International Journal of Advances in Scientific Research and Engineering (ijasre)
ISSN: 2454-8006 [Vol. 03, Issue 4, May -2017]
www.ijasre.net

Effect of the Tribological Behaviour of Hematite Filled Hybrid Composites – A Taguchi Approach

Vithal Rao Chavan[1], Kotresh Sardar[2], Veerbhadrappa Algur[3], Imran Md[4].

[12]Asst. Professor, Department of Mechanical Engineering,
[3] Asst. Professor, Department of Industrial & Production Engineering,
[3]Rao Bahadur Y Mahabaleswarappa Engineering College, Ballari, India.
[4]P.G. Scholar, Department of Mechanical Engineering,

Rao Bahadur Y Mahabaleswarappa Engineering College,

Ballari, India.

ABSTRACT

This paper reports the development and wear performance evaluation of a new class of polymer based composites filled with hematite ore. The ore particles 75-150μm are reinforced in polyester resin to prepare particulate filled composite of three different compositions (with 3,6&9 wt.% of ore). Dry sliding wear trials are conducted following a well planned experimental schedule based on design of experiments (DOE) using a standard pin on disc test setup. Significant control factors predominantly influencing the wear rate are identified. Effect of Fe_2O_3 content on the wear rate of polyester composites under different test conditions is studied. ANOVA approach taking into account training test procedure to predict the dependence of wear behavior on various control factors is implemented. This technique helps in saving time and resources for large number on experimental trails and predicts the wear response of Fe_2O_3filled epoxy composites within and beyond the experimental domain.

Key words:-*Taguchi, Fe_2O_3, ANOVA,E-glass fiber, polyester resin, sliding wear.*

1. INTRODUCTION

Recent days, the researchers are more focused on producing cost-performance based polymer composites from high-performance advanced composites, however composites are known for the low density, reasonably good strength and wear resistance compared to metal alloys (monolithic). In order to cut down the cost, low cost and easily available fillers are the liable option, but it should not degrade the mechanical properties of the composites. Therefore the purpose of filler is not only to reduce the cost but it should improve the mechanical properties, thermal and tribological properties[1].

The polymers are extending over a great area used in sliding components like such as gears, cams, breaks, clutches, bearings, wheels and bushes. Adhesive wear includes galling, fretting, scuffing and surface fatigue. This refers to the damage produced when two mating surfaces move relative to each other under a normal load. Surface asperities interact and very high stresses, strain, and strain rates are generated in localized regions [2].

The improved performance of polymers and their composites in industries and many other applications by the addition of particulate fillers has shown great advantages and so has lately been the subject of considerable interest. The mechanical and tribological behavior of particulate fillers $CaCO_3$ and $CaSO_4$ filled vinyl ester composites have been studied. Wear tests were carried out in dry sliding conditions on a pin-on-disc friction and wear test rig. (DUCOM) at room temperature under sliding velocity (1.57, 2.62 and 3.67 m/sec.), normal load (20, 40 and 60 N), filler content (0, 10 and 20 wt.%) and sliding distance (1000, 3000 and 5000 m).

The plans of experiments is based on the Taguchi technique, was performed to acquire data in a controlled way. An orthogonal array and analysis of variance (ANOVA) were applied to investigate the influence of process parameters on the coefficient of friction and sliding wear behavior of these composites. The coefficient of friction and specific wear rate were significantly influenced with increase in both the filler content. The results show that for pure vinyl ester the coefficient of friction and specific wear rate increases with the increase of normal load, sliding velocity and sliding distance. The coefficient of friction and specific wear rate for CaCO3 filler decreases with the increase of filler content. But, for filler CaSO4 the coefficient of friction and specific wear rate decreases at 10 wt.% and then increases at 20 wt.%. It is believed that a thin film formed on stainless steel counter face was seems to be effective in improving the tribological characteristics. The worn surfaces examined through SEM to elucidate the mechanism of friction and wear behavior.[2]

Epoxy composites reinforced with organo-modified montmorillonite (oMMT) and alumina (Al_2O_3) particles were prepared by incorporating nanoparticles into epoxy via high shear mixing followed by liquid molding. The effects of loading of nanoparticles on the mechanical and wear properties were studied. The results showed that the incorporation of nano- Al_2O_3 with nano-oMMT could effectively enhance the tensile properties of the composites. The tensile strength decreased and Young's modulus of the epoxy increased with the increasing nano-oMMT content. The enhancement effect of the nanoparticles was more significant in the hybrid reinforced composites. The compounding of the two fillers also remarkably improved the wear resistance of the composites under higher load. The average coefficient of friction also decreased in Al_2O_3 filled oMMT-epoxy hybrid composite. It was revealed that the excellent wear resistance of the oMMT+ Al_2O_3 -epoxy hybrid composite was due to a synergistic effect between the oMMT and Al_2O_3 . Nano- Al_2O_3 carried the majority of load during the sliding process and prevented severe wear of the oMMT-epoxy. Further, the specific wear rates of the hybrid composites decreased with the increasing applied load and sliding distance. Nanoparticles distribution and their influence on properties were emphasized. Different wear mechanisms were observed on the worn surfaces of the composites, including pitting, micro-and/or macro-cracks, as well as crack propagation of the matrix in the transverse direction[3].

The E-glass woven fabric-epoxy (LY 556) (GE) composites have been fabricated with varying amounts of silicon oxide (SiO_2) particulate filler viz., 3, 6 and 9 wt % by compression molding followed by hot curing. The fabricated composites were characterized by mechanical properties such as tensile behaviour, flexural behaviour and interlaminar shear strength (ILSS). The effect of silica content on the sliding wear properties such as wear loss, specific wear rate and coefficient of friction of GE composites have been investigated at velocity of 5m/s and constant abrading distance of 1200 m with different loads viz., 30N, 60N and 90N by using pin-on-disc machine. Wear out surface of all the composites were studied using scanning electron microscopy (SEM)[4].

Frictional performance of glass-epoxy composite with influence of Granite and fly ash filler are experimentally investigated under constant load and sliding velocity, varying sliding distance using a pin-on-disc apparatus. Composites were fabricated by standard hand layup technique followed by hot pressing. The wear behaviour of the composites have been performed at varying abrasive distances viz., 5, 10, 15 20 and25 m at a constant load of 10 N. The experiment has been conducted using two different water proof silicon carbide (SiC) abrasive papers of 320 and 600 grit size at a constant speed of 200 rpm under multi-pass condition. The results show that wear loss of the composites was found increasing with the increase in abrading distances. A Significant reduction in wear loss and specific wear rates were noticed after incorporation of SiC and fly ash filler into GE composite [5].

The friction and wear behavior of glass-epoxy (G-E) composites with and without silicon carbide particles (SiCp) filler content as a function of sliding distance, keeping the sliding velocity and applied load constant it is seen that the wear rate increases with increasing sliding distance, but the gradient is not maintained the same all through. An attempt has also been made to correlate the wear loss of the worn surfaces using scanning electron microscopic (SEM) observations. The coefficient of friction is found to be almost same over a wide range of sliding distance employed. Further, the study indicates that the SiCp-G-E composites show lower coefficient of friction and lower slide wear loss compared to G-E composites irrespective of the sliding distance employed. It is found that during the running in wear, the wear of the resin mix as well as very few broken fibers are noticed. The breakage of fibers, the matrix debris formation and interface separation take place at a much later stage (i.e., in the severe wear region). In the steady state region some of the broken fibers are getting disoriented in the matrix and also agglomerations of the debris are seen. Other interesting SEM features have been noticed and discussed taking into account the addition of SiCp filler content (2.5 & 5.0 wt.%)[6].

2. MATERIAL DETAILS AND SPECIMEN PREPARATION

E-glass fabric (300 GSM) of plain weave construction, procured from New tech suppliers of polymers, Bangalore, was used for the study polyester resin matrix with methyl ethyl ketone peroxide catalyst and cobalt octet accelerator were used. The filler were Hematite is one of the most common minerals. The sandstone is most red and brown in color because of hematite presence. Non-crystalline forms of Hematite may be transformations of the mineral Limonite that lost water, possibly due to heat chemical formula Fe_2O_3. The filler used was hematite passed through 75-150 μm. In this work there are four types of composite is being prepared of diameter of 6mm and length of 150mm, by using hand layup technique with help mould.The table (1) show the details of the composites constituents proportion mixed.

Table: 1 composition of filler on specimens

composites	% of filler	Matrix volume %		Reinforcement volume%	
C1	0	polyester	50	Glass fiber	50
C2	3	polyester	47	Glass fiber	50
C3	6	polyester	44	Glass fiber	50
C4	9	polyester	41	Glass fiber	50

3. EXPERIMENTAL PROCEDURE

To evaluate the performance of these composites under dry sliding condition, wear tests are carried out in a pin-on-disc type friction and wear monitoring test rig (supplied by DUCOM) as per ASTM G 99. The experimental set up is shown in Fig 1. The counter body is a disc made of hardened ground steel (EN-32, hardness 72 HRC, surface roughness 0.6 Ra). The specimen is held stationary and the disc is rotated while a normal force is applied through a lever mechanism. A series of test are conducted with three sliding velocities of 062 m/sec, 1.88 m/sec, 3.14 m/sec and 4.39 m/sec under three different normal loading of 4.90N, 9.81N, 14.71N and 19.62N. The material loss from the composite surface is measured using a precision electronic balance with accuracy ± 0.1 mg and the specific wear rate (mm^3/N-m) is then expressed on 'volume loss' basis as

$$WS=\Delta m/\rho t\ VS.\ FN \qquad \text{----Eqn1}$$

Where;

Δm is the mass loss in the test duration (gm).

ρ is the density of the composite (gm/mm^3).

t is the test duration (sec).

VS is the sliding velocity (m/sec)

FN is the average normal load (N).

The specific wear rate is defined as the volume loss of the specimen per unit sliding distance per unit applied normal load.

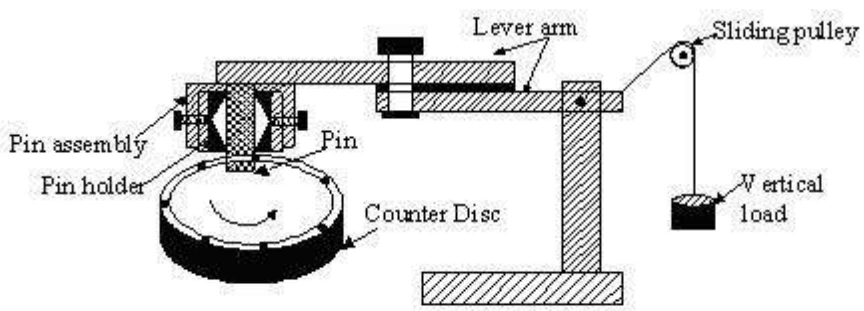

Fig 1 Schematic diagram of a Pin-on-Disc set

4. PLAN OF EXPERIMENTS

The experiments were conducted using L16 orthogonal array (OA) and the output is measured in terms of volumetric wear rate, frictional force and co-efficient of friction as shown in Table 3. The process parameters and their levels selected for the experiment is presented in Table 2. This analysis is carried out to optimize the process parameter levels within the selected range to attain minimum volumetric wear rate, frictional force and co-efficient of friction to attain defect controlled wear of non laminated composites. Analysis of variance was determined for the experimental data obtained for volumetric wear rate, frictional force and co-efficient of friction to study the relative significance of process parameters. In this analysis, "smaller the better" characteristics has been applied to calculate the S/N ratio volumetric wear rate, frictional force and co-efficient of friction. A higher the value of S/N ratio, better the fit for the combined objective.

Table 2 Process parameters and their levels

Process Parameters	Units	Code	Level 1	Level 2	Level 3	Level 4
% iron ore	-	A	0	3	6	9
Load	N	B	4.90	9.81	14.71	19.62
Speed	m/sec	C	0.62	1.88	3.14	4.39

Table 3 L16 orthogonal array with the assigned values

Expt. Run	% of Iron ore	Load	sliding speed	COF	specific wear rate	SNR for COF	SNR specific wear rate
01	0	4.905	0.62	0.407747	0.0002563	7.7058	71.8261
02	0	9.810	1.88	0.411825	0.0001269	15.7867	77.9300
03	0	14.715	3.14	0.162429	0.0001307	9.6225	77.6756
04	0	19.620	4.39	0.330275	0.0000652	9.2038	83.7098
05	3	4.905	1.88	0.346585	0.0000626	9.3585	84.0728
06	3	9.810	0.62	0.340469	0.0001242	10.3636	78.1204
07	3	14.715	4.39	0.303262	0.0000303	11.8284	90.3636
08	3	19.620	3.14	0.256201	0.0000402	6.0887	87.9235
09	6	4.905	3.14	0.496092	0.0000459	9.4106	86.7563
10	6	9.810	4.39	0.338430	0.0000687	6.2812	83.2602
11	6	14.715	0.62	0.485219	0.0001331	9.7304	77.5145
12	6	19.620	1.88	0.326198	0.0001340	8.6352	77.4549
13	9	4.905	4.39	0.370031	0.0000369	10.4664	88.6520
14	9	9.810	3.14	0.299694	0.0000462	11.1740	86.7050
15	9	14.715	1.88	0.276249	0.0000637	9.7304	83.9158
16	9	19.620	0.62	0.326198	0.0001213	7.7058	78.3224

5. EXPERIMENTAL RESULTS AND DISCUSSION:-

Analysis of Control factors

The influence of control factors like % of iron ore, Load (N) and speed (m/sec) on volumetric wear rate, frictional force and co-efficient of friction was been criticized using S/N ratio response analysis. The ranking of control factors using S/N ratio obtained for different parameters levels for volumetric wear rate, frictional force and co-efficient of friction is shown in Table 4 &Table 5 respectively. Fig2& Fig3 shows main effects plots of S/N ratios of co-efficient of friction and Specific wear rate respectively of Hybrid laminated composite. It suggests that the optimum condition for minimum co-efficient of friction and specific wear rate is the combination of $A_1B_2C_2$ and $A_2B_3C_4$ respectively.

Table 4:- Response Table for Signal to Noise Ratios for co-efficient friction

Level	% of iron ore	Load	Speed
1	10.227	7.930	8.291
2	10.189	9.235	9.453
3	7.878	10.901	11.043
4	10.002	10.228	9.508
Delta	2.349	2.971	2.752
Rank	3	1	2

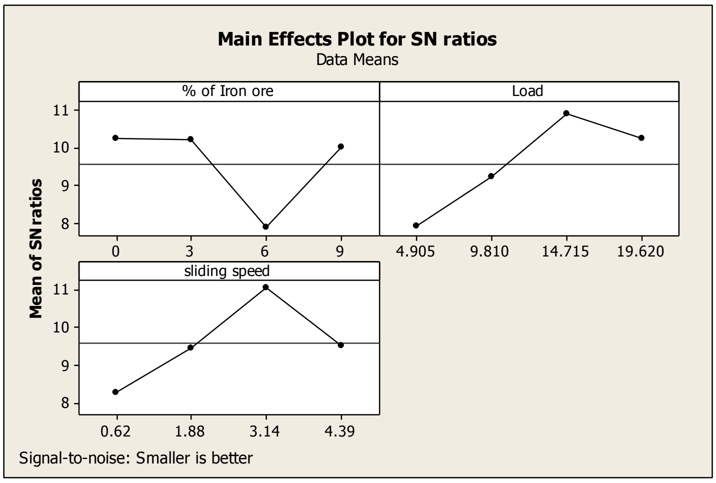

Fig 2: Main effects plots for co-efficient of friction

Table 5:- Response Table for Signal to Noise Ratios for specific wear rate

Level	% of iron ore	Load	sliding speed
1	77.79	82.83	76.45
2	85.12	81.50	80.84
3	81.25	82.37	84.77
4	84.40	81.85	86.50
Delta	7.33	1.32	10.05
Rank	2	3	1

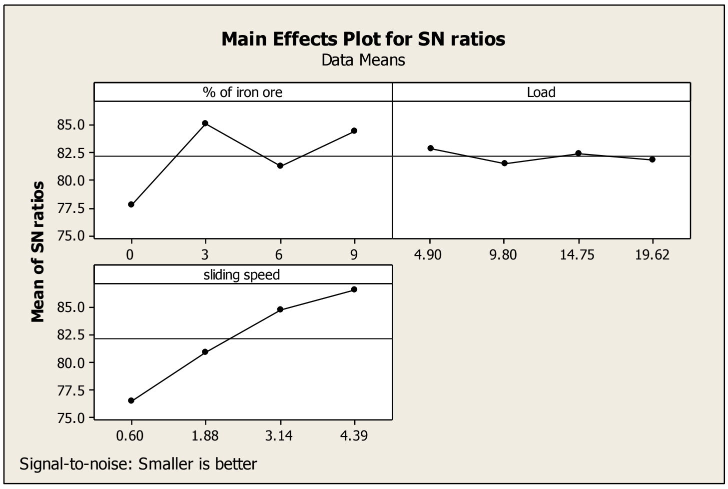

Fig 3: Main effects plots for specific wear rate

5.1 ANOVA

The conducted experimental results were analyzed by using Analysis of Variance (ANOVA) which is used to examine the influence of wear parameters like Normal Load and Sliding speed. By using ANOVA, it can be decided which independent factor dominates over the other and the percentage contribution of that particular independent variable. This analysis was carried out for a level of 5% significance that is up to a confidence level of 95%. Sources with a P-value less than 0.05 were considered to have a statistically significant contribution to the performance measures. Tables 7&8 show the results of ANOVA analysis of Hybrid composite of co-efficient of friction and specific wear rate. It can be noticed from the table 7 all the three parameters has moderately significant influence on co-efficient of friction and specific wear rate

Table 7:- Analysis of Variance for Co-efficient of Friction

Source	DF	Seq SS	Adj SS	Adj MS	F	P	% of contribution
% of iron ore	3	0.026073	0.026073	0.008691	1.46	0.316	25.52
Load	3	0.025185	0.025185	0.008395	1.41	0.328	24.65
sliding speed	3	0.015258	0.015258	0.005086	0.86	0.512	14.96
Error	6	0.035617	0.035617	0.005936			34.87
Total	15	0.102132					100

Table 8:- Analysis of Variance for Specific Wear Rate

Source	DF	Seq SS	Adj SS	Seq MS	F	P	% of contribution
% of iron ore	3	0.67582	0.67582	0.67582	4.7096	0.050780	12.30
Load	3	0.01116	0.01116	0.01116	0.0778	0.785063	00.22
sliding speed	3	3.08312	3.08312	3.08312	21.4854	0.000575	56.13
Error	6	1.72198	1.72198	0.14350			31.35
Total	15	5.49208					100

5.2 Regression Analysis

The Regression analysis is used to develop the correlation between the effective factors (% of iron ore, Normal Load and speed) and co-efficient of friction and specific wear rate (quality characteristic) to observed data.

The Regression Equation for Co-efficient friction.

COF = 0.453528 + 0.00232589 % (A) - 0.00666671 (B)- 0.0159271(C) ---- Eqn 2

R-sq = 65.13%

Specific wear rate = -8.46179 -0.0612745 % (A) +0.0048106 (B)+0.0048106(C)-0.310864---- Eqn 3

R-sq = 68.65%

6. CONCLUSIONS

In this research work, the study is to optimize the process parameter levels within the range analyzed based on minimum of co-efficient of friction and specific wear rate and thereby attaining defect controlled wear of non laminated Hybrid composites. Based on the result obtained, the following conclusions were expressed as follows.

1. Taguchi method has been applied to analyze the co-efficient of friction and specific wear rate of non laminated Hybrid composites.
2. In co-efficient of friction, the % of iron ore (25.52%), load (24.65%) and sliding speed (14.96%) has moderate effect.
3. In specific wear rate, the sliding speed (56.13%), % of iron ore (12.30%) and load has moderate effect.
4. The optimal tribological testing combination for minimum co-efficient of friction and specific wear rate is $A_1B_2C_2$ and $A_2B_3C_4$ respectively for non laminated Hybrid composites.

REFRENCES

[1] C. Allen, A. Ball, “A review of the performance of engineering materials under prevalent tribological and wear situations in South African industries”, Tribology International, vol. 29, No. 2 pp. 105-116, 1996.

[2] Sandeep Kumar, Sant Ram Chauhan , " Mechanical and Dry Sliding Wear Behavior of Particulate Fillers CaCO3 and CaSO4 Filled Vinyl ester Composites, "International Journal of Composite Materials 2012, 2(5): 101-114 DOI: 10.5923/j.cmaterials.20120205.06

[3] B. Suresha, B.L. Ravishankar, L. Sukanya, " Role of nanofiller additions on mechanical and dry sliding wear behavior of epoxy nanocomposites"Usak University Journal of Material Sciences 2 (2012) 79 – 94

[4] B. Shivamurthy, Siddaramaiah and M.S. Prabhuswamy, "Influence of SiO2 Fillers on Sliding Wear Resistance and Mechanical Properties of Compression Moulded Glass Epoxy Composites," Journal of Minerals & Materials Characterization & Engineering, Vol. 8, No.7, pp 513-530, 2009jmmce.org Printed in the USA. All rights reserved

[5] 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(An ISO 3297: 2007 Certified Organization) Vol. 3, Issue 7,July

2014.

[6] B. Suresha, G Chandramohan, P R Sadananda Rao, P Sampathkumaran, S Seetharamu & Varatha venkateswarlu, " Friction and slide wear characteristics of glass-epoxy and glass-epoxy filled with SiCp composites" Indian Journal of Engineering and Material Sciences.

[7] Kishore, P.Sampathkumaran, S.Seetharamu, Vyantheya, S.Murali and R.K. Kumar, SEM observations of the effect of velocity and load on the slide wear characteristics glassfabric- epoxy composites with different fillers, wear, 237 (1), (2000) 20-27.

[8] V.K.Srivastava, and J.P.Pathak, Friction and wear properties of bushising bearing of graphite filled short glass fiber composites in dry sliding, Wear, 197 (1-2) (1996) 145- 150.

[9] Kishore, P.Sampathkumaran, S.Seetharamu, P.Thomas, and M. Janardhana, A study on the effect of the type and content of filler in epoxy-glass composite system on the friction and wear characteristics, Wear, 259 (1-6), (2005) 634-641.

[10]Vithal Rao Chavan et al, Effect of The Tribological Behaviour of Hematite Filled Hybrid Composites – A Taguchi Approach International Journal of Engineering Research And Advanced Technology, Special Volume. 02 Issue.01, May-2016, ISSN: 2454-6135.

[11] V Algur, et al, Analysis of Wear Behaviour of a Heat Treated Modified ZA-27 Alloy by Taguchi Technique. Int Jour of Rec and Innov Trends, 2 (2014).

[12] Veerabhadrappa Algur, V et al, Optimization of Friction performance of a Heat Treated Modified ZA-27 Alloy Using Design of Experiments. International Journal of Current research, 7 (2015) 11526-11533.