[ICAMS: March 2017]
ISSN 2348 – 8034
Impact Factor- 4.022

GLOBAL JOURNAL OF ENGINEERING SCIENCE AND RESEARCHES

OPTIMIZATION STUDIES ON TRIBOLOGICAL CHARACTERISTICS OF CSP AND GGBS FILLED GLASS - EPOXY COMPOSITES

Dr. G. Mallesh[*1], Mr.Paramesha M[2] & Mr.Pradeep kumar V G[3]

[*1]Associate Professor, Department of Mechanical Engineering, S.J.C.E- Mysuru-06, India
[2]Assistant Professor, Department of Mechanical Engineering, S.K.I.T-Bengaluru-560090, India
[3]Assistant Professor, Department of mechanical engineering, S.J.C.E- Mysuru-06, India

ABSTRACT

Composites are the amalgamation of two or more materials which are different in form and chemical constituents. These are gradually gaining more significance as structural materials in the preset day engineering design and development activity; this is because they offer very attractive mechanical properties such as high strength to weight ratio, higher thermal, corrosive and wear resistance. Hence the development of natural fiber reinforced polymer composites has gained popularity in many applications due to their environment friendly characteristics over the synthetic fiber based polymer composites.

In this paper attempts are made to develop composites by hand lay-up technique to estimate tribological property of glass-epoxy composites filled with varying volume fractions of blast furnace slag and coconut shell powder. From the results it was found that the tribological properties of the composites fabricated were increased with the increase in filler content.

Key words: *coconut shell powder, optimization ground granulated blast furnace slag, Wear, Taguchi, ANNOVA.*

I. INTRODUCTION

Fibers are various forms which are intrinsically much stiff and stronger than the same materials in the massive form. The reinforcing fibers are the most important load-transferring agents. In general they are strong and stiff. The geometry of fibers was somehow crucial to evaluate their strength and must be considered in structural applications. In these composites fibers are the main basis for strength, the matrix collectively '**glues**' all the fibers to transfer stress within the reinforcing fibers.

Aramid, Carbon, Glass and Kevlar are some of the popular fibers which are widely used for load bearing applications. “The glass fiber is most popular due to low price and suitable for engineering applications.”

The task of matrix in the composite is to hold reinforcement together, further the matrix include toughness to the composites. There are many matrix materials being used to obtain the desired properties. Commonly used matrix materials are epoxy resins, phenolic resins, unsaturated polyester and polyurethane, etc, are used in combination with glass fibers. Fillers or modifiers are added to reduce cost, improve the desired properties and enhance manufacturing process capabilities.

Major problem associated with urbanization and industrialization is pollution but industrialization is necessity to boost the economy of the developing countries. Urbanization leads to the environmental pollution due the generation of huge amount of solid wastes. Therefore, over recent decades, intensive research efforts are made to utilize unwanted wastes by their conversion into materials for various applications.

From world resource review, 1994 it is noticed that huge quantity of solid waste was formed by blast furnace slag and coconut shell which are not utilized properly leads to environmental pollution.

In the present scenario due growing interest on the natural fibers, attempts are made to use these filler in the development of composite materials for industrial applications and fundamental research.

Hence, in this paper attempts are made to develop new composite material using glass fiber, epoxy resin filled with different weight fractions of slag and coconut shell powder to estimate tribological property.

II. LITERATURE REVIEW

A literature survey is the sources of background information which are relevant to a particular area of research. It provides a methodologies, description and critical assessment of each work. Present research mainly focused on the development, estimation of mechanical properties of slag and coconut shell powder filled glass fiber reinforced epoxy composites.

S. Basavarajappa.et.al, [1] Taguchi analyses using L_9 orthogonal array and ANOVA are used to study three-body abrasive wear behavior of SiC particle filled polymer matrix composites by considering sliding distance, load and speed to identify the contribution of each parameters. It is observed that weight loss increases with increases in load, speed and abrading distance. Further, it is observed that addition of the filler contributes a significant wear resistance. Similar analyses were carried out for hybrid composites with SiC and Graphite as filler.

Sandhyarani Biswas.et.al, [2] erosive wear behavior of bamboo and glass–epoxy composites filled with redmud composites are studied using Taguchi technique. Mechanical and wear properties of both the composites were studied and noticed that bamboo reinforced composite materials shows fairly inferior mechanical properties and good erosive wear resistance compared to that of the glass fiber reinforced composites. Addition of red mud particles in both the composites improves the erosion wear resistance.

K.M. Subbaya.et.al, [3] developed carbon epoxy composite with SiC as filler material as per design of experiments using Taguchi's L_9 orthogonal array to study the abrasive wear behavior using pin-on-disc experimental setup by considering different process factors. ANOVA is employed to determine the significant factor which affects abrasive wear. It noticed from the results that wear resistance increased significantly with the insertion of SiC particles. From the Taguchi and ANOVA it is noticed that abrasive grit size has the most significant factor on abrasive wear behavior.

Mehmet Bagci.et.al, [4] carried out three body erosive wear of Al_2O_3 particles filled glass fiber reinforced epoxy composite materials by varying impact velocities, impingement angle and orientation of fiber and results were compared Taguchi's approach to determine an optimal design parameter to minimize the erosive wear of the composites. Further, to study the surface morphology and presence of particles X-ray diffraction (XRD) and SEM analyses were carried out.

Dr. Ibtihal Abdalrazaq.et.al, [5] Granite, perlite and calcium carbonate ceramic fillers are used to fabricate glass fiber-epoxy composites to study the wear behavior using POD experiments under dry sliding conditions by varying velocity, load and sliding distance. From the results it is observed that wear resistance increase with the addition of these ceramic fillers.

Hanumantharaya R.et.al, [6] friction and dry sliding wear behavior of glass epoxy composites filled with granite - fly ash were developed and wear tests are conducted using on pin-on-disc apparatus using 320 and 600 grit size abrasive papers for different sliding distance at speed of 200 rpm with constant load. It is observed from the results that wear loss was reduced with the addition of SiC and fly ash and wear loss found to be increased with the increase in sliding distance.

M. Sudheera.et.al, [7] PTW/Graphite hybrid fillers are used to develop epoxy/glass composites to study mechanical and wear performance. Addition ceramic whisker about 7.5 wt% by weight improve stiffness and coefficient of friction considerably. However, incorporation of graphite as secondary filler which acts as solid lubricant results in enhancement of mechanical and tribological properties.

Niharika Mohanta.et.al, [8] glass epoxy composite material filled with red mud as a filler are used to study the three body abrasive wear behavior using 150–250µm silica sand as an erodent by varying impingement angle and velocity it is noticed that that 60°impingement angle has major effect on erosion rate.

ISSN 2348 – 8034
Impact Factor- 4.022

C.Anand Chairman.et.al, [9] Glass–Epoxy composites filled with titanium carbide were fabricated to study the two-body abrasive wear behavior using POD experiment by varying load and sliding distance on 400 grit water proof SiC abrasive paper. It is observed from the results that wear resistance increases due to the presence of TiC. Wear mechanisms of these worn out composites were analyzed using SEM- micrographs.

From the literature survey it is found that very limited work has been done on tribological characteristics of slag and coconut shell powder reinforced composite. Hence it is decided to study the tribological properties of slag and coconut shell reinforced composite materials as per ASTM standards.

III. MATERIALS AND METHODS

Fibers are the major elements in FRP composites; the reinforcing fiber is most important load-transferring agents and occupies the largest volume fraction in a composite laminate. Different types of glass fibers used to manufacture fiber-reinforced plastics (FRP) are S-glass and E-glass in industry. Many components for air craft and missile components are developed using S-glass fibers because of its highest tensile strength among all fibers in use. It is noticed that E-glass has the least expensive fibers among all commercially available fibers, because of this reason they are widely used in the FRP industries.

In general, Ceramics, thermoset and thermoplastic are used as common matrix materials. Epoxy resins are extensively used in the manufacture of fiber reinforced composites because of their flexibility, low contraction and exceptional adhesive properties with minimum cost.

Fillers are induced into a polymer matrix to minimize cost, enhance modulus, diminish mold shrinkage, controls the viscosity and to produce good surface roughness. The most common filler used in FRP composites are clay, mica, and glass microspheres, in this paper different weight fractions of slag and coconut shell powder are used as fillers.

A composite sheet of 100 mm X 100 mm X 3 mm thick is fabricated using hand layup and bag molding process for different weight fractions of slag and coconut shell powder reinforced with glass fiber, epoxy resin. Mass of glass fiber, epoxy resin and mass of the fillers were calculated as per their volume and density. Calculated quantity of glass fiber, epoxy resin along with the hardener and fillers are used manufacture composite plates of required dimensions.

The process flow chart to prepare composite material and its characteristics is as shown in **Figure 1.**

Initially number of layers of the glass fibers are marked and cut as per the required dimensions from the glass mat strands with the help of marker and scissors, number of layers are chosen based on the thickness of the laminate. In the next step calculated amount of matrix resin along with hardener is mixed with the filler. First layer of the glass fiber is placed on a flat surface which is cleaned with the help of acetone. First layer is coated with a layer of resin either through a spray gun, or through a brush. Similar procedure will be followed till to get the required thickness of a laminate.

In order to remove the excess mixture, perforated sheet and breather sheet are placed on to the surface of the glass fiber. Vacuum pressure is created in the composite system about 1hr 30min in order to remove the air bubbles and excess resin in between the layers. Curing of the composite system is carried out for an hour at 100^{0}C. Similar procedure is carried out for different weight fractions of fillers keeping glass fiber volume fraction constant.

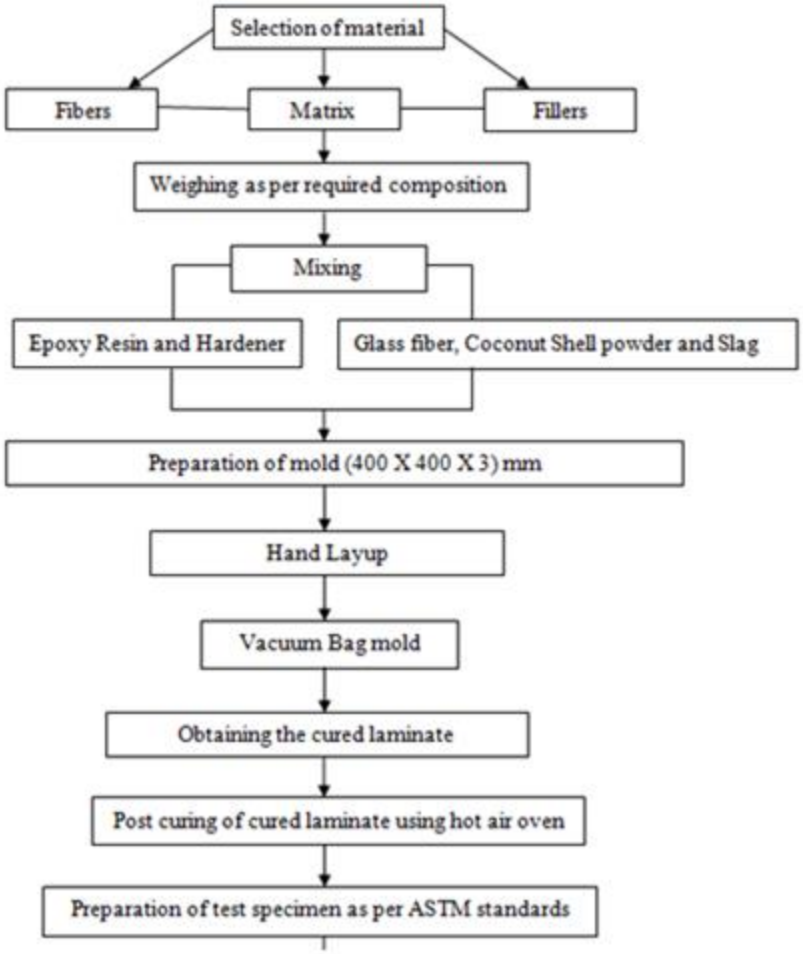


Figure 1: Process flow chart

Finally the slag and coconut shell reinforced composite plates were cut using band knife cutting machine as per ASTM standard to carryout pin on disc wear test.

IV. TEST PROCEDURE

Wear Behavior

Wear occurs as a natural consequence when two surfaces with a relative motion interact with each other. Wear may be defined as the progressive loss of material from contacting surfaces in relative motion.

Abrasive wear can be defined as wear that occurs when a hard surface slides against softer surface. It can be account for most failures in practice. Hard particles or asperities that cut the rubbing surfaces produce abrasive wear.

In the present study test specimens were cut as per the machine requirements the test specimens with holders is as shown in figure 2. Before conducting wear test hardness of the composite materials has to be determined to select suitable disc.

ISSN 2348 – 8034
Impact Factor- 4.022

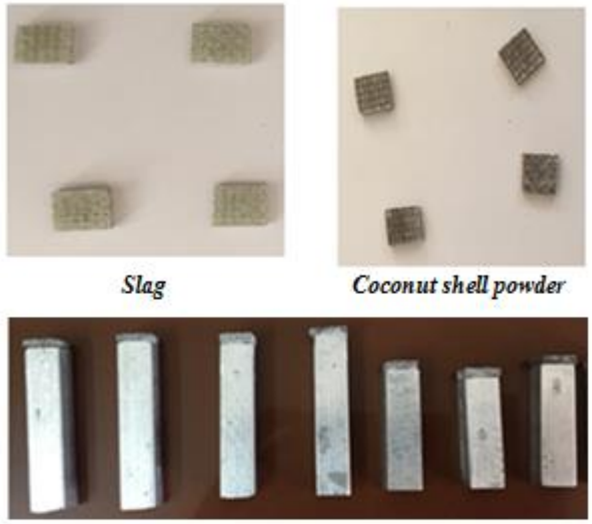


Figure.2: Wear test specimens

Pin-on-disc wear test experimental setup is shown in figure 3. The slider disc has been made up of 0.95 to 1.20% carbon (EN31) hardened steel disc with hardness of 62 HRC having diameter of 180 mm. The initial surface finish (Ra) of the steel disc has been 1µm. It is versatile equipment designed to study wear under sliding condition only. Sliding generally occurs between a stationary pin and a rotating disc. The disc rotates with the help of a D.C. motor; having speed range 0-2000 rpm with wear track diameter 40 mm-160 mm, which could yield sliding speed 0 to 10 m/sec.

Figure: 3. Pin-on-disc apparatus

The dry sliding wear test was carried out at room temperature under dry sliding condition in accordance with the ASTM G 99-95 standard. The composites test samples have been prepared as pins of dimensions 10 mm X 10 mm cross section. A track diameter of 100 mm has been used in all the experiments. The tests have been carried out by applying normal loads varying from 20 N to 60 N in steps of 20 N, sliding velocity of 3,4 and 5 m/s with sliding distance of 1,2 and 3 km for different wt.% of slag and coconut shell powder reinforced glass epoxy composite system. The weight loss was determined using electronic weighing machine with a tolerance of 0.001grams.

Optimization Technique

An optimization problem consists of maximizing or minimizing a real function by systematically choosing input values within an allowed set and computing the value of the functions. In general, optimization includes finding the "best available" value among the variety of objective functions and different types of domains.

Design of Experiments (DOE)

Design of Experiment is one of the important and powerful statistical techniques to study the effect of multiple variables simultaneously and involves a series of steps which must follow a certain sequence for the experiment to yield an improved understanding of process performance.

Taguchi Technique

Taguchi technique is a scientifically disciplined mechanism for evaluating and implementing improvements in products, processes and facilities. Taguchi technique calculates the individual or main effects of independent variables on performance parameters. However, the use of analysis of variance (ANOVA) and regression models in combination with the Taguchi technique helps to quantify the contribution of each process variables.

Plan of experiments

The Taguchi technique for the design of experiments is used for the plan of experiments with three factors at three levels. A standard L_9 orthogonal array was chosen with nine rows and four columns as shown in Table.1. The wear parameters considered were applied load, sliding velocity and sliding distance. The experiment consists of nine tests corresponding to the number of rows and columns are assigned with the parameters.

Table: 1. Taguchi L_9 Orthogonal array

L_9 Test	1	2	3	4
1	1	1	1	1
2	1	2	2	2
3	1	3	3	3
4	2	1	2	3
5	2	2	3	1
6	2	3	1	2
7	3	1	3	2
8	3	2	1	3
9	3	3	2	1

The first column is assigned to applied load, second column to sliding velocity and third column to sliding distance. The factors considered in this experiment and their levels are as shown in Table.2. The experiments were conducted as per the orthogonal array with level of parameters given in each row. The wear test results were subjected to the analysis of variance. The regression equation for the results obtained can be expressed as $Y = b_o + b_1X_1 + b_2X_2 + b_3X_3$

Table: 2. Process parameters and their values

Level	Applied Load (N)	Sliding velocity(m/s)	Sliding distance(m)
1	20	3	1000
2	40	4	2000
3	60	5	3000

Where Y is the weight loss due to wear, b_0 is the response variable of weight loss at the base level, with b_1, b_2 and b_3 are the coefficients associated with each variable (applied load, sliding velocity and sliding distance respectively) within the selected levels of each of the variables. Positive value of the coefficients indicates that wear loss increases with the increasing the respective parameter whereas negative value indicates that wear loss decreases with the increase in the associated parameter.

Analysis of Variance (ANOVA)

ANOVA is used to analyze the influence of wear parameters like load, sliding velocity and sliding distance. The ANOVA establishes the relative significance of factor in terms of their percentage contribution to response. The analyses were carried out for a level of significance of 5% (level of confidence 95%). The signal to noise (S/N) ratio, is used to condense multiple data points within a trial to determine type of characteristics. In this study, “smaller the better” characteristic was chosen to analyze the dry sliding wear resistance. The S/N ratio for wear rate “smaller the better” characteristic developed by Taguchi is represented by the equation

$$\frac{S}{N} = -10 \log\left(\frac{1}{n}\sum_{i=1}^{n} \Sigma y_i^2\right)$$

Where ‘y’ is represented as observed data and ‘n’ is the number of observations. The experiments were conducted as per orthogonal array L_9 to predict the suitable combination for wear studies of the composite developed using optimization software MINITAB 15.

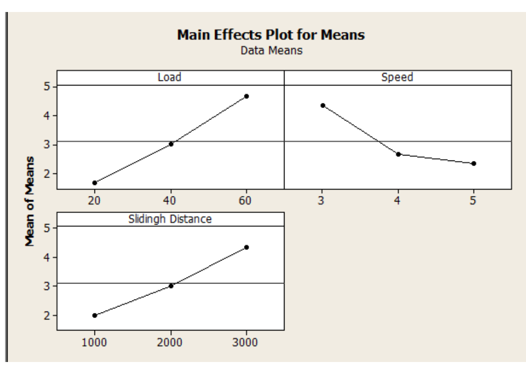
V. RESULTS AND DISCUSSIONS

A series of wear experiments were carried out by means of pin on disc wear testing machine as per the design of experiments to investigate the tribological characteristics of 3, 6, 9 and 12% weight fractions of slag and coconut shell powder by varying load, sliding distance and sliding speed. Results obtained from the POD experiments are used to build mathematical model using MINITAB software. This is used to develop Taguchi analysis, ANOVA and multiple regression models.

Table: 3. S/N ratio for L_9 orthogonal array

Load (N)	Speed (m/s)	Sliding Distance(m)	Wear (mg)	S/N Ratio
20	3	1000	2	-6.0206
20	4	2000	2	-6.0206
20	5	3000	1	-0
40	3	2000	3	-9.54243
40	4	3000	4	-12.0412
40	5	1000	2	-6.0206
60	3	3000	8	-18.0618
60	4	1000	2	-6.0206
60	5	2000	4	-12.0412

Table 3 shows the influence of control parameters such as sliding speed, load and sliding distance on wear was evaluated using S/N ratio response analysis. Process parameters settings with the highest S/N ratio always yield the optimum quality with minimum variance



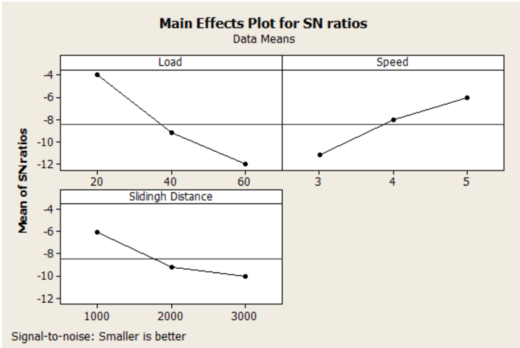


Figure: 4. S/N ratio and means of means plot for unfilled composites.

The main effect plots for mean, S/N ratio for the wear effect plots between the process parameters as shown in Figure 4 (Table:4). The significance of each parameter is determined from the inclination of the main effect plots. A parameter for which the line has the highest inclination will have the most significance. It is very much clear from the main effect plot that applied load is most significant wear parameter while sliding distance also has some effect.

Table: 4. Analysis of variance results for S/N ratio for unfilled composite.

Source	D F	Seq SS	Adj SS	Seq MS	F	P	Pr %
Load	2	99.42	99.42	49.71	2.12	0.321	46.3755
Sliding speed	2	41.06	41.06	20.53	0.87	0.534	19.1529
Sliding distance	2	26.92	26.92	13.46	0.57	0.636	12.5571
Error	2	46.98	46.98	23.49			21.9143
Total	8	214.38					100

Df- Degree of freedom
Seq SS-Sequential sums of squares
Adj SS- adjusted sums of squares
Seq MS/Adj MS-adjusted mean of squares
P-Probability
Pr %-Percentage of contribution

From table 4 it is observed that the applied load (Pr=46.37%), sliding speed (Pr=19.15%) and sliding distance (pr=12.555) has great influence on the wear. The pooled error associate in the ANOVA table is 21.91%. Similar analyses were performed for different weight fractions of slag and coconut shell reinforced composites. It is very much clear from the main effect plots and ANOVA that applied load is most significant wear parameter while sliding distance also has some effect.

Linear regression technique was used to study the dry wear weight loss of Glass- epoxy composite system. The multiple linear regression equation was developed using MINITAB software.

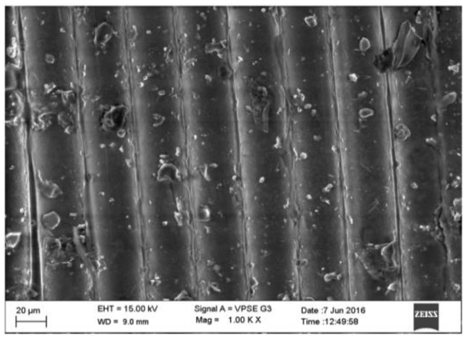
Wear = 1.78 +0.0750 Load - 1.00 Speed + 0.00117 Sliding Distance

It is noticed that co-efficient of load and sliding distance is positive and sliding speed negative. The positive value of the coefficients suggests that sliding wear of material increases with their associated variables where as the negative value of the co-efficient suggests that the sliding wear of the material will decreases with increase in associated variables. It is observed from the equation that load has more effect on wear of the composite which is followed by the sliding distance and speed.
Linear regression equations for different weight fractions of slag and CSP filled glass epoxy composites were developed and observed that wear loss is minimum for 9% weight fraction of slag.

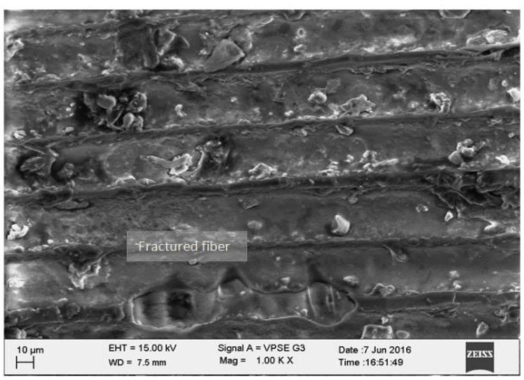
Further conformation tests were conducted using specific combinations of the parameters and levels in order to find the accuracy of the analysis. Error associated with unfilled and filled composites is in the range of 3.2% to 7.09% obtained between the predicted and experimental value showing good correlation with the published results.

Figure.5 shows the scanning electron microscope (SEM) images of the worn out surfaces of different weight fractions of slag and coconut shell powder fillers. From the SEM images it is noticed that there is a perfect interface developed between the matrix and the fibers along with the fillers and also observed that a uniform distribution of fillers in the composite.

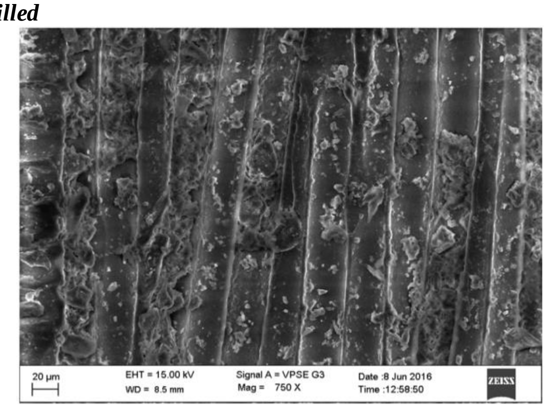
The sliding wear behaviors along the sliding direction of the worn surfaces were observed from the SEM images. It is noticed that due to the plastic deformation, which leads to the formation of parallel deep grooves along with wear debris. The stress concentration during sliding at higher loads is more at the sharp edges of filler particles which initiate cracks in the matrix



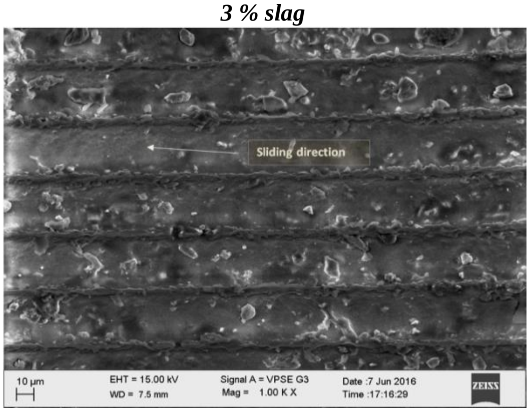
Unfilled



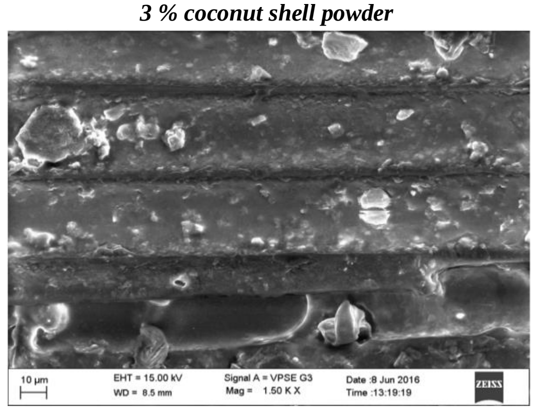
3 % slag



3 % coconut shell powder



9 % slag



9 % coconut shell powder

Figure: 5. SEM images of worn-out surface of different weight fractions of Slag and CSP filled glass epoxy composites

IV. CONCLUSIONS

A series of wear experiments were carried out by means of pin on disc wear testing machine as per the design of experiments by varying load, sliding distance and sliding speed it is observed from the main effect plots that load has highest influencing parameter on dry sliding wear of the composite except 9% weight fraction of slag filled composite this may be due to uniform dispersion of slag particles in the matrix.
The results of wear loss and wear loss by regression model are compared and found that error associated with unfilled and filled composites is in the range of 3.2% to 7.09% which is equal or nearer to the published results.
SEM images of the worn out surfaces depicts that due wear, composites are subjected to plastic deformation which leads to the formation of parallel deep grooves along with wear debris.

REFERENCES

1) *S. Basavarajappa , Ajith G. Joshi , K. V. Arun , A. Praveen Kumar & M. Prasanna Kumar "Three-Body Abrasive Wear Behaviour of Polymer Matrix Composites Filled with SiC Particles" Polymer-Plastics Technology and Engineering (2009) 49:1, 8-12,*
2) *Sandhyarani Biswas , AlokSatapathy "A comparative study on erosion characteristics of red mud filled bamboo–epoxy and glass–epoxy composites" Materials and Design 31 (2010) 1752–1767*
3) *K.M. Subbaya , B. Suresha , N. Rajendra , Y.S. Varadarajan"Grey-based Taguchi approach for wear assessment of SiC filled carbon–epoxy composites" Materials and Design 41 (2012) 124–130*
4) *Mehmet Bagci , HuseyinImrek"Application of Taguchi method on optimization of testing parameters for erosion of glass fiber reinforced epoxy composite materials"Materials and Design 46 (2013) 706–71*
5) *Dr.IbtihalAbdalrazaq,Dr. WafaAbdSoudOrhan Sabah Abdullah "Effects Of Different Types Of Ceramic Fillers On Wear Characteristics Of Glass Fibres-Epoxy Composite" Journal of Engineering and Development, Vol. 17, No.6, December 2013 , ISSN 1813- 7822*
6) *Hanumantharaya R, Ananda Kumar K M, Prem Kumar B G ,Vikas G ,Ashok Kumar G P "Friction and Dry Sliding Wear Behaviour of Granite - Fly Ash Filled Glass Epoxy Composites" International Journal of Innovative Research in Science, Engineering and Technology Vol. 3, Issue 7,July 2014*
7) *M. Sudheera, K. Hemantha, K. Rajua, Thirumaleshwara Bhata"Enhanced Mechanical and Wear Performance of Epoxy/glass Composites with PTW/Graphite Hybrid Fillers"3rd International Conference on Materials Processing and Characterization (ICMPC 2014) Procedia Materials Science Vol-6 (2014) 975 – 98*
8) *Niharika Mohanta, Dr. S K Acharya "Effect of Red mud on solid particle impact behavior of polymer composite" Advances in Polymer Science and Technology: An International Journal, 13 April 2015*
9) *C. Anand Chairman, S. P. Kumaresh Babu1, Muthuk annan Durai Selvam, K.R.Balasubramanian "Investigation on two-body abrasive wear behavior of titanium carbide filled glass fabric-epoxy composites- a Box-Behnken approach" International Journal of Engineering, Science and Technology Vol. 3, No. 4, 2011, pp. 119-129.*