Sliding Wear Analysis of Pultruded Glass Fiber Polyester Composites

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Abstract: **The present article describes the effect of operating parameters like load, speed and sliding distance of the wea response of glass fiber reinforced Polyester composites (GFPC). 75% unidirectional glass fibers adhere with 25% Polyeste resin by Pultrusion technique. Taguchi design of experiments with L_{16} orthogonal array is used to optimize the parameter with respect to load, sliding distance and speed. Dry sliding wear analysis was carried out on a pin on disc machine for th specimens as per the ASTM G99 standard. Results revels that Tribo performance of the GFPC depends on the tes parameters and conditions. Load is the most influenced parameter followed by speed and sliding distance.**

Key words: Composite, Wear, Friction, Pultrusion, Pin on Disk (POD), Glass fiber Polyester composite (GFPC)

I. INTRODUCTION

Tribology deals with the study of friction, wear and lubrication effect between two rotating bodies. Tribologica characterization of a material deals with wear and friction properties of materials at different operating parameters an material parameters. The most influenced operating parameters are load, sliding distance, sliding velocity an temperature while the most influenced material parameters are Fiber weight fraction, fiber length, fiber orientatior filler content etc.

Friction is the resistance to motion whenever one solid body moves over another. It is one of the oldest problems i physics and is of great practical importance in many industrial operations [1]. Wear is defined as progressive loss c material between two interactive surfaces when they are in relative motion. Tribological failure, such as wear an friction related failure leads to heavy cost to the industry. There is a need to replace the conventional material b composite materials which can perform in the stringent conditions like high load, high temperature, corrosive and hig pressure. The concept of composites has come into existence with this thought.

A composite consists of three main groups of tribo- materials, such as polymer matrix composites (PMCs), metal matri composites (MMCs), ceramic matrix composites (CMCs). Among the three groups of tribo-materials PMCs hav shown immersed potential, mainly because of their self-lubricating properties, light weight and resistance to wea corrosion and organic solvents [2].

There are a number of researches done on fiber reinforced composite material under different operating parameters an material parameters. Charanjit Singh & Lakhavir Singh (2012) [3], has worked on the tribological characterization c Al- SiC composite. The material developed by the Powder Metallurgy method instead of casting. Wear testing done o Al- SiC composite on a pin on disc machine under different load and filler concentration; it is observed that Si contents were able to improve the wear rate of Al composite. D.K. Kolluri et al. (2007) [4], has worked in graphit filled phenolic composite, where natural and synthetic graphite with small, medium and long particle sizes wer studied. The wear study was done with pin on disc under different temperature, load, and particle size. The result of th study reveals that increase in load coefficient of friction increase. Also, as temperature increase wear rate increas irrespective of load and particle size.

A.A.El Sayed et al. (1995) [5], worked on Jute and Linen fiber with unsaturated polyester resin which used for bearin application. The result reveals that for a normal orientation wear rate declined to increase in the fiber volume fraction.

C.W.Chin & B.F Yousif (2009) [6], worked on kenaf fibers and observed the effect of orientation of fiber und different operating conditions.

Chittaranjan Deo & S. K. Acharya (2010) [7], performed a wear test on Lantana camara fiber reinforced polymer matri composite and studied its tribological characteristics and proved that fiber volume fraction has an adequate effect c wear rate of the material.

El Tayeb (2008) [8], has done the comparative study of wear rate of glass fiber and natural fiber reinforced composit and proved that the wear rate of natural fiber is lesser compare to the glass fiber.

L. Boopathi et al. (2012) [9], evaluated the effect of Fiber Length on Tribo performance of Borassus Fruit fib reinforced Epoxy composites under different operating conditions. B F Yousif et al. (2009) [10] and B F Yousif et a (2009) [11], have investigated on the tribological characteristics of coir fiber and oil palm fiber reinforced polyest composites respectively. Both have come to the same conclusion that surface treatment of the fiber has great effect c controlling the wear rate.

In the present investigation glass fiber polyester resin used to study the Tribo properties of the material.

II. MATERIALS AND METHOD

A. Material

Fiber: Unidirectional Glass fibers were used because of high tensile strength [12].
Resin: Polyester is used as a resin material due to its low cost and ease of manufacturing.
The GFPC rod of diameter 12 mm procured from Dhanshree Impex, Nadiad. As per ASTM G 99 standard the specimen of length 30mm and diameter 12mm was cut from the long rod. Figure 1 shows the cut specimen for GFPC.

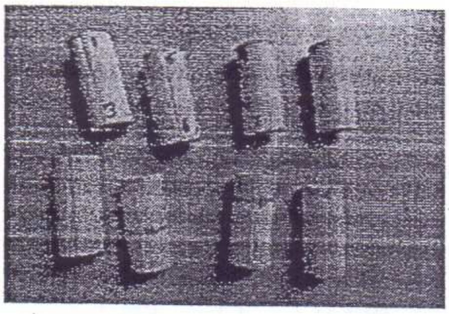

Figure1: Specimen for GFPC

B. Test Parameters

The wear analysis carried out by considering the effect of different most influencing operating parameters like sliding speed, load and sliding distance. Four levels are selected for each variable. The levels of these process variables are listed in the Table 1.

Table I Process Parameters with four different levels

Parameter	Level1	Level2	Level3	Level4
Sliding Dist. (m)	1000	1500	2000	2500
Load (kg)	1	2	3	4
Speed (RPM)	500	750	1000	1250

C. Design of Experiments

Design of experiments (DOE) is a systematic approach to reduce the number of experiments. In the present investigation three parameters each at four levels give 3^4, total 81 numbers of experiments. Taguchi approach is used with Minitab 16 software. Based on three parameters and each of four levels L_{16} orthogonal arrays selected. Total 81 experiments are represented by 16 numbers of experiments.

D. Sliding Wear Test

To evaluate the wear performance of composites under dry sliding condition, wear tests carried out on a Pin on Disc (POD) test rig (supplied by DUCOM, Bangalore). The counter body of the disc made of hardened ground steel (EN-31, hardness 60 HRC, surface roughness 0.6 m Ra). The Specimen is held stationary and the disc is rotated while a normal force is applied through a lever mechanism. Before each test, specimen surfaces prepared by rubbing over a 1000 SiC paper to provide proper contact with the counter surface. The surface of both the samples and disc cleaned with emery paper and with acetone before the test. The test setup used for the experimentation is shown in the Figure 2.

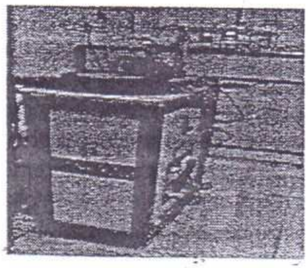

Figure 2: Pin on Disc wear test ring

All the experiments performed for 10 minutes and the wear results noted on Pin on Disc machine.

III. RESULTS AND DISCUSSION

A: Wear Data from Pin on Disc machine

Wear results for GFPC were noted from the POD machine and plotted in the table III.

Table III: Observed data from POD

SD	L	N	Wear(Micron)
1000	1	500	31
1000	2	750	27
1000	3	1000	10
1000	4	1250	30
1500	1	750	38
1500	2	500	23
1500	3	1250	28
1500	4	1000	14
2000	1	1000	37
2000	2	1250	34
2000	3	500	27
2000	4	750	10
2500	1	1250	42
2500	2	1000	34
2500	3	750	14
2500	4	500	12

B. Effect of operating parameters on wear

Figure 3 shows the effect of the main parameters on the wear. The figure reveals that wear is decreased with increasi a load, sliding distance and speed. Hence, these composites reflect good wear properties at higher loads and high spe condition. It may be due to the fact that at higher loads and speed there may be formed of a micro thin layer of transf film which may be reduce the amount of wear rate.

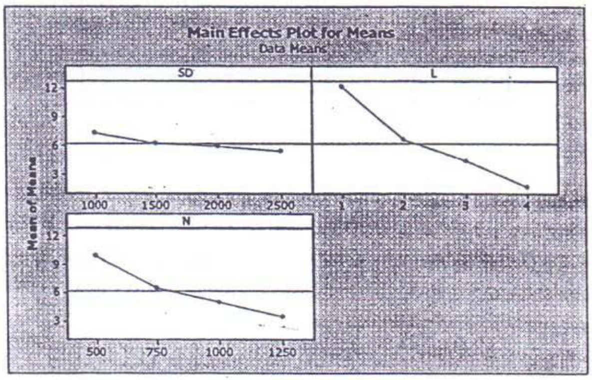

Figure 3: Effect of operating parameter on wear rate

Taguchi method provides Signal-to-Noise ratios (S/N), which are log functions of desired output, and it helps predicting the optimum. In the current analysis wear has to be minimized as a need of that signal to noise ratio set smaller is better, the value of S/N ratio can find from the expression 1.

$$N = -10 \, Log_{10} \text{[mean of sum of squares of measured data]} \quad (1)$$

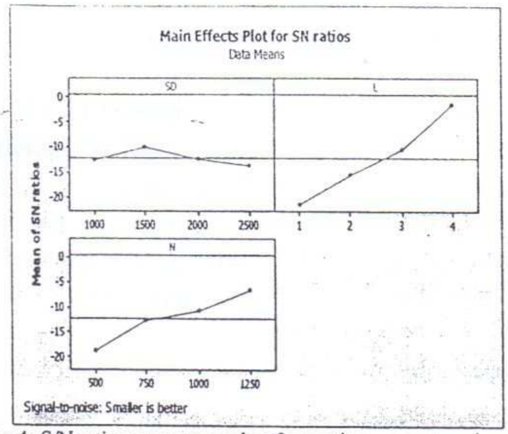

Fig 4: S/N ratio response graphs of operating parameter v/s wear

Figure 4 shows that minimum wear is obtained for sliding distance 1500 meters, load 4 kg, speed 1250 rpm.

Table IV: S/N ratio response table for wear

Level	SD	L	S
1	-12.668	-21.426	-18.958
2	-10.11	-15.505	-12.815
3	-12.488	-10.516	-10.696
4	-13.815	-1.633	-6.638
Delta	3.70	19.79	12.32
Rank	3	1	2

Table IV shows the S/N ratio response for GFPC, reveals that among all the factor load is the most influenced parameter for the wear followed by the speed, while the sliding distance has least effect on the wear.

The ANOVA done to identify the effect of individual parameters on the wear and plotted in the table V. It is observed from the Table V that the applied load is the most influenced parameter with almost 51% effect, Speed is second affecting parameter with 28.1 % contribution while the sliding distance has almost 17.5 % contribution on the wear.

Table V: ANOVA table for wear

Source	DF	Seq SS	Adj SS	Adj MS	F	% P
SD	3	58.059	58.059	2.686	1.52	17.5
L	3	168.425	168.425	79.475	45.02	51.01
N	3	93.099	93.099	31.033	17.58	2801
Error	6	10.592	10.592	1.765		3.2
Total	15	350.175				

Summary of Model

S = 1.32865 R-Sq = 96.98% R-Sq(adj) = 92.44%

IV. CONCLUSION

The following are the observation made from the above investigation.

- From the experiments, it is observed that increase, decrease or stabilization of wear depends on the formation of polyester film on the counterface.
- All the operating parameters have a significant effect on wear. Load is the most influenced parameter followed by speed and sliding distance has minimum effect on wear rate..
- GFPC reflects good wear resistance at high load and high speed condition.

The current concept of these experimental results can be used in the future to design different tribological and mechanical components. In addition to the operating parameters, material parameters like fiber length, fiber volume fraction, fiber orientation can also vary and one can find the effect on wear.

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