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Research Paper

ABRASIVE WEAR PROPERTIES OF GRAPHITE FILLED PA6 POLYMER COMPOSITES

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The abrasive wear wear and frictional properties of graphite micro particle filled polyamide 6 matrix composites are investigated in this work. The composites with varying weight fractions of graphite have been prepared by melt mixing technique. Wear tests were conducted using a pin on disc apparatus under dry contact conditions. Mass loss was determined as a function of sliding velocity corresponding to the loads of 5N, 10N and 15N with an abrading distance of 314.2 m. The wear tests showed that graphite fillers improved the wear resistance and reduced the coefficient of friction of the PA6. The best properties achieved with the composite filler content of 25%. The worn surface of a typical specimen was examined by SEM to know the surface morphology.

Keywords: Graphite powder, Specific wear rate, Coefficient of friction, Polymer composite

INTRODUCTION

There are many technical applications in which noise, friction and wear are critical issues. Some of the applications are bearings, gears, cams, bushings, handles, jacketing for wires and cables, pulleys, safety helmets, seals, artificial joints, aircraft parts, space instruments, office automation machinery etc. Polymer composites containing different fillers and/or reinforcements are frequently used for these applications because of their great strength to weight ratio, extreme load bearing capability and withstand environmental temperature conditions. Because of their extensive application, understanding of polymer tribology is becoming increasingly important. Many research works were carried out to study the tribological behavior of nylon 6 with different filler/reinforcements. F.Van De velde *et al.* (1997), concluded that the wear of PA 6 sliding against steel is moderate even at very high contact pressures and is proportional to the normal load and also PA 6 is sensitive to stick-slip motion at very high contact pressures. Liu *et al.* (1991) found that MoS_2-filled nylon 6 was not very effective in reducing

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the friction but could cause an increase in wear. Xiubing *et al.* (2004) and Bhagyashekar *et al.* (2007) experimented and found that Graphite filled composites exhibited superior tribological properties. The present work focuses on the investigation of the effect of graphite filler on the abrasive wear behavior of PA 6 polymer composite.

EXPERIMENTAL DETAILS

Materials

The data of PA 6 pellets, Graphite powder used in this study are listed in Table 1. The powder used is a natural powder with 300 mesh size and ash content less than 15%.

Specimen Preparation

The varying amounts of Graphite powder viz., 10, 15, 20, 25 and 30% by weight with PA6 were first mixed in a high speed grinder followed by melt mixing in a co rotating intermesh twin screw extruder. The extrudate is then quenched in cold water and pelletized. The resulting PA6/G composite mixers were subsequently molded in an injection molding machine in order to obtain samples of size 6 mm × 7 mm cross section and 90 mm long. These samples are then cut, ground and polished to the specimen size of 6 mm × 7 mm × 32 mm.The sample designations and their composition is given in Table 2.

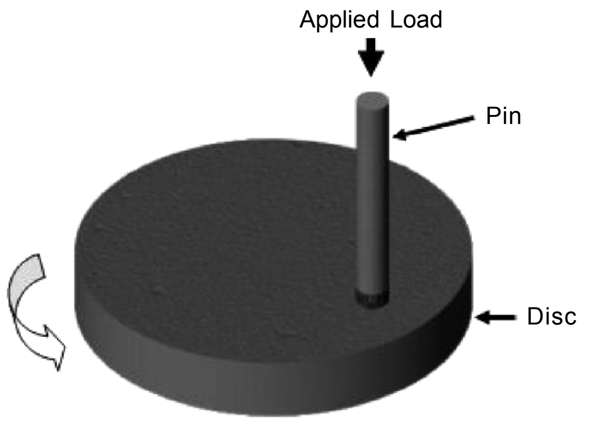
Table 1: Data of the Materials Used in this Study

Material	Form	Trademark	Manufacturer/Supplier	Density (g/cm^3)	Melting Point (°C)
PA 6	Pellet	Ultramid®B3S Q661	BASF	1.13	220
Graphite	Powder	—	B.P Chemicals	2.20	>1000

Table 2: Data of the Composition of the Samples

Sample Designation	Composition (Wt%)
PA6G0	PA6(100)
PA6G10	PA6(90) + Graphite(10)
PA6G15	PA6(85) + Graphite(15)
PA6G20	PA6(80) + Graphite(20)
PA6G25	PA6(75) + Graphite(25)
PA6G30	PA6(70) + Graphite(30)

Figure 1: Schematic Diagram of a Pin on Disc Apparatus



Wear Test Procedure

A pin-on-disc wear tester was used for friction and wear experiments. The schematic diagram of the apparatus is shown in Figure 1.

As shown in Figure 1, the composite specimen was mounted in the holder located on a loading lever arm and the normal load applied, using standard weights (5N, 10N and 15N in these experiments) to simulate different contact pressures. Silicon carbide Abrasive paper of 400 grit size was pasted on the counter face EN 31 steel disc of 170 mm diameter using a double sided adhesive tape. The specimen pin was fixed in a holder on a loading arm.

Normal load (5N, 10N and 15N respectively) was applied to the lever arm during the tests. The rotational speed of the disc was 200 rpm and the diameter of the wear track was 100 mm. The sliding velocity between the pin and the rotating disc was 1.04 m/s. The sliding distance was calculated to be 314.2 m for the test duration of 300 s. The environmental condition in the testing laboratory was 23 °C and the relative humidity 60%. The specimens were cleaned thoroughly with acetone before and after experiment for weighing. Each specimen was weighed to get the mass lost due to wear using highly reliable and a sensitive balance to an accuracy of 0.001 gm. Scanning Electron Microscopy was performed on the worn surface of the one typical specimen to understand the mechanism of wear.

The Specific Wear rate is calculated as the ratio of mass volume of the worn material per unit applied load and density as under.

$$W_s = \frac{\Delta W}{2\pi \, rNt\rho} \quad ...(1)$$

where W_s = Specific Wear rate in m^3/Nm.

ΔW = Weight loss in grams.

r = Wear track radius in m.

N = Rotational speed of the disc in rpm.

t = Test duration in min.

ρ = Density of the composite in gm/m^3.

The Coefficient of friction is calculated as the ratio of the frictional force to the applied normal load as under.

$$\mu = \frac{F_f}{F_n} \quad ...(2)$$

where μ = Coefficient of friction.

F_f = Frictional force in N.

F_n = Normal applied load in N.

RESULTS AND DISCUSSION

The Specific wear rate Ws as defined by Equation (1) for the composites was plotted against the normal load for different filler content. Figure 2 shows the influence of load on the Specific wear rate of the composites. The Specific wear rate decreases with the normal load. The Specific Wear rate was relatively high at lower load (5N) because of less penetration and less numbers of abrasive particles were in action with rubbing surface. The abrasion wear was greatly increased at higher load due to most of the abrasive particles were penetrated in to the surface and created more grooves resulting in more material removal by a severe plastic deformation. The wear rate decreases with addition of graphite powder up to 25%. However at 30% filler content it was relatively higher than 25%.loading. The optimum value of specific wear rate obtained for the composite with 25% graphite content. In fact this has attributed to the fact that the composite with 25% graphite content shown highest tensile strength as well as high hardness. A similar trend is seen when graphite is used as filler in epoxy and glassy carbon composites. (Michita *et al.*, 2000; and Bhagyashekar *et al.*, 2007).

Figure 3 shows the variation of coefficient of friction with time. It is obvious that the coefficient of friction increases initially to a higher value due to the fresh abrasive paper and as the process continues it almost remains same for the entire test period. It is also

Figure 2: Effect of Graphite Content on Wear Rate of PA6 Polymer Composite

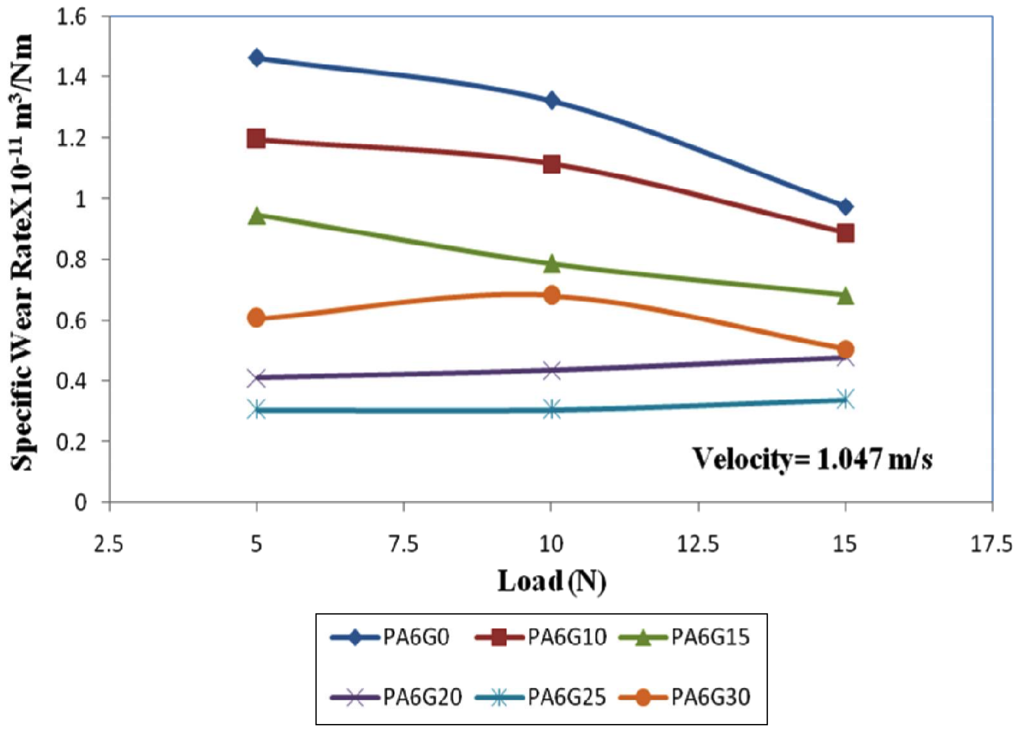
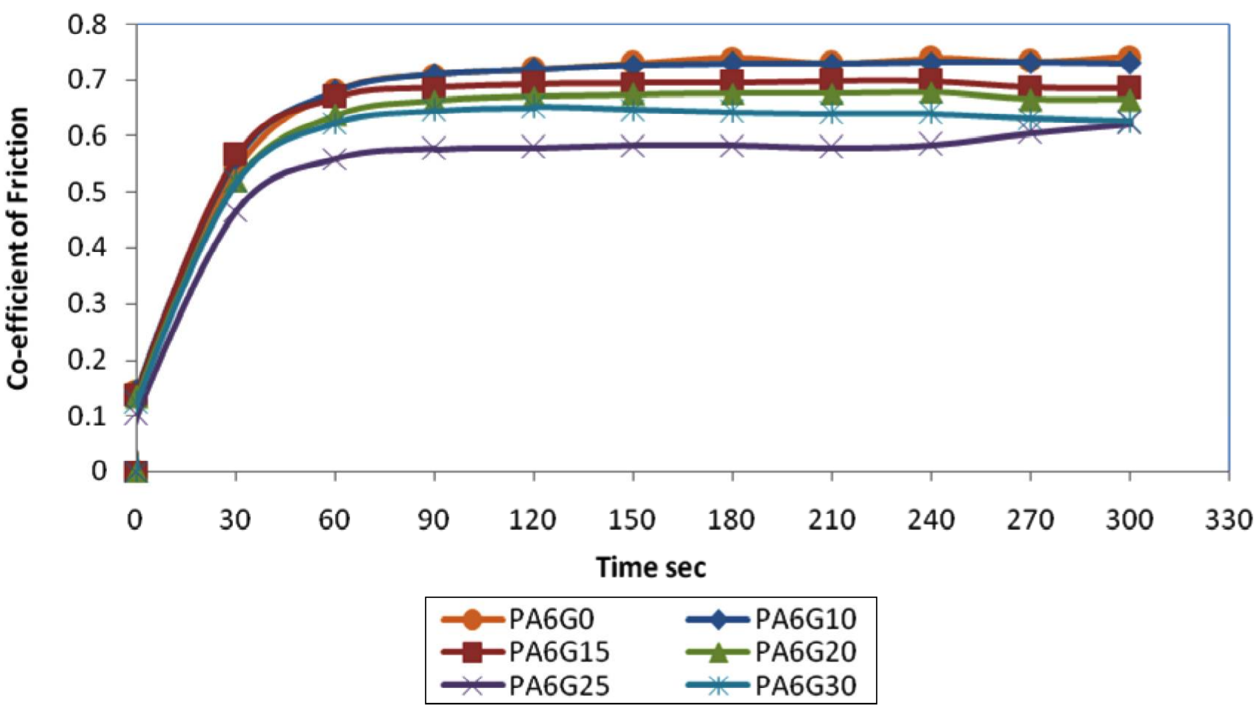


Figure 3: Effect of Graphite Content on Coefficient Friction of PA6 Polymer Composite

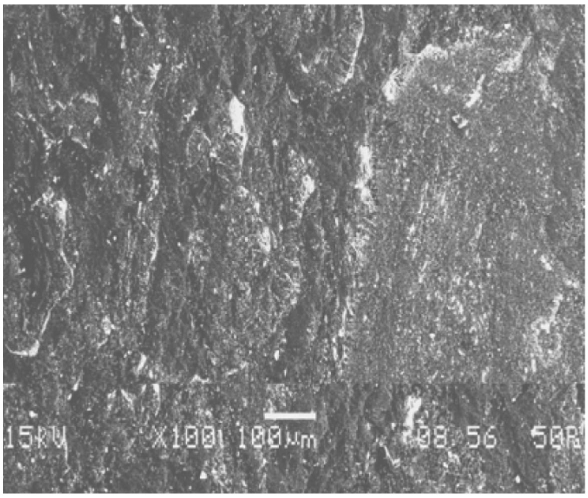


observed that the coefficient of friction decreases when the filler content increases. It is because of the lubricating property of the graphite filler. Here also 25% filler content gave the least value for coefficient of friction.

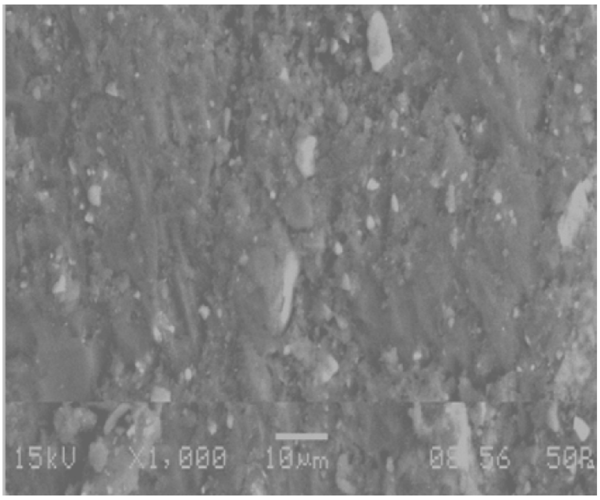
Figure 4 shows the Scanning Electron Micrographs (SEM) of worn surface of the 25% filler composite tested with a load of 15N. It can be interpreted as a formation of transfer film between the composite and the counterpart surface. There is no crack formation or any pullout of the particle signifying good bonding between the filler and the matrix material.

Figure 4: SEM Photographs of the PA6G25 Polymer Composite

(a) With a Magnification of 100



(b) With a Magnification of 1000



CONCLUSION

The wear behavior of the G-PA6 composites was studied in terms of wear rate and COF under varying normal load condition. Incorporation of graphite filler into PA6 can significantly reduce the abrasive wear loss. The optimum wear resistance property was obtained at the filler content of 25% weight fraction. The coefficient of friction decreases with increase of filler content up to 25%.

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