# Abrasive wear performance of epoxy engineering essay

Engineering

Sudheer M#1, Sandesh Kubanooraya#2, Raju K#3, Thirumaleshwara Bhat#4#Department of Mechanical Engineering, St. Joseph Engineering College, MangaloreKarnataka-575028, India1Research Scholar: msudheeem2002@yahoo. co. in[corresponding author]2PG Student: sandesh. udupi@gmail. com3Professor: rajuksjec@rediffmail. com4Professor and Head: tbhatsjec@gmail. comAbstract— This paper discusses two-body abrasive wear behaviour of Potassium Titanate Whisker (PTW) reinforced vacuum moulded epoxy/glass composites. The effects of whisker content, sliding distance, normal load and abrasive grit size on wear behaviour of composites were evaluated by pin-on-paper abrasion tests. The tests were conducted at ambient conditions and constant disc speed of 200 rpm. The wear loss of composites was found increasing with the increase in normal loads, abrading distances and coarser abrasive papers. The effect of whisker content to minimize wear loss was highly dependent on abrasive grit sizes. The friction coefficient has shown decreasing trend with normal load and mixed trend with sliding distance and whisker content. The scanning electron microscope (SEM) images of composite specimen worn at higher loads, distances and for finer abrasive grit sizes were evaluated and results indicate more severe damage to epoxy/glass composites as compared to PTW filled epoxy/glass composites. Keywords— Two body abrasion, ceramic whiskers, glass fibers, polymer composites, wear mechanisms

## I. Introduction

Wear is defined as damage to a solid surface, generally involving progressive loss of material, due to relative motion between contacting surfaces. The five main types of wear are abrasive, adhesive, fretting, erosion and fatigue wear, which are commonly observed in practical situations. Abrasive wear is the most important among all the forms of wear because it contributes almost 63% of the total cost of wear [1]. Nowadays Polymer Matrix Composites (PMCs) are increasingly employed in various industrial equipments that are subjected to abrasive wear situations. This includes highly abrasive wear systems such as conveyor aids, vanes and gears for pumps handling industrial fluids, sewage and abrasive contaminated water; bushes, seals and chute liners in agricultural, mining and earth moving equipment; roll-neck bearings in steel mill subjected to heat, shock loading, water; and guides in bottle handling plants [2]. A literature survey indicated that fiber reinforcement along with ceramic fillers improved abrasive wear performance of polymers [3-8]. PTW is known to be an advanced multi-component ceramic whisker and its potential to reinforce with polymers and metals is currently being investigated by many researchers [9]. The studies done on PTW modified and fiber reinforced polymer composites are scanty as on date. Hence, present work deals with preparation of epoxy/glass composites with varying percentage of PTW ceramic fillers and its characterization for abrasive wear performance.

## II. Materials and METHODS

A. MaterialsAmbient temperature curing Epoxy resin (LY556) and triethylene tetramine (TETA) hardener (HY951) supplied by M/s. Huntsman advanced materials India Pvt. Ltd., Bengaluru, India was used as matrix material. The plain weave E-glass fibers of aerial density 212 g/m2, obtained from M/s. Arun fabrics, Bengaluru, India were used as main reinforcement. The PTW fillers used as secondary reinforcement were supplied by Hangzhou

Dayangchem Co. Ltd., Hong Kong, China. These fillers are of whisker shape with diameters 0. 5-2. 5µm and lengths 10-100µm. The photo micrographs of glass fibers and PTW fillers are presented in Figs 1 and 2 respectively. D: Abrasive wearSEM abrasive 15 02 201315-2-13gl5. jpgFig. 1 SEM picture of glass fibersFig. 2 SEM picture of PTW fillersB. Composite FabricationThe composites were prepared using vacuum bag molding technique. Epoxy/glass/PTW composites were prepared by varying the percentage (2. 5, 5 and 7. 5 wt%) of PTW fillers. Epoxy/glass composite without the fillers was also prepared for comparison purpose. The Fig 3 illustrates vacuum bag method. The detailed procedure can be referred elsewhere [10]. The composites prepared are designated as EG0, EG2. 5, EG5 and EG7. 5, numbers indicate weight percentage of PTW filler in composites. C. Abrasive Wear TestingTwo-body abrasive wear tests were performed using a pin-on-disc machine (Model TR201C, DUCOM, Bengaluru, India) under multi-pass conditions. The composite specimen of 10×10×3 mm3 with the rubbing surface of 10×10 mm2 was glued to steel specimen of 10×10×30 mm3 and rubbed against different abrasiveFig. 3 Vacuum bagging techniquepapers. The abrasive paper was pasted on disc by means of suitable adhesive. The test configuration is illustrated in Fig 4. Before starting the experiment, composite surface was abraded against a fine abrasive paper of grade 800 to ensure uniform contact. The effects of various loads (5, 10 and 15 N), sliding distances (20, 40, 60 and 80 m) and abrasive papers (120, 320 and 600 grit size) under a constant sliding velocity (0. 6283 m/s corresponding to 200 rpm) were studied. The wear in terms of weight loss was determined after each experiment using 0. 1 mg digital weighing scale (Shimadzu AY220, Japan). Coefficient of friction (COF) is determined as ratio of frictional force measured from test machine to applied normal load. Each test conditions were repeated three times and average of the closest data was reported. Fig. 4 Schematic of pin-on-disc configuration

## III. Results and discussion

A. Coefficient of Friction (COF)Values of COF for different composites under varying loads and distances in case of 600 grit SiC paper are indicated in Table 1. COF values were found to decrease with applied load. This behaviour is in accordance with reports available in literatures [11]. However, with sliding distance, COF was found to initially increase and later decrease. During sliding, initially effective area at sliding interface steadily increases. This offers more frictional resistance. Hence COF tends to increase. However, with further sliding, clogging [4] in abrasive paper provides easy shear and tend to reduce COF values. The variation in COF with respect to filler content has shown no common trend. It is well known that friction and wear under abrasive mode is a more complex phenomenon. The transition between two-body and three-body contact [12] with testing parameters and several mechanisms simultaneously acting at sliding interface results in such varying trend of COF. Considering effect of abrasive grit size, COF values lied in range of 0. 75-0. 51 for 600 grade SiC paper, 0. 87-0. 48 in case of 320 grade SiC paper and 0. 84-0. 32 in case of 120 grade SiC paper. Hence it is clear that range of COF values have narrowed down with finer abrasive papers. Thus almost stable COF is observed under mild abrasive wear sliding conditions. B. Abrasive Wear Loss (AWR)The effect of sliding distance on abrasive wear behaviour of composites for different abrasive papers is presented in the Fig 5. It can be observed that wear loss increases with sliding distance and it reduces with finer abrasive papers. This is an expected behaviour in all types of composites. With increase in sliding distance, more material is removed from the composite surface and it results in increased wear loss. A close examination of Fig 5 indicates that wear loss increases at a higher rate during initial sliding (up to 40m distance) and later increases, but at a slower rate. This observation under multi-pass conditions is mainly because of SiC particles loosing their abrasiveness with continuous sliding [5]. The wear loss was found to be dependent on counterface. In case of finer abrasive paper, small abrasive particles cause less damage to composite surface than coarser paper with large abrasive particles. Hence lesser wear loss was observed with finer abrasive papers. The effect of normal load on abrasive wear behaviour of composites for different abrasive papers is presented in Fig. 6. The wear performance observed is similar to that obtained for sliding distance effect. With increase in load, abrasives penetrate deeper into composite surface and increase material loss. The effect of abrasive grit size on the wear behaviour can be interpreted from Fig. 7. It can be observed that, inclusion of PTW has improved abrasive wear performance of epoxy/glass composites. However, optimum percentage of filler to minimize the wear loss was dependent on abrasive media. In case of 120 SiC paper, EG2. 5 composites performed best, where as EG5 composites showed minimum wear loss in case of 320 SiC paper.

**Table 1. COF values for different specimens under varying loads and distances**

**Sliding distance**

**Load**

**10m**

**20m**

**30m**

**40m**

**50m**

**60m**

**70m**

**80m**

**EG0**

**5N**

0. 6700. 7200. 6800. 7000. 6900. 6400. 6200. 610

**10N**

0. 6450. 7000. 7100. 6800. 6900. 6750. 6600. 645

**15N**

0. 5500. 5600. 5760. 5450. 5350. 5300. 5350. 525

**EG2. 5**

**5N**

0. 7200. 7350. 7450. 7400. 7300. 7250. 7200. 710

## 10N

0. 6300. 6450. 6500. 6450. 6400. 6350. 6300. 625

## 15N

0. 5760. 5900. 6000. 6100. 5950. 5900. 5800. 570

## EG5

## 5N

0. 7400. 7500. 7350. 7200. 7300. 7250. 7150. 710

## 10N

0. 6600. 6800. 6750. 6600. 6650. 6550. 6450. 640

## 15N

0. 5960. 6100. 6250. 6150. 6000. 5900. 5800. 560

## EG7. 5

## 5N

0. 6900. 7100. 7200. 7050. 6950. 6800. 6700. 665

## 10N

0. 6100. 6200. 6350. 6400. 6300. 6200. 6100. 620

## 15N

0. 5360. 5400. 5460. 5300. 5400. 5200. 5100. 510

## Fig. 5 Effect of sliding distance on abrasive wear loss of composites

## Fig. 6 Effect of normal load on abrasive wear loss of composites

## Fig. 7 Effect of abrasive grit size on abrasive wear loss of composites

## Fig 8. Surface topographies of composite specimen (a). EG0, (b) EG2. 5, (c) EG5 and (d) EG7. 5 composites. (Sliding conditions: Load 15N, distance 80m and speed 200 rpm)

All PTW filled epoxy/glass composites performed well with 600 SiC paper and EG7. 5 composites exhibited least wear loss. This trend clearly indicates an existence of relationship between size of abrasive particles and content of filler in epoxy/glass composite systems. Under 120 SiC paper, adding a small amount of PTW filler (2. 5 wt%) to epoxy/glass composites has reduced wear loss by 22%. Further increase of whisker content has increased wear loss and EG7. 5 composites exhibited wear loss higher than EG0 composites. EG5 composites has shown 23% reduction in wear loss in case of 320 SiC paper and EG7. 5 composites has shown 40% reduction in wear loss in case of 600 SiC paper in comparison to EG0 composites. These results indicate beneficiary effect of adding PTW into epoxy/glass material systems. C. Worn Surface MorphologyThe worn surface topographies of composites run under maximum conditions considered in test and for 600 SiC abrasive paper is presented in Fig 8a-d. SEM pictures indicated different trends in severity of wear. The severity of abrasive wear, i. e. micro-cutting [8] on the worn surfaces of EG0 composites can be observed in Fig 8a. Some instances of wear debris collected on surface and pits formed between glass fibers due to removal of matrix material can be seen in case of EG0 composites. Altogether a severe damage of surface can be evidenced from micrograph of EG0 composites. This indicates poor abrasive wear property of pristine epoxy/glass composites. On other hand, PTW filled composites showed smoother surfaces with lesser damage. Even though some instances of fiber damage can be observed in case of EG2. 5 and EG5 composites (Fig 8b and c), glass fibers are well protected and remain attached to composite surface. Matrix loosening [6] and some wear scar marks on fibers by SiC abrasive particles can be observed in these micrographs. SEM picture of EG7. 5 composite shows a pit formed which may due to SiC abrasive. The sheared and compressed fiber impressions can also be observed in case of EG7. 5 composites. The SEM findings are in line with abrasive wear data presented in Fig 7.

## IV. CONCLUSIONS

A series of epoxy/glass/PTW composites with varying PTW content were prepared and evaluated for abrasive wear performance. From this experimental investigation, following conclusions can be arrived. 1. COF decreased with normal load and has shown mixed trend with sliding distance, abrasive grit size and PTW content. 2. Abrasive wear loss increased with sliding distance and applied load. Performance ranking of epoxy/glass/PTW composites under abrasive wear depends upon grit size. No composite performed best in all abrasive conditions and deciding optimum content of filler to minimize wear loss is a multi-criteria optimization problem. 3. SEM pictures revealed that micro-cutting is dominant mechanism in case of EG0 composites and matrix fracture as prevalent mechanism in case of epoxy/glass/PTW composites. This study revealed that PTW can be used as a filler to improve abrasive wear resistance of epoxy/glass composites.

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