Wear Behavior of TiO_2 and WC Reinforced Epoxy Resin Composites

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Abstract - *The comparative study of wear resistance and hardness of Titanium dioxide (TiO_2) and Tungsten carbide (WC) reinforced epoxy resin composites has been examined. Tio_2 and WC added in the epoxy matrix in three different volume proportions (0%, 5% and 10%). Specimens were fabricated by hand layup technique by pouring epoxy resin and reinforcement mixture in wooden moulds. Wear and (shore-D) hardness test were performed as per the ASTM G99-95a and ASTM D 2240 standard. Wear resistance of specimen was checked on pin on disk set up by varying load and speed of disk. From results it was observed that both reinforcement in epoxy resin results in lower wear rate compared to pure epoxy. Load on specimen and sliding speed of disk has greater influence on wear rate of specimen.*

Key Words: Wear rate, Hardness, Pin on Disk, Shore D, ASTM,

1. INTRODUCTION

Composite materials are engineered materials they are combination of two different materials which has significantly different mechanical and chemical properties. One is in matrix phase while other is in reinforcing phase. These reinforcement are in different forms, fiber reinforced polymer composites are commonly used composites in aircraft and automobiles because of light weight and high stiffness. Metal matrix composites shows a good wear resistance compared to polymer composites. Dry sliding wear behavior of aluminium matrix reinforced with rice husk ash and silicon carbide particles hybrid composites shows that it has a higher wear resistance compared to unreinforced matrix. Ceramic particle reinforcement in conventional metal matrix were proved as one of the promising reinforcement to increase tribological properties of matrix phase [1]. Polymer composites are also used for wear applications. Tribological properties of carbon fiber reinforced epoxy composite was modified by adding alumina filler in it. Fillers such as MoS_2, CuO, CuS, Al_2O_3, graphite, tungsten carbide, silicon carbide and other ceramics and metal oxides were used as secondary fillers to enhance wear behavior [2]. Effect of silicon carbide and graphite fillers on glass fiber reinforced epoxy resin composites shows increased wear resistance characteristics compared to unfilled composites. Wear behavior was checked on the pin on disk set up varying loads and speed of disk [3]. Graphite filled glass-epoxy composites were emerged as a viable alternate material for metals and alloys. Wear behavior of polymer matrix composites were tailored by adding graphite filler in it [4]. SiC and graphite particles filled polymer matrix composites has also proven as one of the best wear resistance material. Effect of wear parameters like load on specimen, sliding speed of disk and sliding distance on mass loss was studied by taguchi approach and results shows that. SiC and graphite fillers increase wear resistance of polymer matrix composites and load and sliding distance are important factors influencing the wear rate of materials [5]. Basalt reinforced polyester resin composite shows a very uniform wear resistance. For some volume fraction there is slight decrease in wear rate of materials. Particle size of basalt powder also has influence on the wear resistance of composites [6]. Glass-epoxy composites with HTBN rubber and graphite filler at different levels shows increased wear resistance. Coefficient of friction goes on increasing with load and decrease with increasing sliding velocity. Graphite filled glass-epoxy composite shows lower wear rate than HTBN rubber [7].

From survey of various papers it is observed that materials like graphite, basalt and some ceramic materials like silicon carbide, boron carbide added in polymer matrix composites shows increased wear resistance than unfilled polymer matrix composites. In present study tungsten carbide and titanium dioxide were reinforced in epoxy matrix to study effect of these reinforcement on wear rate of epoxy resin. Specimens were fabricated by hand layup technique. Wear rate was checked on pin on disk set up.

2. EXPERIMENTAL

2.1 Materials

For present study epoxy (Lapox T 22) resin and K6 hardener were selected as matrix system. It is supplied by Atul Ltd. Gujrat. The TiO_2 was obtained from Fisher Scientific, Mumbai. WC was obtained from Reliable Bearing Company, Mumbai. Properties of TiO_2 and WC are shown in table 1 and 2.

Table-1: Properties of TiO_2

Sr. No	Properties	
1	Molar mass	79.866 g/mol
2	Appearance	White solid
3	Density	4.23 g/cm3
4	Melting point	1800 ^{0}C
5	Tensile Strength	333.3 MPa
6	Young's Modulus	230 GPa

Table-2: Properties of WC

Sr. No	Properties	
1	Chemical Formula	15.25 Mg/M^3
2	Density	350 GPa
3	Bulk Modulus	350 GPa
4	Tensile strength	370 MPa
5	Young's Modulus	600 GPa

2.2 Fabrication

Fillers such as TiO_2 and WC were added to the epoxy resin in three different weight percentages (0%, 5%, and 10%). and stirred in a glass beaker. Stirring is done manually and it was continued till the particles get dissolve in resin. After that K6 hardener was added to the mixture for curing. Hardener and epoxy ratio was 1:10. Hardener was added slowly by continue stirring. Following table shows different specimen's matrix and filler content. After adding hardener to the epoxy resin mixture is poured into the wooden moulds to which wax and release agents was applied. Curing time is 24 hr. at room temperature. After curing specimens were removed from molds. Specimen pin has Dia. of 8 mm and length of 30 mm as per set up requirement and ASTM standard.

Table-3: ASTM Standards

Sr. No.	TEST	ASTM
1	Wear Test	G 95-99a
2	Hardness Test	D2240

Table -4: Specimen composition

Sr. No.	Epoxy (Wt. %)	Titanium Dioxide (Wt. %)	Tungsten carbide (Wt. %)
1	100	0	-
2	95	5	-
3	90	10	-
4	95	-	5
5	90	-	10

2.3 Wear Test

Wear test of specimens was carried out on pin on disk set up. It is used for investigation of dry sliding wear characteristics of materials. Surface of pin specimen comes in contact with hardened disc of hardness 62 HR_C. Disc was made up of En 32 steel with surface roughness 0.84 µm. Test was conducted on a track of 120 mm diameter [3]. Test was conducted at two different sliding speeds (2 m/s and 3m/s) and at three different loads (1 kg, 2 kg, 3 kg) sliding distance is 1000 meter for all specimens. Before the test specimens were cleaned with soft paper soaked in acetone. Pin specimens were weighted on digital weighing machine (0.001 gm accuracy). After test specimen pins were removed and again weighted. Difference between initial and final weight is a measure of wear rate of specimen. Total six experiments were conducted for each type of composition. Wear rate is given by following formula.

$$\text{Wear rate} = \frac{\text{Weight Loss}}{\text{Sliding Distance}} \text{ gm/cm} \quad [8].$$

Where,

Weight loss = initial weight - Final Weight

Sliding Distance = 2 π r n t

n = RPM of disk

r = track radius

t = test time (sliding speed x sliding distance)

2.4 Hardness Test (Shore-D)

Shore D hardness test is used to determine indentation hardness of the polymer matrix composites. Indentation hardness is determined by the durometer. Durometer is a device used to determine the indentation hardness of rubbers and elastomers and polymer composites. It usually consist penetration of indenter into specimen under predetermined spring load. Hardness numbers are derived from scales.

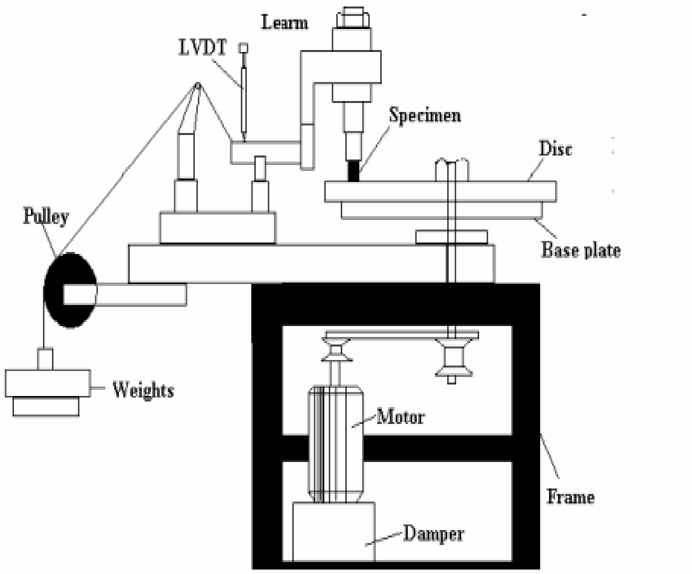

Figure-2: Schematic arrangement of pin on disk set up.

Figure-2: Shore- D hardness tester

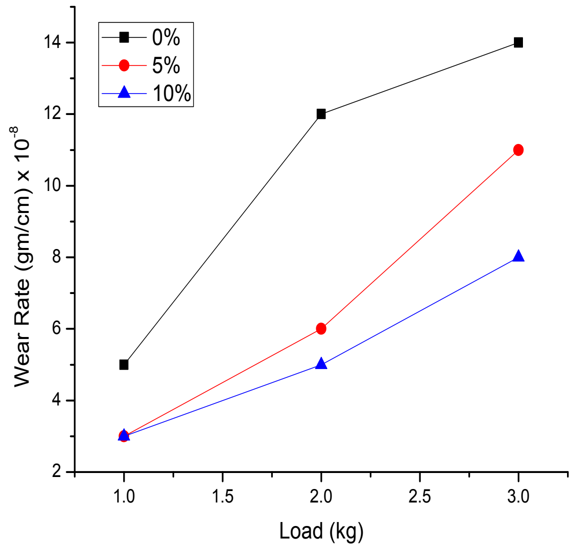

Figure-3: Graph for Wear Rate of Epoxy + Tio_2 at 2 m/s

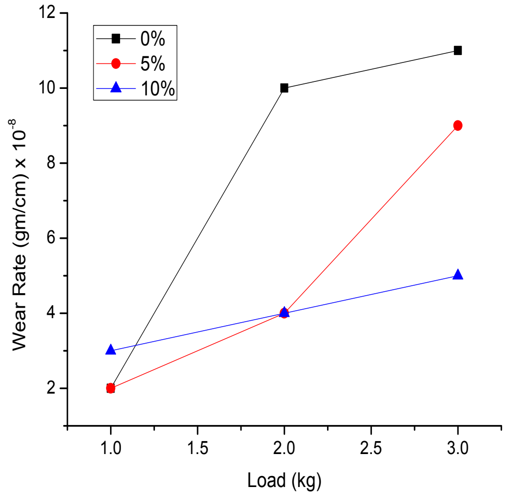

Figure-4: Graph for wear rate of epoxy + Tio_2 at 3 m/s

3. RESULTS AND DISCUSSION

3.1 Wear Test

Figure3 shows a wear rate of TiO_2 reinforced epoxy composites. From graph it is observed that TiO_2 filled epoxy has lower wear rate than unfilled epoxy. Lower wear rate was observed for 10% of TiO_2 filled epoxy composites. Particles uniformly distributed in the resin and they have lower density so it has a lower particle settling during curing and results in lower wear rate. At all sets of load 10 % of TiO_2 filled epoxy results in lower wear rate compared to unfilled and 5% of TiO_2 filled epoxy.

Figure 4 shows a wear rate of TiO_2 filled epoxy composites at sliding speed of 3 m/s. Lower wear rate was observed for 10% of TiO_2 filled epoxy composites. Wear rate goes on increasing with load. Lowest wear rate at 3 kg load is for 10% of TiO_2.

Figure 5 shows wear rate for WC filled epoxy composites. For WC filled epoxy composites wear rate goes on increasing with load and both 5% and 10% of WC filled epoxy composites will results in lower wear rate than unfilled epoxy resin.

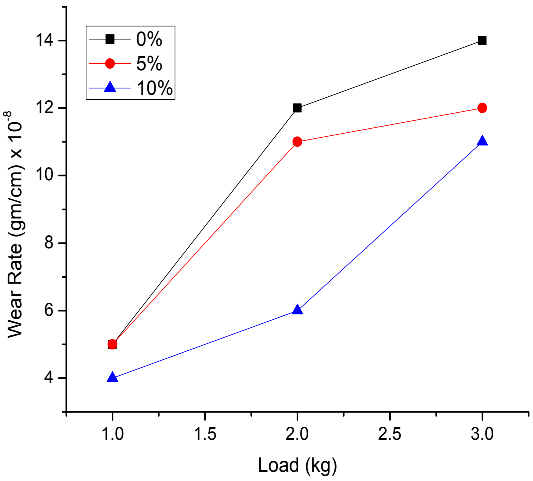

Figure-5: Graph for wear rate of epoxy + WC at 2m/s.

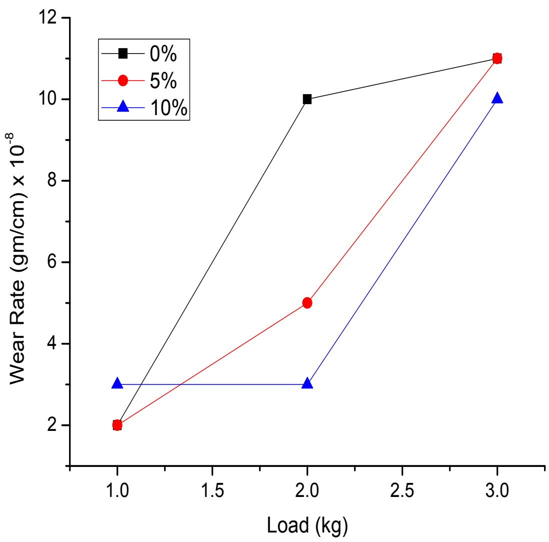

Figure-6: Graph for wear rate of epoxy + WC at 3 m/s.

Figure 6 shows wear rate for WC filled epoxy composites at sliding speed of 3 m/s. lowest wear rate was observed for 10% of WC filled epoxy composites. Lowest wear rate was achieved at 2 kg load compared to 5% of WC filled epoxy composites and unfilled epoxy.

Figure 7 shows graph for both TiO_2 and WC filled epoxy composites at sliding speed of 2 m/s. Both TiO_2 and WC filled epoxy composites results in lower wear rate than unfilled epoxy composites. Lowest wear rate is achieved for 10% of TiO_2 filled epoxy composites at all three loads. Wear rate goes on increasing with increase in loads. WC particles in epoxy resin results in agglomeration because of high density of particles.

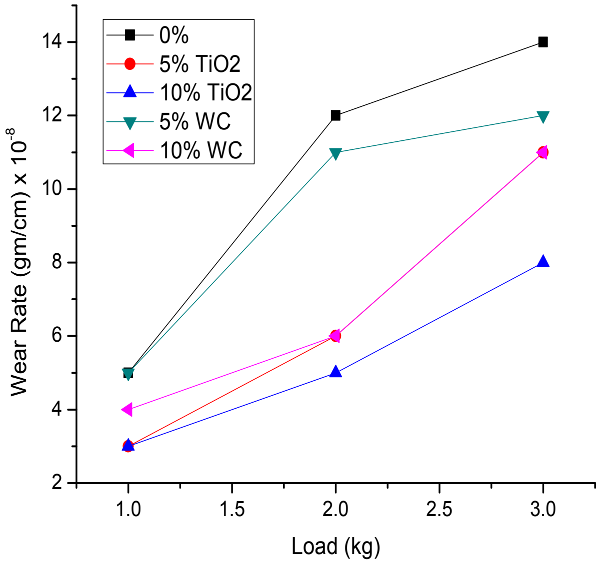

Figure-6: Graph for wear rate at 2 m/s.

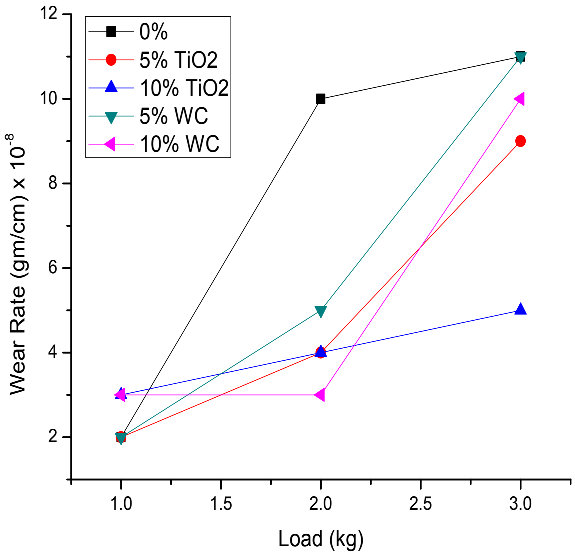

Figure-8: Wear rate at 3 m/s.

Figure 8 shows wear rate at sliding speed 3 m/s. for all compositions. Both TiO2 and WC filled epoxy composites results in lower wear rate than unfilled epoxy. Lowest wear rate was observed for 10% of TiO_2 filled epoxy composites. Wear rate goes on increasing with increase in load. Time of experimentation also has influence on wear rate. With increase in sliding speed wear rate goes on decreasing. Again sliding speed is directly proportional to test time. Wear rate goes on decreasing with increase in test time or contact time of specimen and disk.

3.2 Hardness Test

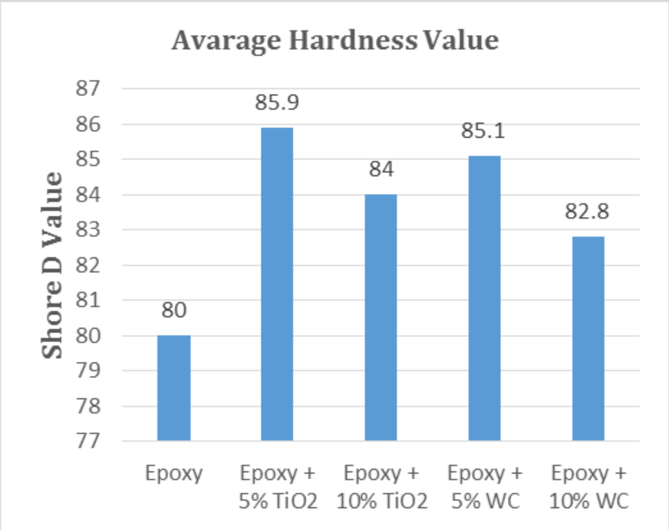

Figure-9: Shore-D hardness value

Figure 9 shows hardness value for both TiO_2 and WC reinforced epoxy composites. Hardness value changes from point to point because of uneven distribution of reinforcing particles in epoxy matrix. Hardness value is high for both type of reinforcements. Highest hardness value is observed for 5% of TiO_2 reinforced epoxy composites. Both 10% of WC and TiO_2 reinforced epoxy has lower hardness value than 5%.

4. CONCLUSION

Effects of TiO_2 and WC content in epoxy resin system on wear rate and hardness was checked experimentally and following conclusions were drawn.

- Both TiO_2 and WC reinforcement in epoxy resin system results in lower wear rate than unfilled epoxy resin.
- Increasing sliding speed of disk results in decrease in wear rate.
- Wear rate increases with increase in load.
- Lowest wear rate was observed for 10% of TiO_2 filled epoxy composites.
- Highest hardness value is high for both TiO_2 and WC filled epoxy compared to unfilled epoxy.
- 5% of TiO_2 filled epoxy has highest hardness value of 85.9.
- Uneven distribution of filler particles in epoxy results in variation in hardness value.

REFERENCES

1. Dora Siva Prasad, ChintadaShoba, "Hybrid composites – a better choice for high wear resistant materials", Journal of Materials Research and Technology, 2014, pp.172–178.
2. Devaraj, Eand Haseebuddin.M.R, "Study of mechanical and Wear behavior of carbon fiber reinforced epoxy resin composites with alumina filler additions", International Journal of Engineering Research & Technology (IJERT, Vol. 2 Issue 10, October – 2013 pp. 2602-2607.
3. B. Suresha, G. Chandramohan, J. N. Prakash, V. Balusamy and K.Sankaranarayanasamy, "The Role of Fillers on Friction and Slide Wear Characteristics in Glass-Epoxy Composite Systems" , Journal of Minerals & Materials Characterization & Engineering, Vol. 5, No.1, 2006 pp. 87-101, 2006.
4. S. Basavarajappa, S.Ellangovan, K.V. Arun, "Studies on dry sliding wear behaviour of Graphite filled glass–epoxy composites", Materials and Design 30 (2009), pp. 2670–2675.
5. S. Basavarajappa, K.V. Arun, J. Paulo Davim, "Effect of Filler Materials on Dry Sliding Wear Behavior of Polymer Matrix Composites – A Taguchi Approach", Journal of Minerals & Materials Characterization & Engineering, Vol. 8, 2009, pp. 379-391.
6. A. Todic, D. Cikara, V. Lazic, T. Todic, I. Camagic, A. Skulic, D. Cikara, "Examination of Wear Resistance of Polymer – Basalt Composites", Vol. 35, No. 1 (2013), pp. 36-41.
7. Kishore, P. Sampathkumaran, S. Seetharamu, P. Thomas, M. Janardhana, "A study on the effect of the type and content of filler in epoxy–glass composite system on the friction and slide wear characteristics", Wear 259 (2005), pp.634–641
8. Farah.T. Mohammed Noori, Nadia Abbas Ali and Ekram A. Al ajaj, "Comparison study of wear and hardness of EP/ nano and micro TiO_2 composites", Volume 2, Issue 3, March 2013, ISSN 2319 – 4847.

BIOGRAPHIES

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