Effect of fiber and filler loading two-body and three-body abrasive wear behavior of polyamide66 composites

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***Abstract*— The influence of fiber and fillers addition on two body and three body abrasive wear behavior of polyamide66 (PA-66) composites have been evaluated in this article. Three different composition of composite materials were used for evaluating the abrasive wear behavior phenomenon, viz. polyamide66 (PA-66)+Polytetrafluoroethylene (PTFE), (PA-66+PTFE+GF), (PA-66+PTFE+GF+SiC+Al_2O+MoS_2+nano fillers). Abrasive wear studies were carried out for different abrading distances (1, 2 and 3 m), under a constant load of 10 N by using different grades of SiC abrasive paper (80 and 150 grit size). Low stress (three-body) abrasive wear test have been explored on (PA-66) composite using dry sand rubber wheel abrasion test rig. Experiments were conducted for different abrading distances (150, 300 and 450 m), under a constant load of 40 N and at a speed of 200 rpm, using angular silica sand of 212 µ particle size as dry and loose abrasive. The results showed that PA-66 filled with PTFE showed better wear resistance compared to other composite.**

***IndexTerms*— Polyamide66 (PA-66), Polytetrafluoroethylene (PTFE), Three body abrasive wear.**

I. INTRODUCTION

Engineering polymers are extensively used in mechanical engineering, as structural applications because of their superior properties such as light weight, high strength, ease of fabrication, low cost and excellent thermal stability, combined with wear and solvent resistance [1]. Because of these excellent properties polymer composites are used in many applications like bearings, pipes, cams, brakes, automotive, aerospace, sports and electronic industries. Wear is defined as damage to a solid surface, generally involving progressive loss of material, due to relative motion between contacting surfaces. Wear depends strongly on material properties, experimental conditions and wear system.

The five main types of wear are abrasion, adhesion, erosion, fretting, and fatigue which are commonly observed in practical situations [2]. Abrasive wear considered as the most important among all the forms of wear because it contributes almost 63% of all cost of wear in industries [3]. Abrasive wear can occur as two-body abrasion, three-body abrasion or both. The two body abrasion wear is defined as the wear is caused either by hard protuberances on one surface which can only slide over the other or by the rolling and sliding of hard free particles on solid surfaces, the former is named as two body fixed abrasive wear and the latter two body free abrasive wear [4]. In three-body, particles are trapped between two solid surfaces but are free to roll as well as slide.

The rate of material removal in three-body is one order of magnitude lower than that for two body fixed abrasive wear, because in 3-BA the loose abrasive particles abrade the solid surfaces between which they are situated only about 10% of the time in sliding, while they spend about 90% of time in rolling [2,4]. The difference between two-body and three-body abrasive are, two-body is a process in which particles or asperities are rigidly attached to the surface of a solid body, whereas in three-body, the abrasive particles are loose and free to roll, which emphasizes the presence (three-body) or absence (two-body) of a separate counter face present as a second body backing the abrasive [5].

Three combination of material were prepared using a plastic injection molding technique. The main objective of the present work was comparative critical evaluation of wear behavior [7] of the materials under dry sliding against SiC abrasive paper (two-body); as well as under three-body condition against rubber wheel [8], to study the effect of fiber and fillers on tribological performance and wear mechanism of the PA-66 based composites. In this research the effect of fiber, fillers, lubricant and nano fillers on three-body and two-body characteristics of PA-66 composite showed that the PA-66+PTFE ratio highly influenced the wear resistance of the composites compare to the addition of fiber and fillers to the PA-66 composite. This investigation indicated that an increase in the abrading distance caused an increase in the wear volume loss.

II. EXPERIMENTAL DETAILS

Materials

In this investigation Polyamide 66 (PA-66) is selected as an important thermoplastic and being widely used in injection molded components, with strong commercial advantages of lower manufacturing cost. The glass fiber (GF) reinforced material posses high mechanical strength, high stiffness and demonstrate excellent wear resistance makes the GF an attractive choice for bearing applications. PTFE used as thermoplastic polymer to reduce friction and wear and it maintains high strength, toughness and self lubrication. SiC and Al_2O used as fillers, added to composite material to lower the consumption of more expensive binder material or to better some properties of the mixture material like strength, hardness etc. Molybdenum disulphide (MoS_2) is a well known solid lubricant. Nano fillers are used to improve performance. Three compositions were involved in this work, viz. PT (PA-66+PTFE), GPT (PA-66+PTFE+GF), and FGPT (PA-66+PTFE+GF+SiC+Al_2O+MoS_2+nano fillers).

Techniques

A Multi-pass two-body abrasive wear tester rig machine figure 1, (as per ASTM G-99 standards, make; Magnum Engineers, Bangalore) used for two-body abrasive wear (bi-directional single pass condition) tests. The test specimen were prepared after proper punching of circular surface, glued to a pin of 8mm diameter and 25mm length. The composite sample was abraded against the water proof abrasive paper SiC, which was fixed on a rigid plate. The embedded hard SiC particles abrade the test sample [9].The pin assembly was initially weighed to an accuracy of 0.0001g in an electronic balance (Mettler Toledo). The difference between the initial and final weights is the measure of sliding wear loss.

Figure 1. Schematic diagram of multi-pass two body abrasion machine tester rig.

Three body abrasive wear studies of PA-66 and their composites were studied on a dry sand/rubber wheel abrasion test (RWAT) rig (TR-50-M1,DUCOM,Bangalore) as shown in figure 2.

1. Nozzle, 2.Rubber lined wheel, 3.Specimen, 4.Silica sand, 5.Lever arm, 6.Weights

Figure 2. Schematic diagram of dry sand/rubber wheel abrasive wear test rig.

It was felt that this test produced the closest simulation of the real tribo system. The sample was placed in specimen holder and it was pressed against a rotating wheel at a specified force by means of lever arm. The abrasives were introduced between the test specimen and rotating wheel with chlorobutyl rubber tire. The abrasive feeding system consists of a hopper and it allows silica sand to fall under gravity through narrow throat on to silica wheel. The silica wheel was rotated by motor through timer belt and motor speed determines discharge rate of silica sand. The rotation of the rubber wheel was such that its contact face moves direction of the sand flow. The pivot axis of the lever arm lies within a plane, which was approximately tangent to the rubber wheel surface, and normal to the horizontal diameter along which load was applied [10]. The specimen holder was designed to ensure that samples are removed and replaced during each test such that wear scar was always at the same location. The wear was measured by the loss in weight, which was then converted into wear volume using the measured density data.
The wear volume(ΔV) was calculated from the equation:

$$\Delta V = \frac{M}{D} \text{ mm}^3 \qquad (1)$$

Where M is the mass loss in grams, D is the density in gm/mm^3.

The specific wear rate (Ks) was calculated from the equation:

$$Ks = \frac{V}{L \times D} \text{ m}^3\text{/Nm.} \qquad (2)$$

Where V is the volume loss in m^3, L is the load in Newton and D is the abrading distance in meters.

III. RESULT AND DISCUSSION

Dry sliding abrasive wear volume

The variation in abrasive wear volume of composites worn on 80 and 150 grit SiC paper at 10N against various abrading distances under bi-directional single pass condition (in two-body wear test) is shown in figure 3(a) and 3(b) respectively. The wear data of the composite reveal that the wear volume tends to increase linearly with increasing abrading distances and strongly depends on the grit size of the abrasive paper.

Table 1: Test conditions used in the present study

Test parameter	Two-body test	Three-body test
Load	10 N	40 N
Speed	200 rpm	200 rpm
Distance	1, 2, and 3 m	150, 300 and 450 m
Size of the specimen	6 mm x 2.5 mm	61 mm x 40 mm
Abrasive paper/ particles	SiC of 80 and 150 grit size	Silica sand, angular 212μm
Sand flow rate	-	343 ± 5g/min
Diameter of rubber wheel	-	228.6 mm

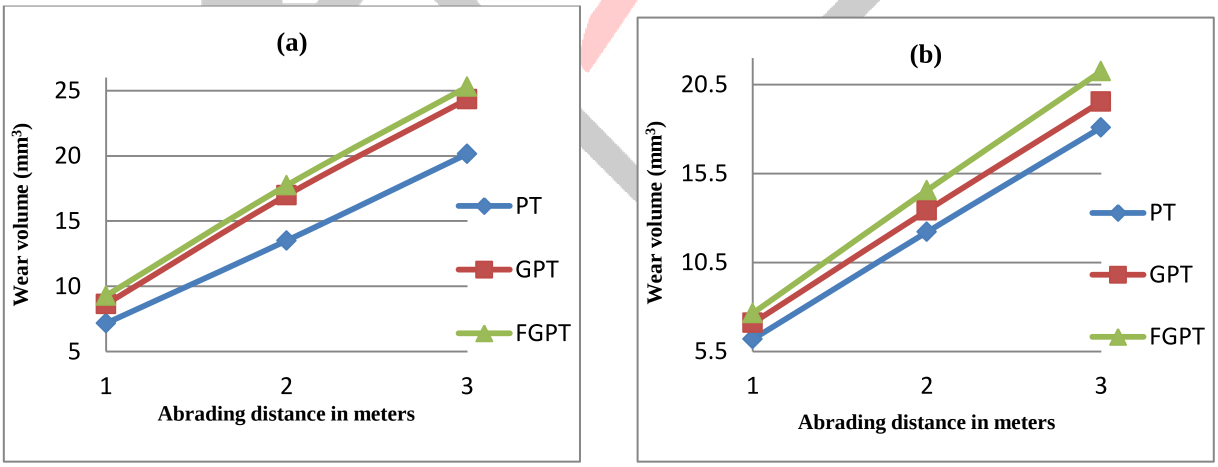

Figure 3. Variation in wear volume against various abrading distances of PA-66 composites at (a) 10 N, 80 grit SiC paper and (b) 10 N, 150 grit SiC paper.

Figure 3 it is obvious that the wear volume of composites worn on two different SiC papers increased with increasing abrading distances. The wear volume of PT is much lower than those of other composites and also the wear volume increased with increasing percentage weight of filler. In addition, the highest wear volume is obtained in specimens worn on 80 grit SiC paper. As shown in figure 3, the wear volume of the composite is 13.82% times higher in 80 compared to 150 grit size. The wear volume is less in PTFE filled with PA-66 because of self lubricating nature of PTFE.

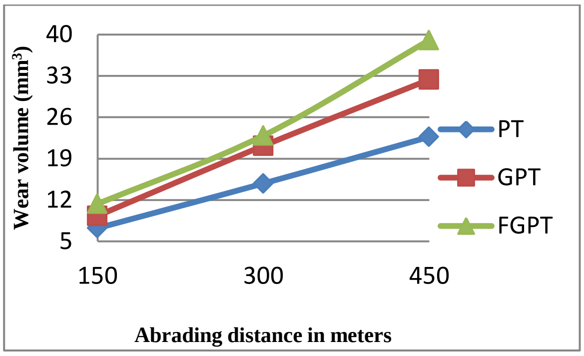

Figure 4. Variation in wear volume against various abrading distance of PA-66 composites at load of 40 N.

The comparative performance of all the composites abraded at different distances, under a load of 40 N and at a sliding speed of 200 rpm can be seen in fig 4. Wear volume tends to increase linearly with different abrading distance and strongly depends upon the applied load. The neat PT showed the lowest wear volume while other composite exhibited high wear volume. The polymer matrix are collided by sand particles and gradually stripped from the surface resulting in high roughness of worn surface. From the literature survey it is evident that very little work has been reported on three-body abrasive studies of polymers and their composites [11-13]. Budinski [10] investigated the abrasion resistance of 21 types of plastic and reported that polyurethane had better abrasion resistance over the other materials. Also it is reported that, the hard reinforced and filled engineering plastics had relatively poor abrasion resistance to silica sand (215–300 µm).

Giltrow [14] made an attempt to establish relationship between abrasive wear rates of thermoplastic polymers with their cohesive energies (cohesion between polymer chains). The relationship was non-linear, and this was attributed due to the complex nature of polymeric materials and high strain rates are involved during the abrasion process and reduction in polymer chain mobility. It was also reported by Giltrow [15] that thermoplastic polymer with high degree of crystallinity have high cohesive energies is likely to have high resistance to abrasion. Whereas in amorphous polymer have reduced cohesive energy and reduced abrasion resistance. In the present study PT exhibited better abrasive wear resistance as compared to other thermoplastic material. It has been reported by Voss and Friedrich [15] that tougher thermoplastic matrices usually exhibit a better abrasive wear resistance than brittle ones. It has been reported in the literature that thermoplastic polymers show a better abrasive wear resistance than thermosetting polymers.

Dry sliding abrasive specific wear rate

Comparative specific wear rate of PA-66 and their composites, as a function of different abrading distances under two-body and three-body abrasive wear conditions is shown in Figure 5 and Figure 6 respectively. The specific wear rate (K_s) decreases non linearly with increase in abrading distances for two-body abrasive wear under single pass conditions, whereas in case of three-body abrasive wear specific wear rate increases non linearly with increase in abrading distance.

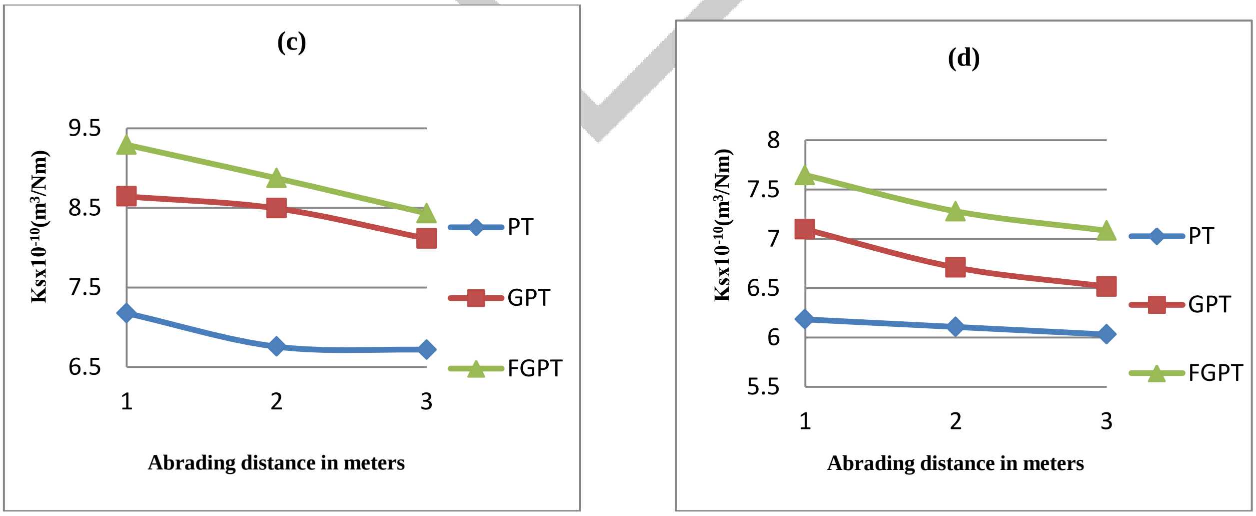

Figure 6 . Variation in specific wear rate, against various abrading distance of PA-66 composites at (a) load of 40 N.

In three-body abrasive wear, specific wear rate increases for all the materials with increase in load. This is because the sliding speed was high, the material softens somewhat and causes crack propagation. This results in increase of specific wear rate.

IV CONCLUSION

Based on experimental observations of two-body and three-body abrasive wear of PA-66 based composites, the following conclusions may be drawn.

- With increase in sliding distance, wear volume increases linearly for two-body (single pass condition) and three-body abrasive wear.
- The comparative wear performance of all the composites abraded under two-body and three-body abrasive wear situation at different distances can be seen from the Fig. 3. It was observed that two-body abrasion single pass condition (grit size 80) is more effective in removing material as compared to the other two abrasive wear conditions.
- It was observed that specific wear rate of two-body abrasive wear (single pass condition) is greater than three body abrasive wear. In the two-body abrasion process particles or asperities are rigidly attached to the second body, whereas in three-body abrasion the abrasive particles are loose and free to roll. Hence, two-body abrasion conditions are expected to produce higher wear rates than three-body conditions because the contact between the abrasive particle and the wearing surfaces is sliding rather than rolling.

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