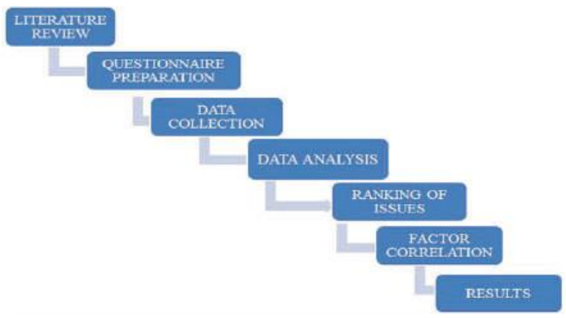

Fig 1 Methodology

Fig 1 shows methodology adopted in this work is the collection of data by the method of survey. Surveying with a help of questionnaire was found to be most efficient based on the literature review conducted. Literature review mostly focussing on the psychosocial environment and psychosocial

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issues of workers targeting wide range of job categories, age ranges, and experience factors.

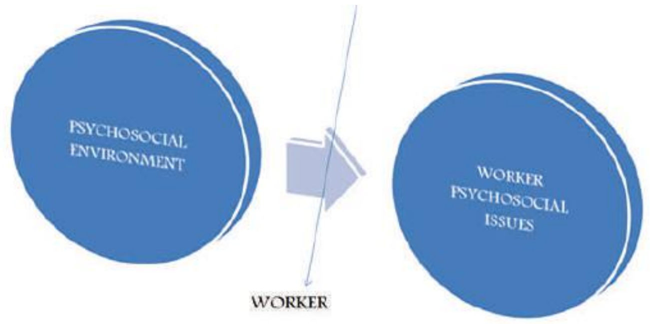

Fig. 2. Relationship between psychosocial environment and psychosocial issues.

There is a connection between environment and issues, so 2 type of questionnaires are used.

Questionnaire preparation

Psychosocial issues questionnaire

- Questionnaire was prepared with all the questions representing about major psychosocial issues listed and the workers are asked to tick the question they are related with.
- Scales yes/no, severity ratings 1/0
- Based on questionnaire the issues were ranked accordingly and frequent types of disorders in workers were identified.

Psychosocial environment questionnaire

- Adapted from COPSOQ (Copenhagen psychosocial questionnaire).
- Scales 5 point likert scale, severity ratings100/75/50/25/0

IV. DATACOLLECTION

Data was collected from 3 metal manufacturing industries, mainly a small medium and large scale industry. Around 163 samples were collected and analysed.

Psychosocial environment

- Quantitative demands
- Cognitive demands
- Emotional demands
- Demands for hiding emotions
- Work pace
- Influence at work
- Possibilities for development
- Variation of work
- Control over working time
- Meaning of work
- Predictability
- Recognition
- Role clarity
- Role conflicts
- Illegitimate tasks
- Quality of leadership
- Social support from supervisor
- Social support from colleagues
- Sense of community at work
- Commitment to the workplace
- Work engagement
- Insecurity over employment
- Insecurity over working conditions
- Quality of work
- Satisfaction with work – job satisfaction
- Work life conflict
- Horizontal trust
- Vertical trust
- Organizational justice

V. DATA ANALYSIS

A. Reliability statistics

- From reliability analysis cronbach's alpha of .839 was obtained.it shows high internal consistency and the data is a good to measure entire spectrum of issues.

B. Factor Analysis

- Bartlett's test of sphericity & Kaiser meyer olkin measure of sampling adequecy-0.502-according to rule of thumb,>0.5-sampling is adequate for use.
- Significance value 0.000- useful data for further analysis.

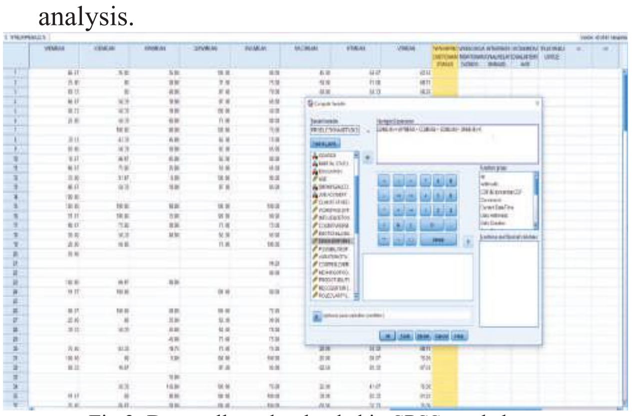

Fig.3. Data collected uploaded in SPSS worksheet

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Rotated Component Matrix[a]

	Component 1	2	3	4	5
QUANTITATIVEDEMANDS				.634	
WORKPACE				.614	
INFLUENCEATWORK					.816
COGNITIVEDEMANDS				.625	
EMOTIONALDEMANDS				.709	
DEMANDSFORHIDINGEMOTIONS		.687			
POSSIBILITIESFORDEVELOPMENT	.672				
VARIATIONOFWORK					.700
CONTROLOVERWORKINGTIME					
MEANINGOFWORK	.657				
PREDICTABILITY			.673		
RECOGNITION			.835		
ROLECLARITY	.668				
ROLECONFLICT		.792			
ILLEGITIMATETASKS		.817			
QUALITYOFLEADERSHIP					
SOCIALSUPPORTFROMSUPERVISOR	.618				
SOCIALSUPPORTFROMCOLLEGUES	.854				
SENSEOFCOMMUNITYATWORK	.751				
COMMITMENTTOWORKPLACE					
WORKENGAGEMENT					
INSECUIRITYOVEREMPLOYMENT			-.697		
INSECUIRITYOVERWORKINGCONDITIONS					
QUALITYOFWORK	.745				
SATISFACTIONWITHWORKJOBSATISFACTION					
WORKLIFECONFLICT		.723			

Rotated Component Matrix[a]

	Component 1	2	3	4	5
HORIZONTALTRUST				-.690	
ORGANISTAIONALJUSTICE					
VERTICALTRUST					

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.

Fig. 4. output of factor analysis

Fig 4 shows exploratory factor analysis, factors were identified above loading factor 0.5 and tabulated in table 1

TABLE. 1. FACTOR CATEGORISATION

TYPE OF WORK DEMAND AND TASKS	INTERPERSONAL RELATIONSHIPS AND LEADERSHIP	CONFLICTS AND EMOTIONS	WORK NATURE	PREDICTIONS AND RECOGNITIONS
Quantitative demands	Role clarity	Demands for hiding emotions	Influence at work	Predictability
Work pace	Social support from supervisor	Role conflicts	Variation of work	Recognition
Cognitive demands	Social support from colleagues	Illegitimate tasks		
Emotional demands	Sense of community at work	Work life conflict		
	Possibilities for development			
	Meaning of work			
	Quality of work			

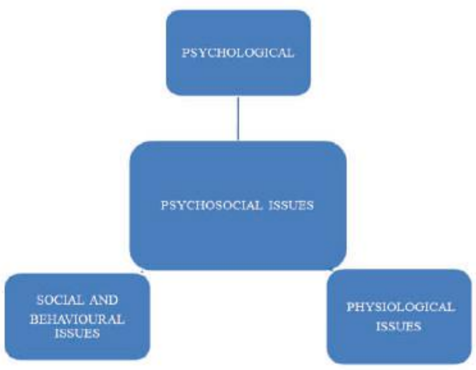

Fig. 5. Psychosocial issues

Psychosocial issues is divided into 3

Psychological
1) Generalised anxiety disorder
2) Obsessive compulsive disorder
3) Depression
4) Acrophobia
5) Claustrophobia
6) Specific phobia
7) Technophobia

Physiological
1) Mental illness
2) Musculoskeletal disorder
3) Respiratory diseases
4) Hypertension

Social & behavioural
1) Physical inactivity
2) Excessive alcohol
3) Drug consumption
4) Nutritional imbalance
5) Sleep disturbance
6) Absenteeism

From fig 5 psychosocial issues is divided into 3 which represents an employee's psychological, physiological and socio behavioural issues

TABLE. 2. OBSERVED PSYCHOSOCIAL DOMAIN SPLIT-UP

Domain	No of workers affected	% of Issues
Psychological	154	43%
Physiological	91	25%
Socio and behavioural	117	32%

TABLE. 3. RELATION BETWEEN PSYCHOLOGICAL PHYSIOLOGICAL AND SOCIO BEHAVIOURAL ISSUES

Correlations

		PSYCHOLOGICAL	PHYSIOLOGICAL	SOCIALBEHAVIOURAL
PSYCHOLOGICAL	Pearson Correlation	1	.071	.154
	Sig. (2-tailed)		.369	.058
	N	162	161	152
PHYSIOLOGICAL	Pearson Correlation	.071	1	.149
	Sig. (2-tailed)	.369		.069
	N	161	161	151
SOCIALBEHAVIOURAL	Pearson Correlation	.154	.149	1
	Sig. (2-tailed)	.058	.069	
	N	152	151	152

From the table 3, it shows there is a significant relationship with a low positive correlation between the domains.

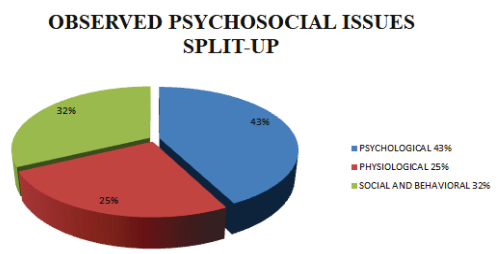

Fig. 6. Observed psychosocial domains issues split-up.

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From fig 6 observed issues were spit into 3 represented in pie chart.

C. Types of psychosocial issues versus no of workers affected

TABLE. 4. TYPES OF PSYCHOSOCIAL ISSUES VERSUS NO OF WORKERS AFFECTED.

Types of psychosocial issues	No of workers affected	% of workers affected
Generalised anxiety disorder	46	10.29%
Obsessive compulsive disorder	12	2.68%
Depression	8	1.70%
Acrophobia	91	20.35%
Claustrophobia	34	7.60%
Specific phobia	2	0.45%
technophobia	6	1.34%
Mental illness	4	0.89%
Musculoskeletal disorder	40	8.94%
Hypertension	37	7.60%
Respiratory diseases	12	2.68%
Physical inactivity	5	1.11%
Excessive alcohol/smoking	4	0.89%
Drug imbalance	0	0.00%
Nutritional imbalance	30	6.71%
Sleep imbalance	94	21.02%
Absenteeism	22	4.92%

From table 4 total no of workers affected in each issues were analysed.

D. Psychosocial issues ranked by no of workers

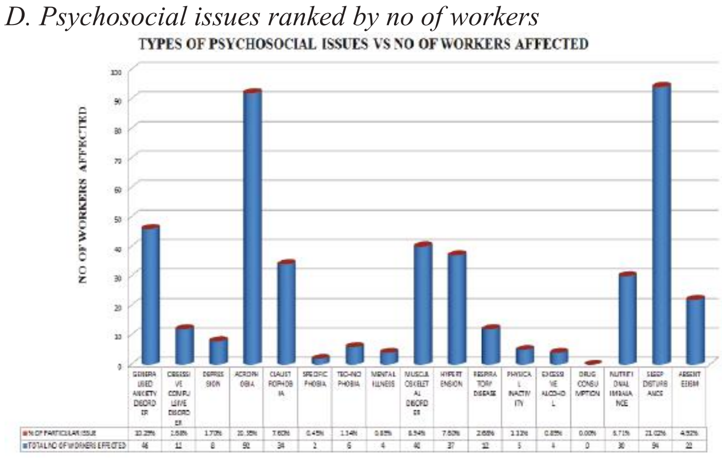

Fig. 7. Types of psychosocial issues versus no of workers affected.

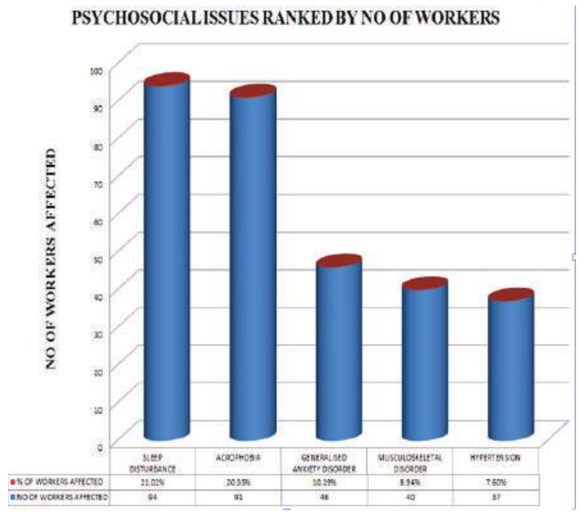

Fig. 8. Psychosocial issues ranked by no of workers.

By analysing fig 7 and fig 8 ,sleep disturbance and acrophobia ranks the top.

E. Analysis done based on age factor of workers

TABLE. 5. ANALYSIS DONE BASED ON AGE FACTOR OF WORKERS.

PSYCHOSOCIALDOMAIN	AGERANGE				
	18-23	24-30	31-40	41-50	>50
PSYCHOLOGICAL(P_1)	22	23	53	42	55
PHYSIOLOGICAL(P_2)	12	14	21	17	29
SOCIAL & BEHAVIOURAL(P_3)	17	17	23	28	70

	Pearson correlation coefficient(r)
P_1 & P_2	0.89
P_2 & P_3	0.91
P_1 & P_3	0.68

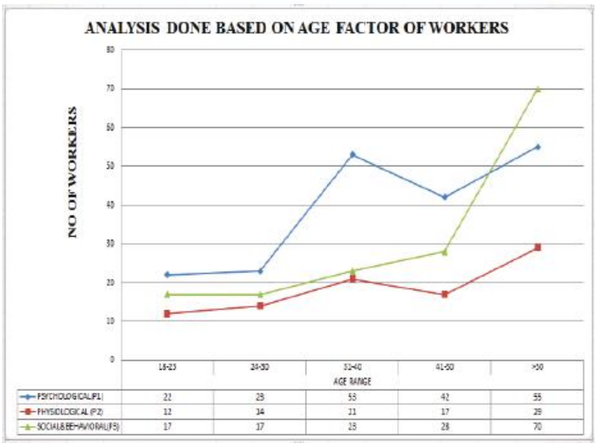

Fig. 9. Scatterplot diagram shoing splitup of issues versus age factor of workers.

From table 5 and fig 9 ,the value of r Pearson correlation coefficient obtained are 0.89,0.91,0.68 respectively, hence they form a moderate positive correlation and socio and behavioural domains play a major role in age factors of workers, mainly the age range greater than 50.

Suggestions

1) overloading of work should be avoided.
2) proper communication between the workers.

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3) Proper health check-ups.
4) Proper refreshments during work should be provided.
5) age group >50 are purposefully admitted to work in morning shifts

F. Analysis done based on experience range of workers

TABLE. 6. ANALYSIS DONE BASED ON EXPERIENCE RANGE OF WORKERS

PSYCHOSOCIAL DOMAIN	EXPERIENCE RANGE OF WORKERS						
	<3	3 to 6	7 to 10	11 to 14	15 to 20	21 to 25	>25
PSYCHOLOGICAL(F_1)	62	25	13	13	22	19	45
PHYSIOLOGICAL(F_2)	29	12	8	5	9	8	22
SOCIAL & BEHAVIOURAL(F_3)	43	7	9	13	14	15	54

	Pearson correlation coefficient(r)
F_1 & F_2	0.99
F_2 & F_3	0.86
F_1 & F_3	0.85

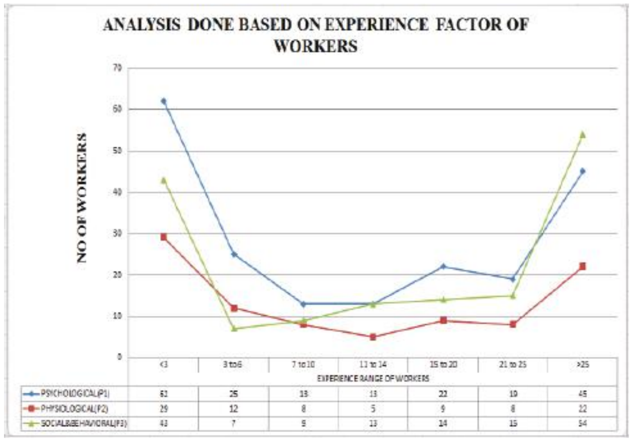

Fig. 10. Scatterplot diagram showing splitup of issues versus experience factor of workers

From table 6 and fig 10 implies the value r (Pearson correlation coefficient) obtained are 0.99,0.86,0.85 respectively, hence they form a strong positive correlation and psychological issues of experience range <3 and socio behavioural domain of experience range between >25 play a major role in experience factors of workers.

Suggestions

1) A new employee always need a time to collaborate with the work environment.
2) Adequate support from colleague and supervisor can reduce the psychological problems they are facing.
3) Instead of bullying, conflicts ,harassment, provide a platform to develop their skills, treat them fairly.

G. Analysis done based on occupational group

TABLE. 7. ANALYSIS DONE BASED ON JOB CATEGORY OF WORKERS

PSYCHOSOCIAL DOMAIN	OCCUPATIONAL GROUP			
	APPRENTICE	OFFICE WORKER	OPERATIONAL GROUP	TECHNICIAN
PSYCHOLOGICAL(F_1)	29	47	110	13
PHYSIOLOGICAL(F_2)	17	10	61	5
SOCIAL & BEHAVIOURAL(F_3)	25	25	96	9

	Pearson correlation coefficient(r)
F_1 & F_2	0.95
F_2 & F_3	0.99
F_1 & F_3	0.98

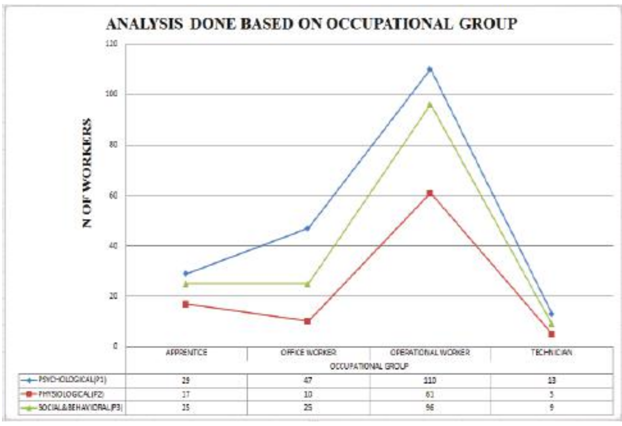

Fig. 11. Scatterplot diagram showing splitup of issues versus occupational group of workers

From the fig 11 and table 7 shows ,the value r (Pearson correlation coefficient) obtained are 0.95,0.99,0.98 respectively, hence they form a strong positive correlation and all the domains play a major role in operational workers.

1) Alcoholics and chain-smokers shows a positive relationship with job stress and anxiety and absenteeism
2) Suggestions
3) Appreciation will turn productivity.
4) Contradictory demands & illegitimate tasks should get reduced.
5) Create a good atmosphere between colleagues and supervisor.
6) Excessive alcoholics should get counselling.
7) Absenteeism should get monitored ,ask them about that.
8) Ensure adequate ventilation of the workplace
9) Wear PPE's such as safety gloves, masks ..

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VI. CONCLUSION

1) There are number of psychosocial issues increasing in manufacturing sector that affect workers health and well being.
2) Its important for HR department to have a knowledge on the range of factors that have the potential to cause stress. Managers should consider strategies for finding and reducing psychosocial issues.
3) Among them sleep disturbance, acrophobia, generalised anxiety disorder, musculoskeletal disorders, hypertension are some of the psychosocial issues which are ranked in top levels by the workers and hence additional importance in reducing these types of issues should be made and adequate treatments for respective disorders should be carried out by the organisation where the workers are working.
4) These include raising awareness of psychosocial issues to promote a culture in which labour's actively raise potential stressors to management and putting in place adequate support mechanisms like work design, social support networks and training.

VII. LIMITATIONS & FUTURE SCOPE

a) Limitations

This study was conducted only in small,medium, large scale metal manufacturing industries of Kerala. Also only government large scale production firms under government was taken in order to standardise the results. Almost 162 samples were taken which can be expanded for more precise work.
Contract employees and private firms were not explored for this research. If this variables are taken it will fetch rightful study.

b) Future Scope

The study can be extended to include comparison among Small scale organizations and medium scale organisations and then the results can be compared. This study can also be extended to include private organizations outside Kerala. This gives a more general idea of the psychosocial behavioural pattern.

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ERP Readiness Assessment of an Organization Using FUZZY- ANP Approach

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Abstract: Every organization is trying to gain competitive advantage over the other, and implementing ERP in an organization is considered to be a stepping stone for the same. But the process of implementing ERP is not an easy task and has got lot of risk factors which may lead to failure of the project and thus making a huge loss to the organization. Previous studies report unusually high failure in enterprise resource planning (ERP) projects. Thus, it is necessary to perform an assessment at the initial stage of an ERP implementation program to identify weaknesses or problems which may lead to project failure. In this paper, the firm's readiness to implement ERP is presented and fuzzy extent analysis method is used to calculate the weights of factors and sub factors that impact the ERP system implementation, structured questionnaire and focus group technique were used to gather information from the expert panel (India). The firm's current condition regarding ERP project can be determined and necessary changes prior to implementation of ERP system can be specified. The readiness for ERP implementation is decomposed into project management, organizational, and change management areas. The proposed framework is applied to a real case and the advantages are illustrated.

Keywords: ERP, Fuzzy, ANP

I. INTRODUCTION

To survive and grow consistently SMEs are required to improve the quality of their business. One way to increase such competitive advantage is by improving the effectiveness and efficiency of the planning and management of company resources, which can be achieved by using information technology (IT) [1]. The advancement of IT such as Software as a Service (SaaS) and Enterprise Resource Planning (ERP) are proven to provide benefits for many organizations [2]. ERP system is considered as one of important aspects when we talk about automating and integrating business processes. Saputro et al. [3] stated that the ERP system may be one solution to help SMEs to perform simplification, integration and automation of the business processes. While Molla and Bhala [4] in their study of an Asian company in a developing country, showed that ERP enables organizations to achieve competitive advantage, although this technology cannot be considered the sole cause.

ERP system is an information system that supports and integrates the various aspects of a business, including planning, manufacturing, sales, and marketing [5], making it easier for each functional unit to share data [6]. Yuanqiang et al. [7] defined ERP as an integrated software solution used to manage resources owned by the company. Baki et al. [8] defines ERP as a system that manages all resources required to perform a business function. By implementing ERP, companies can obtain information real-time such as customer, supplier, and competitor information and condition of the whole company.

Considering their revenue, SMEs are not as enthusiasm as large companies in adopting ERP, there are several reasons why the number of SMEs implementing ERP is still low, among others: limited budget, lack of experiences in implementing ERP, cost of software and services that are not affordable for SMEs, limited internal capability to implement ERP, and as well as SMEs consider ERP as complex information systems. The same were confirmed in a study conducted by Vilpola [10] who said that the SMEs have their own challenges when trying to implement ERP, the resource constraints in the selection of the ERP package, and also in the implementation.

In addition to the above challenges, in general, the possibility of failure in ERP implementation is also high. Panorama Consulting Group [11], in 2011, conducted a survey of ERP implementation during 2010. The survey was conducted on 185 participants from 57 countries (30% from North America, while 70% of the countries around the world). The survey results showed 61.1% of respondents said ERP implementations take longer than expected; 74.1% stated bloated budget, and 48% felt the realization of benefits is less than 50%. To increase the success of ERP implementation, researchers conducted numerous studies, for example related to the identification of critical success factors of ERP implementation. Razmi et al. [9] took a different approach by constructing ERP readiness assessment in a practical framework. The results of the assessment are used to determine the status of the organization's readiness to

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implement ERP and further identify areas that should be improved before entering the implementation phase. Related to this, the study aims to develop a framework of ERP implementation readiness self-assessment. The proposed framework is expected to help SMEs in assessing their readiness in implementing ERP. As a case study to conduct the assessment, we selected an SME engaged in software development, which plans to implement an ERP.

II. LITERATURE REVIEW

ERP implementation often cannot run smoothly as expected. Many challenges in ERP implementation as it poses some risks [12]. These risks should be measured as early as possible to avoid potential challenges in the later stages. This underlies the need for organizations to assess their readiness to implement ERP [9].

Readiness assessment was considered as a separate stage in the ERP project, and should be carried out before the implementation phase. This assessment not only shows the capability of the company to implement ERP, but it also identifies those areas that are becoming weaknesses of the company, so that the company can improve performance in these areas to get to a higher level of readiness.

Various researchers have developed several frameworks regarding readiness assessment of ERP implementation such as that developed by [9], as well as a framework developed by [13].The method used or steps followed were almost similar in many studies and they are, firstly-identify the determinants of ERP implementation readiness, secondly-build an assessment tool by using determinants obtained in the first phase. Thirdly- identify importance (weight) of each determinant and finally build assessment scheme for each determinant of ERP implementation readiness.

The framework proposed by [13] was prepared using 37 Critical Success Factors (CSFs) that are grouped into 4 categories: technoware, humanware, inforware, and orgaware. Razmi et al. [10] proposed their framework by dividing the goal of ERP readiness into three parts, namely organizational, project management, and change management readiness sub-goals. For the sub-factors, they used 15 CSFs which are grouped into five factors, namely project, vision and goals, systems and processes, culture and structures, and human resources.
Related to the assessment, Soysa and Nanayakkara [13] used the framework of Analytic Hierarchy Process (AHP), which has been simplified, as well as Hidayanto et al. [14] which also used AHP for measuring business intelligence in SMEs. Razmi et al. [9] used variation of of AHP, by using Fuzzy Analytical Network Process (Fuzzy ANP) which is actually the most common form of AHP combined with Fuzzy sets theories to deal with uncertainty in the assessment. According Razmi et al. [9], the ANP method is considered more superior in doing modeling for complex decision environment compared to AHP.

III. METHODOLOGY

A. *Framework for ERP Readiness Assessment*

As discussed in the literature review, this study adapts the framework which was introduced by Razmi et al. [9] to measure ERP implementation readiness. This framework defines the ERP implementation readiness in three categories, namely:
Project management readiness.
Organizational readiness.
Change management readiness.

Meanwhile, the readiness of each aspect depends on the readiness of the five factors and each factor is composed of several sub-factors. These factors and sub-factors are summarized in Table II.
Here is description of each sub-factor of ERP implementation readiness [9]:

- Project championship: The role of the ERP implementation project championship is much larger than other information system implementations. Project champion is needed to drive consensus and oversee the entire project. Thus, a project champion should be able to push and sustainably manage resistance and changes during implementation.
- Resource allocation: ERP implementation requires a different allocation of organizational resources such as time, money, and personnel. Resources should be allocated according to resource planning as an important part of project management program.
- Assign responsibilities. ERP project requires the cooperation of several units of the organization. The responsibilities of each unit should be clear as one of keys to success of an ERP implementation.
- Project team. ERP project requires the project team containing the best employees who have the business skills and technical ability. Project teams should be balanced, cooperative, and cross functional.
- Project scope. The scope of the ERP project should be clearly identified, whether is it just limited to part/whole functional unit, part/whole site, part/whole business process, and so on. The scope of the project will directly affect the time and cost of implementation. It is also important to establish

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milestones and a realistic delivery time for the ERP project.

- ERP implementation vision. ERP Implementation also requires a clear vision of the organization. The vision is needed to guide the implementation of ERP and should contain goals and objectives that can be measured.
- ERP mission and goals. Organizations should also define the mission and goals of the ERP system clearly. The mission and goals must be understood by the organization. The implementation of the ERP system must have clear justification, considering the risks, costs, and resources needed.
- Existing system. Before implementing ERP, organizations must understand the current system is. Understanding the existing system is needed to identify the changes required at the time of implementation of ERP systems.
- Existing process. Existing process improvements and adjustments need to be identified before the implementation of ERP. In addition, organizations should design a system architecture and ensure the chosen ERP system reflects the organization's business processes are complete.
- Culture. Given the ERP implementation caused major changes in the organization, organizational culture plays an important role in the implementation phase. Organizational culture can be a facilitator or a major obstacle to change. Successful implementation of ERP requires a corporate culture that emphasizes the value to share a common goal in the interests of the individual and the value of trust between colleagues, employees, managers, and companies.
- Decision mechanisms. Decision-making requires the accuracy of the data. Therefore, the ability to search for information is an important factor in making a decision.
- Organizational structure. The organizational structure and hierarchy positions must match and support the implementation of ERP. The changes made by the ERP system must be backed existing management and structure of work in the organization.

- Communication. Expectations and objectives of the ERP project should be communicated effectively between stakeholders in all levels in the organization. The entire implementation phase, which will include the reasons of ERP implementation, change management strategy, project scope, and others should be communicated to all interested parties.
- Top Management. Many literature suggests that top management support on IT projects is critical to the success of the project, including the ERP project. Top management should view ERP as a priority project of the organization, financing projects and take an active role in leading change. Management must be involved in every step of ERP implementation, monitor project progress and provide direction to project team.

- Personnel. The success of ERP implementation requires the commitment and cooperation of personnel from all business segments. The personnel must be assured that the organization is committed to implementing the ERP system. The personnel should be well prepared for the change to prevent resistance and chaos in the implementation phase.

B. *Readiness assessment*

Razmi et al. [9] have provided weights for each factor and sub-factors in accordance to the three categories of readiness which are project management, organizational and change management readiness as can be seen in Table I. Unfortunately, Razmi et al. [9] did not provide guidance on how to conduct an assessment of each of these sub-factors. Related to this, we developed a questionnaire that could measure the sub-factors and based on the results obtained from this questionnaire we could decide under which linguistic variable each sub-factors falls.

TABLE I. WEIGHTS OF EACH FACTOR AND SUB-FACTORS ON EVERY ASPECT OF READINESS [9]

Factors	Project readiness	Organizational readiness	Change management readiness
Project	0.23	0.11	0.19
Project Championship	0.064	0.031	0.053
Resource Allocation	0.032	0.015	0.027
Assign Responsibilities	0.023	0.011	0.019

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Project Team	0.062	0.030	0.051
Project Scope	0.048	0.023	0.040
Vision and goals	0.20	0.11	0.13
ERP impl. Vision	0.064	0.035	0.042
ERP mission & goals	0.136	0.075	0.088
Systems and processes	0.13	0.26	0.16
Existing system	0.065	0.130	0.080
Existing process	0.065	0.130	0.080
Culture and structures	0.21	0.25	0.27
Culture	0.078	0.093	0.100
Decision mechanisms	0.032	0.038	0.041
Organizational structure	0.036	0.043	0.046
Communication	0.065	0.078	0.084
Human resources	0.23	0.27	0.25
Top Management	0.156	0.181	0.170
Personnel	0.074	0.086	0.080

The steps followed for ERP readiness assessment in the organization is described below in detail.

- The various sub-factors regarding the ERP readiness assessment are assessed through nominal group technique using the questionnaire that was developed, the findings are then mapped into linguistic variables. This linguistic variable is then transformed into a numeric al score as follows: very low - 0, low - 25, medium - 50, high - 75, very high - 100.

- Now the score of each factor is calculated by averaging the scores of their respective sub-factors. These average scores are then translated into forms of linguistic variables by using fuzzy scale as shown in Table II. For example, the average score for a certain factor is 12. According to Table II, 12 falls into two categories: very low and low. In order to determine which category is representing this score, we should calculate the membership values of this score for each category. The category is determined by seeking the category which has the highest membership value. This process uses a fuzzy membership function (μ) that we defined in Table III.

TABLE II. LINGUISTIC VARIABLES FOR MEASURING SUB-FACTOR AND FUZZY SCALE [10]

Linguistic variables for sub-factors	*Fuzzy scale*
Very low	(0, 0, 25)
Low	(0, 25, 50)
Medium	(25, 50, 75)
High	(50, 75, 100)
Very High	(75, 100, 100)

TABLE III. LINGUISTIC VARIABLES FOR MEASURING SUB-FACTOR AND FUZZY MEMBERSHIP FUNCTION [10]

Linguistic Variables for sub-factors	*Fuzzy membership function*
Very Low	$\mu(x)$ ={1, if x =0; 0,if $x\geq 25$; $(25-x)/25$, if $0 \leq x \leq 25$}
Low	$\mu(x)$ ={1, if x =25; 0,if x= 25 or $x \geq 50$; $x/25$, if $0 \leq x \leq 25$; $(50-x)/25$, if $25 \leq x \leq 50$ }
Medium	$\mu(x)$ ={1, if x =50; 0,$x \leq 25$ or $x \geq 75$; $(x-25)/25$, if $25 \leq x \leq 50$; $(75-x)/25$, if $50 \leq x \leq 75$ }
High	$\mu(x)$ ={1, if x =75; 0,$x \leq 50$ or $x \geq 100$; $(x-50)/25$, if $50 \leq x \leq 75$; $(100-x)/25$, if $75 \leq x \leq 100$ }
Very High	$\mu(x)$ ={1, if x = 100; 0,if $x \leq 25$; $(x-75)/25$, if $75 \leq x \leq 100$}

- Finally the assessment of sub goals were done, here we assess the readiness of sub goals by adding up the multiplication of sub-factor score and its respective weight (as shown in Table I) for all their respective sub-factors. The numerical score obtained is then translated into a form of linguistic variables using the same way as the assessment of factor perspective.

IV. RESULTS AND ANALYSIS

Assessment results and ERP implementation readiness analysis in company ABC is shown in this section.

A. Readiness assessment for ERP implementation

As mentioned previously, sub-factors were assessed by nominal group technique to obtain consensus on the score of each sub-factors. The results of assessment for each sub-factors can be seen in Table IV and that of factors can be seen in Table V.

TABLE IV. SUB-FACTOR SCOR*ES*

Sub factors	*Score*
Project championship	25

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Resource allocation	50
Assign responsibilities	50
Project team	50
Project scope	25
ERP implementation vision	25
ERP mission and goals	25
Existing system	25
Existing process	25
Culture	50
Decision mechanism	50
Organizational structure	25
Communication	25
Top management	50
Personnel	75

TABLE V. FACTOR SCORES

Factors	*Scores*
Project	40
Vision and Goals	25
System and Process	25
Structure and cultures	37.5
Human Resources	62.5

These numerical scores are translated into linguistic variables, using fuzzy membership functions as described previously, in order to obtain the value of readiness for each factor. The result is presented in Table VI.

TABLE VI. READINESS LEVEL OF EACH FACTOR

Factors	*Readiness level*
Project	Medium
Vision and Goals	Low
System and Process	Low
Structure and cultures	Medium
Human Resources	High

Based on Table VI, we can see that human resource has the highest readiness factor. While the results of the assessment in the perspective of sub-goals can be seen in Table VII. By considering readiness level of each sub-factor and also the readiness level of each sub-goal which are still low, it indicates that for now, company ABC is not yet ready to implement an ERP.

B. Suggestions to organization

Considering the assessment result we had for company ABC, we formulated some recommendations to assist company ABC in preparing implementation of ERP in the future.

Considering the Project factor, company ABC needs to prepare a proper guideline that can be used to carry out all the activities of the project, including the control mechanisms to ensure the procedure runs. In addition, they should also start a training program for the team who will be involved in the ERP implementation project.

In accordance to Visions and Goals factor, company ABC needs to formulate visions and goals of the ERP implementation. The visions and goals should be documented in the form of a formal document, and must be approved from the top level management as a commitment to ERP project implementation. The vision and mission should be communicated to all employees intensively.

With respect to system and process, the company ABC has to ensure that the current system can be integrated with new one without any failure and thus should adapt new practices which could help to attain the same.

Related to Culture and Structures factor, company ABC has to reorganize the ownership structure of data and information, so that the ownership of data and information becomes more apparent. For that, they need to establish formal procedures to define the duties and responsibilities associated with decision-making. To increase the awareness of employees, it requires intense communication about the benefits of ERP.

The human resource factor is high for company ABC and this could be considered as one of the important advantage of the company, still they could improve to attain more success in future.

TABLE VII. NUMERICAL SCORES FOR SUB GOALS

Sub factors	Project manageme nt readiness	Organization al readiness	Change manageme nt readiness
Project Championship	1.6000	0.7750	1.3250
Resource Allocation	1.6000	0.7500	1.3500
Assign Responsibilitie	1.1500	0.5500	0.9500

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s			
Project Team	3.1000	1.5000	2.5500
Project Scope	1.2000	0.5750	1.0000
ERP impl. vision	1.6000	0.8750	1.0500
ERP mission and goals	3.4000	1.8750	2.2000
Existing system	1.6250	3.2500	2.0000
Existing process	1.6250	3.2500	2.0000
Culture	3.9000	4.6500	0.5000
Decision mechanisms	1.6000	1.9000	2.0500
Organizational structure	0.9000	1.0750	1.1500
Communicatio n	1.6250	1.9500	2.1000
Top Management	7.8000	9.0500	8.5000
Personnel	5.5500	6.4500	6.0000
Total	38.2750	38.475	34.225

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V. CONCLUSION

The readiness assessment for ERP implementation has been conducted in the company ABC and from the results obtained it is very clear that the company is not ready to implement ERP and various suggestions have been given to the company in order to improve their abilities to implement ERP in future.

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