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Effect of Various Particle Sizes of Filler on Dry Sliding Wear Behavior of Fiber Reinforced Polymer Matrix Composite

Akshatha B S
Department of Mechanical Engineering
VTU Belgaum, AT, Chikkamagalore

Dr. Thammaiah Gowda
Department of Mechanical Engineering
VTU Belgaum, AIT, Chikkamagalore

***Abstract*— Polymers and their composites are emerging as viable alternative products to metal-based and alloy-based ones in many common and advanced engineering applications. The feature that makes polymer composites so promising in industrial applications is the possibility of tailoring their properties with special fillers. Polymers matrix composites are extensively used in bearings, belts and brake pads applications.**

The slide wears characteristics of glass-epoxy composites with influence various particle size variations of silicon carbide particles (SiCp) will be studied using a pin-on-disc apparatus. The laminates will be fabricated by a hand lay-up technique. The tribological properties will be investigated in accordance with ASTM standards. Weight loss will be determined as a function of sliding distance, sliding velocity and applied loads.

Keywords—*Dry Sliding Wear; Polymer Matrix; Tribology; Sliding Distance; Sliding Velocity; Fibre Reinforced Composite*.

1.INTRODUCTION

Polymer matrix composites are being utilized for different designing and modern applications, for example, flying machine parts, cars, wearing merchandise and so forth. Tribological utilizations of polymer framework composites have recognized for applications, for example, gears, orientation, belts, brake cushions and so forth.

New applications are additionally being endeavored where polymers can supplant the customarily utilized material, for example, metals and its compounds. Glass fiber is utilized as strengthening material with epoxy as a grid material. Filler materials are often added to polymer matrix composites to improve the mechanical properties of the network, fillers can enhance the wear resistance depending on the characteristics such as its shape and size.

In the present work an endeavor has been made to build up the mechanical and tribological properties of the polymer network composites. Fillers used are silicon carbide (SiC). The point of including the hard filler silicon carbide (SiC) to the delicate grid is to build the hardness of the material and abatement the wear rate. The part of silicon carbide (SiC) fillers in the polymer lattice composite has a strong ointment. The impacts of inorganic filler on the wear of glass-epoxy composite under dry sliding condition are explored utilizing pin-on-plate contraption. The wear normal for the composites is seen under fluctuating sliding rate, connected load and sliding separation.

In the previous five decades impressive consideration has been committed to composite materials. Matrix is adhesive binder that holds the fibre and transfers the load to the fibers. Matrix materials may be selected from metallic, ceramic and organic resin materials. The reinforcements are the structural constituents, giving high quality to the inner structure of the composite.

1.1 Classification of Composite materials

Composite materials can be ordered in a few routes, in view of the lattices, reinforcement and applications that include.

1. Polymer Matrix Composites (PMCs)
2. Metal Matrix Composites (MMCs)
3. Ceramic Matrix Composites (CMCs)

1.1.1 Polymer Matrix Composites (PMCs)

The most develop and broadly utilized composite frameworks are polymer framework composites (PMCs), otherwise called Fiber Reinforced Polymers (Plastics) which gives the real center to this work.

1.1.2 Metal Matrix Composites (MMCs)

In MMCs, pottery or metals are utilized as fortifications and metals as network material. The bond in the middle of fiber and network is as often as possible solid in metal grid composites, the most extreme interfacial shear anxiety is normally constrained by the metal's yield quality.

1.1.3 Ceramic Matrix Composites (CMCs)

In CMCs, the framework materials are ceramics and fortifications are either metals or earthenware production. CMCs are exceedingly cutting-edge materials and their utilization is limited to applications with other building applications are their absence of plastic conduct at room temperatures and their low resistance to imperfections

2. BACKGROUND AND RELATED WORK

Kishore et al., (2001) investigated the SEM features of glass fiber-epoxy composites subjected to sliding wear for distances ranging from 500 m to 6 km. They found out that there is an existence of noticeable features on the worn surfaces. Interface separation is noticed for the longer distance run specimen, while for shorter run specimen matrix debris formation and occasional glass fiber fragmentation are seen. They also highlighted the effect of load and sliding velocity on the wear loss pattern

Hasim et al., (2002) studied wear behavior of woven 300 and 500 glass fabrics and aramid fiber-reinforced composite materials for 500 and 710 RPM speeds and at two different loads of 500 and 1000 g using a block-on-shaft wear tester. They measured the weight losses at different sliding distance conditions. It was observed that the applied load on the specimens has more effect on the wear than the speed. Also the weight loss in the woven 500 glass fabric reinforced is more than that in the woven 300 glass fabric-reinforced composite. The weight loss of aramid fiber-reinforced composite is quite low compared with woven glass fabric-reinforced composites.

Yamamoto et al., (2004) demonstrated the friction and wear characteristics of fiber-reinforced PEEK and PPS in water using a face-contact sliding tester. They conclude that under boundary lubricating conditions, PEEK reinforced with glass fiber was little improved in friction and wear characteristics, since both PEEK and glass fiber had poor resistance to wear in water. On the other hand, with PPS the wear characteristics were considerably improved. They also described that the fiber aligned perpendicular to sliding direction exhibited higher wear resistance than those parallel to sliding direction.

Shyam (2000), have found when polymers slide against metal counter faces, transfer films are formed. This is also the case when sliding occurs between a polymer and another polymer. The transfer film formed on a non-polymer counter face is governed by the counter face material and roughness, and of course the sliding conditions. The growth of transfer film with the number of passes is presented and the effect of counter face roughness is examined.

He showed that when polymers are modified, such as by the addition of fillers, the transfer film affects the tribological behavior. Some filler affect the development of transfer film and enhance its adhesion to the counter face. Such fillers reduce the wear rate of polymer, often drastically. On the other hand, there are many types of filler which have no such effect on the transfer film and wear in these cases is increased.

Dieter et al., (2006) in their experimental study reported that friction and wear behavior of gross slip fretting tests under unlubricated conditions at room temperature against steel ($100Cr_6$) and ceramic (SiC). Tests with a ball-on-disk contact were performed in laboratory air with different content of water vapour. The results show clearly that the relative humidity has a significant effect on friction and wear behavior. All tests in dry air lead to higher friction and higher wear rate than in normal air.

3. OBJECTIVES

1. To fabricate the polymer matrix composite with fillers Silicon Carbide.
2. To perform wear test by shifting the parameters, for example, sliding speed, connected load and sliding separation.
3. The wear properties of plain glass-epoxy composite are also evaluated under dry sliding condition.
4. To perform wear test by varying the particle size of the Silicon Carbide.
5. The wear test results are analyzed by using scanning electron microscope (SEM).

4. METHODOLOGY

4.1.3 Design and fabrication of polymer matrix composite

Taking into account the composite outline the example must be manufactured by utilizing hand lay-up procedure. The best possible volume part of strands, epoxy, fillers and introduction of filaments are to be controlled. The overlays are cured for a time of around 24 hr. At that point the specimen is slice to an obliged size for the tests.

4.1.3 Wear properties testing

Wear test are to be directed according to ASTM G99 gauges utilizing pin-on-plate testing machine. The wear rate of the composites will be considered with changing the diverse test parameters like connected burden, sliding velocity, sliding separation, rate of support and filler materials.

4.1.4 Results Analysis

The ragged surface of the composites will be investigated by utilizing checking electron magnifying instrument (SEM).

5. MATERIALS AND EXPERIMENTATION

To study the dry sliding wear conduct of polymer network composites, different experiments have to be conducted. The matrix and the reinforcement material used for fabrication of composites are discussed.

5.1 MATERIALS

5.1.1 Reinforcement material

Fortresses can be both normal and man-made. Most business fortresses are synthetic. Instead of basic metal materials, filaments have anisotropic properties. High modulus and quality in one heading is joined by just restricted quality in the parallel measurement.

5.1.2 Glass fiber

The most ordinarily utilized essential materials for fortified plastic are E-glass filaments. They are additionally utilized as a part of a considerable measure of different applications, going from information transfers to protection materials. The fortification utilized as a part of this study is 7-mil E-glass fiber.

Table 5.1 Properties of E-glass fiber

Density (g/cm^3)	2.48
Tensile strength (MPa)	3448
Modulus of elasticity (GPa)	72.4
Poisson’s ratio	0.19

5.1.3 Matrix material

To utilize great and solidness of strands in a composite material suitable for outlining applications, fibers are bound with a structure material whose quality and robustness are, regularly, much lower than those of fibers. Framework materials give the last condition of the composite structure and manage the parameters of the gathering method.

Table 5.2 Properties of Epoxy resin

Density (g/cm^3)	1.29
Modulus of elasticity (MPa)	3200
Tensile strength (MPa)	89.6
Poisson’s ratio	0.35

5.1.4 Filler materials

Filler materials lessen the expense of the composites, as well as meet execution prerequisites, which couldn't have been accomplished by utilizing fortification and tar fixings alone. Filler can enhance mechanical properties including fire and smoke execution by decreasing natural substance in composite covers. Additionally, filled gums recoil not exactly unfilled pitches, along these lines enhancing the dimensional control of shaped parts. Essential properties, including water resistance, weathering, surface smoothness, solidness, dimensional dependability and temperature resistance, can be moved forward. Filler materials used in the glass-epoxy composite is inorganic fillers such as silicon caride particles (SiC) that passed through 4 and 7 microns.

5.1.4.1 Silicon Carbide

Silicon Carbide extremely hard abrasive was the first of the synthetic abrasives to be produced. Silicon Carbide is the only chemical compound of carbon and silicon. Silicon Carbide is extremely hard and brittle particles are sharp and they break to form new sharp particles. Today the material has been developed into a high quality technical grade ceramic with very good mechanical properties and lighter in weight. SiCp are high strength, high hardness, high elastic modulus, excellent thermal shock resistance and superior chemical inertness. Due to these properties silicon carbide has a great potential for use in tribological applications.

Table 5.3 Properties of Silicon Carbide

Density (g/cm^3)	3.2
Young’s modulus (GPa)	200-300
Maximum operating temperature (^{o}C)	600
Poisson’s ratio	0.16-0.18

Table 5.4 Details of specimen prepared SiCp size of 4 microns

Sample code	Matrix	Volume %	Reinforcement	Volume %	Fillers	Volume %
1	Epoxy	45	Glass fiber	50	SiCp	5
2	Epoxy	40	Glass fiber	50	SiCp	10

Table 5.5 Details of specimen prepared SiCp size of 5 microns.

Sample code	Matrix	Volume %	Reinforcement	Volume %	Fillers	Volume %
1	Epoxy	45	Glass fiber	50	SiCp	5
2	Epoxy	40	Glass fiber	50	SiCp	10

6. RESULTS AND DISCUSSION

In the present study, the dry sliding wear test investigations were done on glass-epoxy composites to study the impact of filler SiC. In this part the outcomes were indicated and discussions were made for the got results.

6.1 WEAR BEHAVIOUR OF SILICON CARBIDE G-E COMPOSITES

Effect of sliding velocity, connected load and sliding separation on dry sliding wear conduct of glass-epoxy with SiC filler composites are discussed in the following section.

6.1.1 Effect of sliding velocity

Table 6.1 shows the result of variation of weight loss against speed with constant load and sliding distance for particle size of 4 microns.

Variation of weight loss against speed with constant load and sliding distance.

Particle size in %	Speed RPM	Sliding distance Time	Load (N)	Wt loss in gms
0%	94	7.15	45	0.00080
	156			0.00092
	219			0.00107
	281			0.00125
	344			0.00130
5%	94	7.15	45	0.00080
	156			0.00085
	219			0.00090
	281			0.00095
	344			0.00100
10%	94	7.15	45	0.00080
	156			0.00090
	219			0.00100
	281			0.00110
	344			0.00120

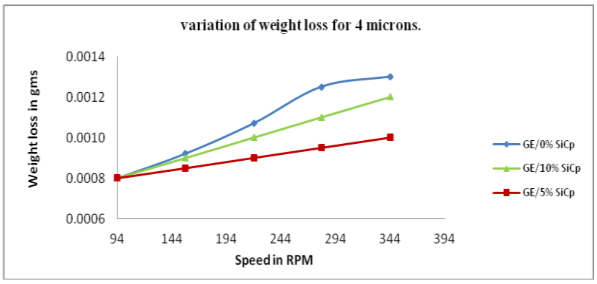

Fig.6.1 Variation of weight loss against Sliding speed (velocity) at consistent applied load of 45 N and at a sliding separation (time) of 7.15 (min) for a molecule size of 4 microns.

Fig.6.1 shows a comparative plot of the filled and unfilled glass-epoxy composites for sliding velocity (speed) range from 94 to 344 RPM at steady connected of 45 N and sliding separation (time) of 7.15 min. At the point when the sliding speed is low, it is watched that the weight reduction is less and there is a continuous increment with expansion in sliding speed.

6.1.2 Impact of the load applied

The impact of connected heap of filled and unfilled glass-epoxy composites under dry sliding conditions is exhibited in Fig.6.2. The connected burden is differed from 15 to 75N, at consistent sliding (speed) and sliding separation (time) 218 RPM and 7.15min separately. It is seen from the Fig.5.2, weight reduction of filled and unfilled glass-epoxy composites under dry sliding condition increments to the most extreme worth when the connected burden is 75N.

Table 6.2 shows the result of variety of weight reduction against load with constant speed and sliding distance for particle size of 7 microns.

Variation of load with constant speed and sliding distance 7 microns

Particle size in %	Load (N)	Sliding distance (Time)	Speed (RPM)	Wt loss in gms
0%	15	7.15	218	0.0005
	30			0.0007
	45			0.0008
	60			0.0010
	75			0.0011
5%	15	7.15	218	0.0001
	30			0.0002
	45			0.0002
	60			0.0003
	75			0.0004
10%	15	7.15	218	0.0001
	30			0.0003
	45			0.0004
	60			0.0005
	75			0.0007

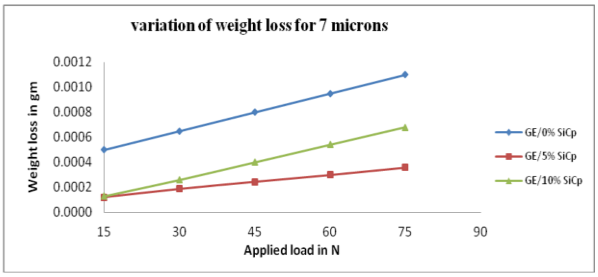

Fig.6.2 Variation of weight loss against applied load at constant sliding distance (time) of 7.15 (min) and Sliding velocity (speed) of 218 RPM for a particle size of 7 microns.

5.2.3 *Effect of sliding distance*

Fig.6.3 shows variety in weight reduction against sliding separation, sliding speed (pace) of 218 RPM and at a applied load of 45N. This uncovers that composite having filler has less weight reduction. It is additionally seen that the weight reduction fundamentally increments with increment in sliding separation.

Table 5.5 shows the result of variety of weight reduction against sliding separation with consistent load and pace for molecule size of 4 microns.

Variation of sliding distance with constant load and speed				
Particle size in %	Sliding distance (Time)	Speed (RPM)	Load (N)	Wt loss in gms
0%	5.550	218	45	0.0011
	6.600			0.0035
	7.145			0.0048
	7.406			0.0054
	7.570			0.0058
5%	5.550	218	45	0.0022
	6.600			0.0040
	7.145			0.0040
	7.406			0.0043
	7.570			0.0045
10%	5.550	218	45	0.0004
	6.600			0.0016
	7.145			0.0022
	7.406			0.0025
	7.570			0.0027

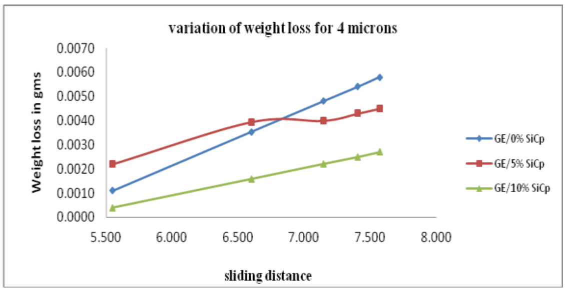

Fig.5.5. Variation of weight loss against sliding separation at consistent sliding speed (rate) of 218 and at a connected heap of 45N for a molecule size of 4 microns.

6.2 *Discussions*

When the glass-epoxy composite system is subjected to the dry sliding wear, it is observed that there is an increase in weight loss with the increase in sliding velocity and applied load and the same illustration was also evidenced by Kishore et al., and Suresha et al (2007). From the obtained results it is revealed that the wear loss increases with increase in sliding velocity irrespective of the load employed. Addition of SiC filler in the composite not only reduces the voids but also increases the strength and wear resistance. Wear occur primarily at asperity tips either as abrasion or micro fracture. This generates subsurface inter granular cracking and leads to subsequent grain pullouts. These grain pull outs forms three body abrasives wear between the sliding couple, causes ploughing and readily penetrates the polymeric surface, which begins to operate an emery cloth. This in turn results in increasing the weight loss of the composites. The composite filled with 5% vol. SiC gives a considerably higher wear resistance. Some of the features of worn surface are illustrated in SEM micro graphs taken at the central region, for selected specimen.

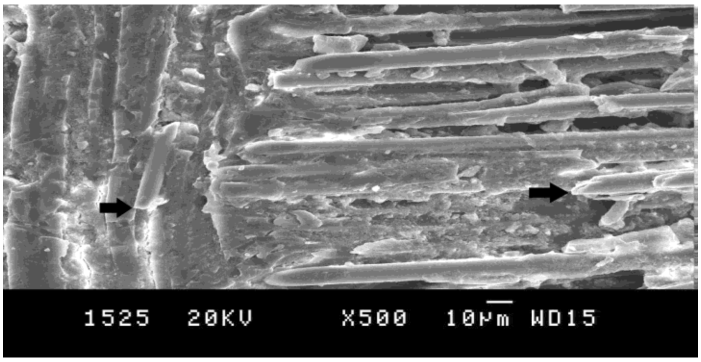

Plate.6.1 SEM micrograph of specimen 0 vol % fillers at 45N, 7.15 min and 344 RPM.

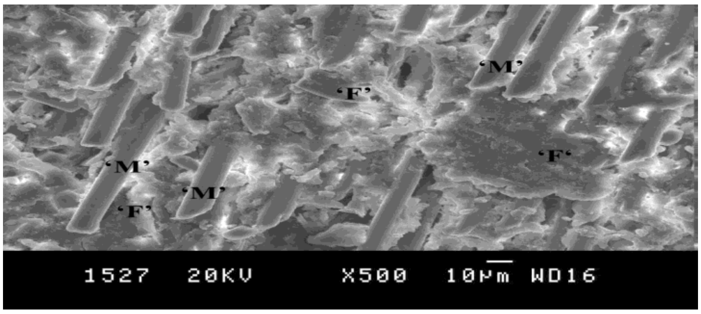

Plate.6.2 SEM micrograph of specimen 0 vol % fillers at 75N, 7.15 min and 344 RPM

Plate 5.1 and 5.2 represents the worn surface features of glass-epoxy composite subjected to increasing applied load 45N, at constant sliding velocity (speed) and sliding distance 344 RPM and 7.15 min respectively. From the Plate 5.1 it can be noticed that, there is a formation of debris on the fibers in both transverse and longitudinal fibers. And also it can be observed that few of the broken fibers in the SEM (as indicated by blacked arrow). The test specimen subjected to still higher applied load of 75 N at 7.15mins and 344 RPM is shown in plate 5.2.

7. CONCLUSIONS

The accompanying conclusions can be drawn from the test study on wear conduct of glass-epoxy composite and glass-epoxy composites loaded with SiCp.

1. Intrusion of different volume percentage of SiCp particles in G-E composite exhibits better wear resistance.
2. The incorporation of 5 vol % SiCp particles in glass-epoxy composite shows better wear resistances compared to 10% SiCp.
3. The rupture of the surface reflects characteristically the effect of applied load during dry sliding wear experiment.
4. It is observed that there is a gradual variation in the matrix of specimen from continuous mass form to small debris formation at the application of lower loads.
5. At higher applied loads, it is observed that there is a separation interfaces before debris gets detached which leads to a greater amount of weight loss in the specimen.
6. A grain size particle of SiCp significantly effect for wear applications.
7. The weight reduction diminishes at lower connected loads because of a diminishment in the between consideration separation of particles, which prompts lower densities and littler grid grain sizes for composite with SiCp size of 4 and 7 microns SiCp filled glass-epoxy composite decreased the wear at higher connected loads successfully.

8. SCOPE FOR FUTURE WORK

The work presented in this study can be expanded and enhanced by undertaking the following tasks.

1. Further study can be extended by varying the volume fraction of matrix, reinforcement and fillers.
2. In the present experimental study work silicon carbide particles are simultaneously used in the single composite. An attempt may be made by using nano particles.
3. In this present experimental study only one inorganic filler component is used, it may be extended by using some more inorganic fillers.

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