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Investigations of tribological and mechanical properties of copper filled epoxy composites

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Abstract—**The tribological and mechanical behaviour of copper filled epoxy composites is reviewed. The composites were casted at various volume fractions. Worn surfaces were studied with help of SEM images. The mechanical properties of commercial resin type have been investigated both unfilled and filled with varying weight fraction of copper particles.**

Key words: Glass mould, SEM images, flexural strength, wear.

I. Introduction

Composite materials (Composites) are defined as a structural materials created synthetically or artificially by combining two or more materials at macroscopic level having dissimilar characteristics. Polymer matrix composites are used increasingly in applications where friction and wear are important factors. Normally the parts manufactured from conventional materials exhibit low strength to weight ratio, high COF, and high loss of material due to wear. Hence, the estimation of tribological properties of PMC based on known system parameters and composite structure is often a difficult task. Thus there is a need for better understanding of how and why different type of reinforcements and compositions influence the tribological properties at different application like gears, cams, bearings, bushes, bearing cages, etc.

II. Raw materials

The matrix system used is a medium viscosity Epoxy resin (Lapox L-12), a room temperature curing polyamine hardener (K-6) and pure copper powder of size 44 µm is used as filler material supplied by Leo Chemicals, Bangalore, India

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III. Fabrication

The dimensions of the Glass mould used for producing the specimen slabs are of 200mm*180mm*5 mm. The photograph in fig 1shows the two halves of the mould. All slabs were fabricated in open glass mould technique. Pure copper powder with 44µm is used as the reinforcement, which is compatible to epoxy resin. The epoxy resin and copper powder were mixed with the hardener in the ratio 10:1by volume. This whole mixed composition was stirred to the duration of 8 minutes.

Mould is prepared by using materials of Teflon glass, transparent sheets, silicon rubber card (5mm sq cross section), and holding clips.

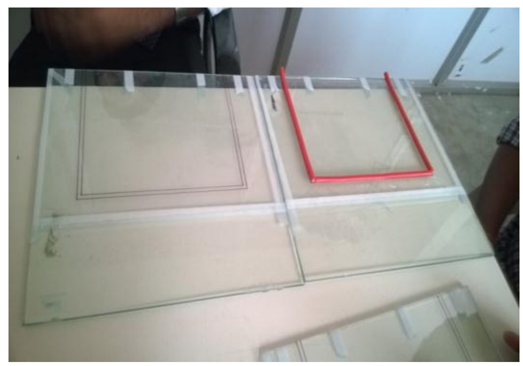

Figure 1. Two halves of mould

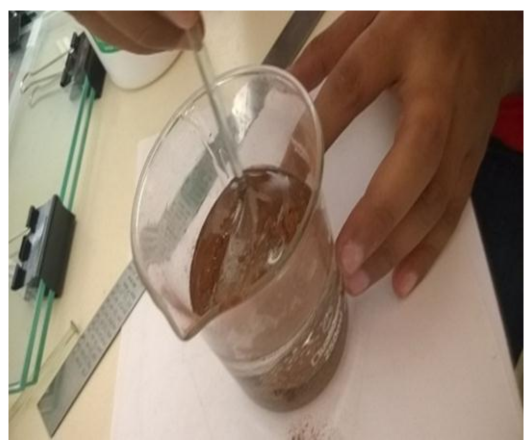

Figure 2. Mixing Epoxy-Copper with Hardener

Teflon glasses were cleaned by thinner solution then transparent sheets were stick on inner surfaces of the glasses. Requiredmould dimensions(200mmX180mmX5mm) is drawn on it by marker then silicon rubber card of 5mm thick is stick on that drawing by using glue. A releasing agent is applied on the both surface of the mould for easy removal of the composite and to obtain accurate surface finish. Both glasses are placed on the other with gap of silicon rubber card 5mm. This whole arrangement was held tight by tensioned clips. The mixture was then poured into the mould.

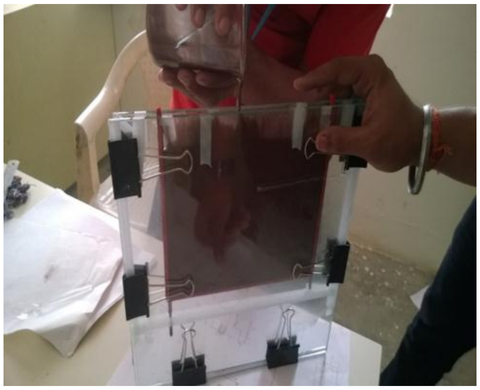

Figure 3. Pouring of Mixture in the Mould

Allowed to cure for 24 hours at room temperature and then curing is done in an electric oven at 50^{o}C for 4 hours. Specimens were prepared in 4 compositions by varying the copper content in matrix material. All compositions were shown in table I.

TABLE I. COMPOSITES DETAILS

Sample No.	Matrix	Filler	Copper wt (%)
1	Epoxy	---	---
2	Epoxy	Copper	2%
3	Epoxy	Copper	5%
4	Epoxy	Copper	10%

IV. Experimental details and Results

The following tests were conducted to study mechanical and tribological properties of composites.

A. 2-Body wear test
B. 3-Body wear test
C. Scanning electron Microscopy(SEM)
D. Tensile and Bending test
E. Hardness test

A. 2-Body Wear Test

2-body wear test was conducted with abrasive papers (SiC paper).This abrasion test is used in many practical applications to evaluate wear in devicessuch as, conveyor belt, tillage tools and wind blades. It's a complex process often involving high strain of soft material and plastic deformation and fracture of in micro scale volumes of the material.

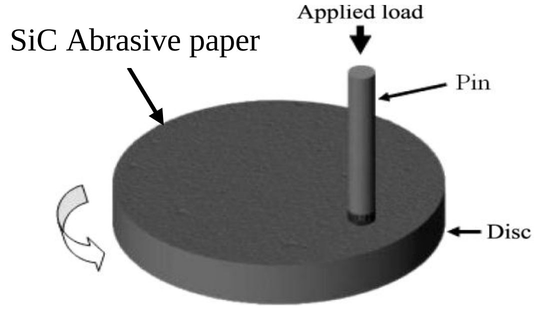

Figure 4. Rotating Disc with SiC paper

2-body wear test is conducted by using a Pin-on-Disk machine as per ASTM-G99. The dimensions of samples (5mmX6mmX25mm) as shown in figure 5.

Figure 5. Specimens for 2-body wear test

This comes in contact with silicon carbide (SiC) abrasive papers. The SiC paper is pasted on rotated steel disc by using a strong adhesive. The arrangement is shown in figure 4. For different abrading distance, new SiC abrasive paper has been used. The abrasion wear test was conducted on a track of 50mm radius. The composite specimens are abraded against 100 and 180 grit SiC papers at constant load of 10N at 200rpm and at four abrading distances (Distance from the center of the disc to pin) of from the centerat intervals of 25minutes. The specimen weight is recorded using an electronic balance. The difference between initial and final weight of specimen were measured as the slide wear loss.

With increase in abrading distance, wear loss increases linearly for two body abrasive wear.The copper powder as filler was observed to be beneficial to abrasive wear performance.

TABLE II. PIN-ON-DISC MACHINE SPECIFICATIONS

Specification	Range/Maximum limit
Speed	Up to 2000rpm
Diameter of track	42mm to 180 mm
Load range	200N maximum
Loading lever ratio	1:1 ratio
Disc size	Diameter 120mm*8mm thick
Pin size	8mm to 12mm
Software	MAGVIEW 2000
Wear	±2000µ to ±2µ
Frictional force	200N maximum

TABLE III. 2-BODY WEAR TESTING DATA SHEET

Distance(m)	Weight loss due to wear(gram)			
	Neat epoxy	2% Cu	5% Cu	10%Cu
25	0.177	0.141	0.168	0.137
50	0.166	0.159	0.168	0.155
75	0.146	0.138	0.128	0.186
100	0.154	0.133	0.169	0.182

Load applied:10N, Abrasive paper Grit Size: 100, Track radius: 50mm,Speed: 200rpm

TABLE IV. 2-BODY WEAR TESTING DATA SHEET

Distance(m)	Weight loss due to wear(gram)			
	Neat epoxy	2% Cu	5% Cu	10%Cu
25	0.095	0.092	0.077	0.079
50	0.092	0.086	0.083	0.083
75	0.131	0.138	0.166	0.129
100	0.144	0.121	0.141	0.1

Load applied:10N, Abrasive paper Grit Size:180, Track radius: 50mm,Speed: 200rpm

The higher copper loading (10% wt.) had better abrasion resistance as compared to lower wt. % copper filled epoxy composites and neat epoxy.

B. 3-Body Wear Test

The test samples were cut to size 70mm X 27mm X 6mm for three body abrasion test. Surface of the specimens are smooth.It's necessary to make it rough for ensuring the commencement of the wear, this is done rubbing of specimen by using emery paper. Before conducting the experiment all the specimens were weighed using electronic balancing instrument.

It's very essential to fill the sand into the hopper which is located above the rubber wheel. Apply the dead weight based on table which is supplied by manufacturer to loading span. Allow to setup the run with predetermine speed.

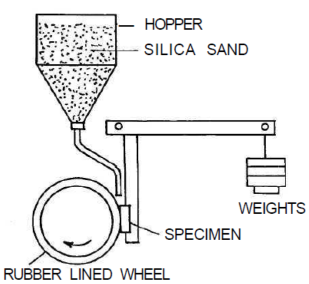

Figure 6. Schematic diagram of dry sand/rubber wheel abrasivewear test rig

3-Body Abrasive wear test is conducted by using a Dry Sand Abrasion Testing machine as per ASTM-G65. Samples of dimension (5mm X 27mm X 70mm) are prepared from the fabricated composites blocks. The composite specimens are abraded against a rubber disc of diameter 228.6mm and dry Silica sand, at constant load of 12N and 24N, 200rpm and at four abrading distances 250m, 500m, 750m and 1000m. Wear length of each specimen are calculated in terms of the experiment duration by using relationship of linear velocity and speed of rubber wheel. The specimen weight is recorded using an electronic balance. The difference between initial and final weight of specimen were measured as the slide wear loss.

Figure 7. Specimen for 3-body wear test

Figure 8. Dry Sand Abrasion Tester for 3-body wear testing

TABLE V. 3-BODY WEAR TESTING DATA SHEET

Distance(m)	Weight loss due to wear(gram)			
	Neat epoxy	2% Cu	5% Cu	10%Cu
250	0.056	0.048	0.028	0.019
500	0.064	0.058	0.035	0.025
750	0.091	0.087	0.059	0.045
1000	0.106	0.098	0.078	0.063

Load applied: 12N, Sand used: Dry Silica Sand, Disc dia: 228.6mm,Speed: 200rpm

TABLE VI. 3-BODY WEAR TESTING DATA SHEET

Distance(m)	Weight loss due to wear(gram)			
	Neat epoxy	2% Cu	5% Cu	10%Cu
250	0.145	0.125	0.070	0.050
500	0.175	0.160	0.120	0.062
750	0.242	0.225	0.150	0.143
1000	0.261	0.245	0.180	0.152

Load applied: 24N, Sand used: Dry Silica Sand, Disc dia: 228.6mm, Speed: 200rpm

With increase in abrading distance, wear loss increases linearly for three body abrasive wear.The copper powder as filler was observed to be beneficial to abrasive wear performance.

The higher copper loading (10% wt) had better abrasion resistance as compared to lower wt% copper filled epoxy composites and neat epoxy.

C. *Scanning Electron Microscopy SEM*

After wear test, the selected worn surfaces were examined using a scanning electron microscope (JSM 840A MODEL and JEOL make). Before the microscopic examination, a thin gold film was deposited on the surfaces to enhance the conductivity of the samples then photos were taken at specified magnification. The energy exchange between the electron beam and the sample, results in the emission of electrons and electromagnetic radiation which can be detected to produce an image.

Particularly SEM is used to study the worn surfaces including the debonding between the matrix and filler, configuration, distribution and direction of scratches or gauges as well as indication of preferential removal of specific particles or worn debris which can be viewed under. Wear track of 150 grit size is compared with fresh Sic paper with same magnification in order to know the particles pulled from Sic paper due to increase in wear resistance of copper composites. The frictional force is produced between these surfaces.

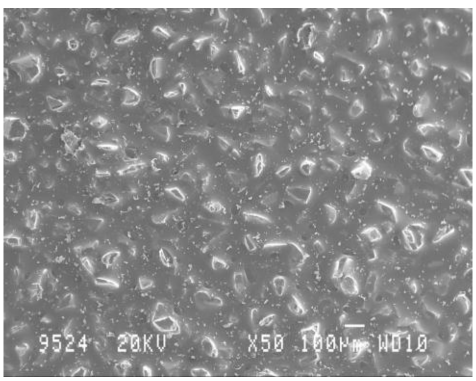

Figure 9. Emery paper with grit size of 150(a) 50X

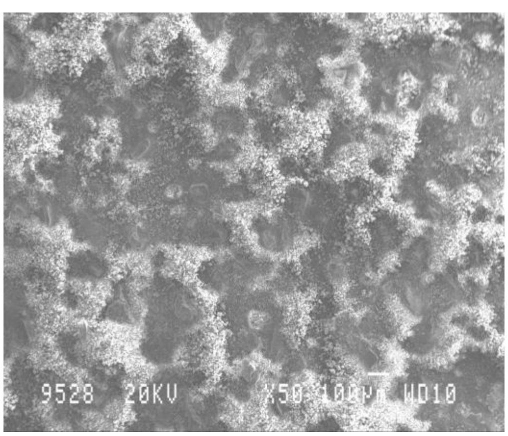

Figure 10. Wear track of neat epoxy with 15N and 250m of 150 grit size (a) 50X

The microscopyis done to study the shape and configuration of edges and to establish whether or not they have fractured during the wear process.

D. *Tensile and Bending Test*

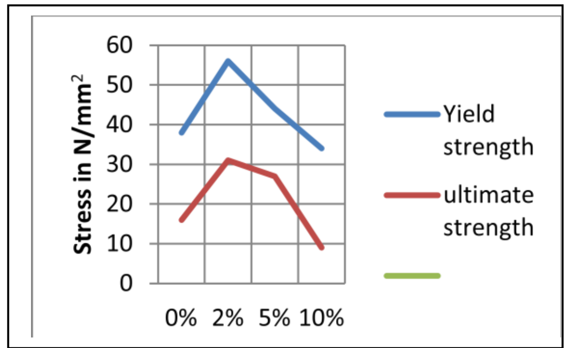

Figure 11. Tensile test graph

Behavior of the copper filled epoxy composite is plotted in the graph. After sensible load the specimen is start getting elongated linearly with increasing in load.

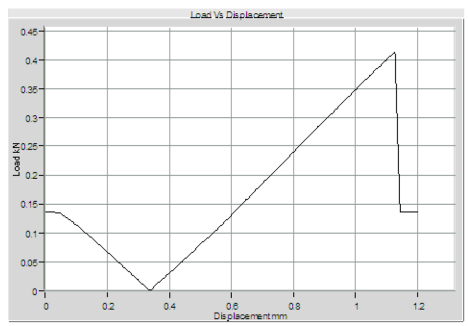

Figure 12. Bending test graph

Behavior of the copper filled epoxy composite is plotted in the graph. After sensible load the specimen is start getting elongated linearly with increasing in load. In load bearing property of the composite is increased upto 2 percentage of copper in composite.

Rockwell Hardness Test

Rockwell hardness test was carried out on unfilled and filled composites as per the standard IS: 1500-2005. Rockwell Hardness scale 'L' was used to evaluate the hardness of the specimens.

TABLE VII. HARDNESS MACHINE SPECIFICATIONS

Model	AI-RABI
Max Test Height	225 mm
Indenter	¼" Steel ball
Scale	L
Applied Load	80 kg

Figure 13. Specimen for hardness test.

Since the specimens were made of polymer material, the scale selected was L-scale with a ball indenter of 2.5 mm diameter.

TABLE VIII. ROCKWELL HARDNESS TESTING DATA SHEET

Composite Composition	Rockwell Hardness (HRL)
Neat Epoxy	55
2% Copper filled Epoxy	58
5% Copper filled Epoxy	64
10% Copper filled Epoxy	70

Load applied: 80kg, Scale: L, Dial: Red Indenter: 2.5mm Steel ball

Table VIII shows the hardness values of Copper-Epoxy composite. An increase in copper content increases the hardness of Cu-Ep composite.

Conclusion:

Increasing in the copper percentage in the epoxy is influence the wear resistance property of the composite, since its manufactured using the glass mould technique the surface finish of the slabs were good, can use as laminated blocks for wall and decorative light with different opacity by varying copper percentage. Mechanical properties like tensile, hardness and bending increased up to 2 percentage and load bearing ablity of the composite is decreased.

References:

1. F.W.Billmeyer, textbook of POLYMER SCIENCE, JOHN WILEY and sons 1994
2. V R Gowrikar, N V Vishwanathan, Jayadeva Sreedhar, POLYMER SCIENCE, New age international publishers, 2007.
3. R.V GADAG, A. NITYANANDA SHETTY, ENGINEERING CHEMISTRY, IK International Pvt Ltd.
4. Autar kaw- A text book on mechanics of composite materials
5. Afaghi-Khatibi, A. and Mai, Y.W. “Characterization of fiber/matrix interfacial degradation under cyclic fatigue loading using dynamic mechanical analysis”, Compos. A., Vol. 33, pp. 1585-1592, 2002.
6. Ahmed, A. and Jones, F.R. “A review of particulate reinforcement theories for polymer composites”, J. Mater. Sci., Vol. 25, pp. 4933-4942, 1990.
7. Anand Chairman, C., Kumaresh Babu, S.P., Muthukannan Durai Selvam and Balasubramanian, K.R. “Investigation on two-body abrasive wear behavior of titanium carbide filled glass fabric-epoxy composites-a Box-Behnken approach”, Int. J. Eng. Sci. Technol.Vol. 3, No. 4, pp.119-29, 2011.
8. Archard, J.F. “Contact and rubbing of flat surface”, J. App. Phys.,Vol. 24, pp. 981-985, 1953.
9. ASTM G99-05, “Standard test method for wear testing with a Pin-ondiskapparatus”, 2010.
10. Autar Kaw, K “Introduction to composite materials” in Mechanics of composite materials, CRC Press, London, 1996.
11. Bahadur, S. and Gong, D.L. “The role of copper compounds as fillers in the transfer and wear behaviour of polyetheretherketone”, Wear, Vol. 154, pp. 151-165, 1992.
12. Bahadur, S. and Zheng, Y. “Mechanical and tribological behavior of polyester reinforced with short glass fibers”, Wear, Vol.137, pp. 251-266,1990.
13. Basavarajappa, S., Ajith, G. Joshi., Arun, K.V., Praveen Kumar, A. and Prasanna Kumar, M. “Three-body abrasive wear behaviour of polymer matrix composites”, Poly. Plast. Technol. Eng., Vol. 49, pp. 08-12, 2010. 156
14. Bhushan, B. and Gupta, B.K. “Hand book of Tribology: materials, coatings and surface treatments”, McGraw-Hill Publications, New York, 1991.
15. Chand, N., Naik, A.M. and Neogi, S. “Three-body abrasive wear of short glass fiber polyester composite”, Wear, Vol. 242, pp. 38-46, 2000.
16. Cirino, M., Friedrich, K. and Pipes, R.B. “The abrasive wear behavior of continuous fiber polymer composites”, J. Mater. Sci., Vol. 22, pp. 235-247, 1987.
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