EFFECT OF FIBER AND FILLER LOADING OF MECHANICAL AND TRIBOLOGICAL BEHAVIOR OF POLYAMIDE-66 COMPOSITES

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***Abstract*- 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 [1] of the materials under three-body condition against rubber wheel and to study the mechanical properties of the PA-66 based composites. In this research the effect of fiber, fillers, lubricant and nano fillers on three-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. 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.**

***Index Terms*- PTFE, PA-66,Wear, abrading distances, nano fillers**

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[2]. 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 [3]. 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 [4]. Abrasive wear can occur as two-body abrasion, three-body abrasion or both. 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].

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. Nanofillers 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).
The mechanical characterization includes determination of Tensile strength, and Density of the

composite laminates The tribological characterization includes three body abrasive test.

Three body abrasive wear studies of PA-66 and their composites were studied on a dry sand/rubber wheel abrasion test (RWAT) rig as shown in Fig.1.

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

Fig.1. Schematic diagram of dry sand/rubber wheel abrasive wear test rig.

It was felt that this test produced the closest simulation of the real tribosystem. 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 [6]. 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:

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

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:

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

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

Mechanical test like Density test, tensile tests are conducted. Tensile test are conducted according to the ASTM standards on Universal testing machine.

III. RESULTS AND DISCUSSION

1. Density Test

The theoretical and measured densities along with the corresponding volume fraction of voids were presented in Table 1. The plots of various density test parameters as a function short glass fiber and fillers are shown in fig 2.

Table1. Density values of different materials

Composites	**Designation**	**Density (MPa)**
PA-66/PTFE	N1	1.31
PA-66/PTFE+SGF	N2	1.36
PA66+PTFE+SG+MoS$_2$+Al$_2$O$_3$+SiC	N3	1.55

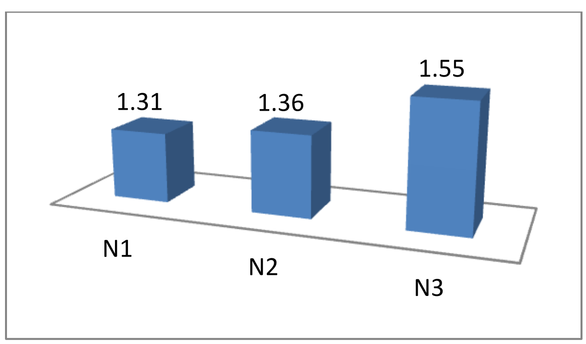


Fig.2. The plots of various density test parameters as a function short glass fiber and fillers

2 Tensile Test Results

The results obtained from the tensile test performed on nano fillers, short glass fiber filled with PA-66/PTFE composites are reported in table 2. The plots of various tensile strength parameters as a function short glass fiber and fillers are shown in fig 3.

Table 2. Tensile results of different materials

Composites	Designation	Tensile	Tensile elongation
PA-66/PTFE	N1	60 ± 1	13.89 ± 0.2
PA-66/PTFE+SGF	N2	90 ± 1	17 ± 0.5
PA66+PTFE +SGF+MoS_2 +Al_2O_3+SiC	N3	54±1	12 ± 0.5

The mechanical properties of polymer blend (N1), short glass fiber reinforced blend (N2) and micro fillers ,short glass fiber reinforced polymer blend (N3) such as tensile strength, percentage elongation at yield was studied. The effect of short glass fiber alone on the mechanical properties of PA66/Teflon blends was studied. Further, the effect of micro level alumina and silicon carbide fillers on short glass fibers reinforced PA66/PTFE blends was studied. The tensile tests were performed at the cross head speed of 5mm/min. When the polyblend (68 wt.% PA66-12wt.% Teflon) was reinforced with short glass fiber, the tensile strength was significantly increased from 59.8N/mm^2 to 90 N/mm^2 which is a 50% increase. As for the ductility, with the addition of the short glass fiber to the polyblend, the ductility of the polyblend increased slightly from 13.9 N/mm^2 to 17.2 N/mm^2 which is 23% increase. This shows that the addition of short glass fiber to the polymer blend have superior degree of compatibility between the polymer matrix and the glass fibers and also good adhesion. With the addition of 2.1 wt.% molybdenum disulphide (MoS_2), 5.3 wt.% alumina (Al_2O_3) and 5.3 wt.% silicon carbide (SiC) as fillers with 17.3 wt.% of short glass fiber reinforcement to the polyblend (60 wt.% PA66-10wt.% Teflon) slightly reduces the tensile strength and also the ductility of the polyblend. Alumina is a refractory material and SiC is abrasive material. This shows that more number of fillers will have poor degree of compatibility with the studied polymer blend. The final response of the material with different fillers is deteriorating against the pure polyblend in terms of tensile strength and ductility. The typical tensile curve with different loads is shown in Figure 3(a) and the plot of tensile strength of all the studied composites is shown in Figure 3(b).

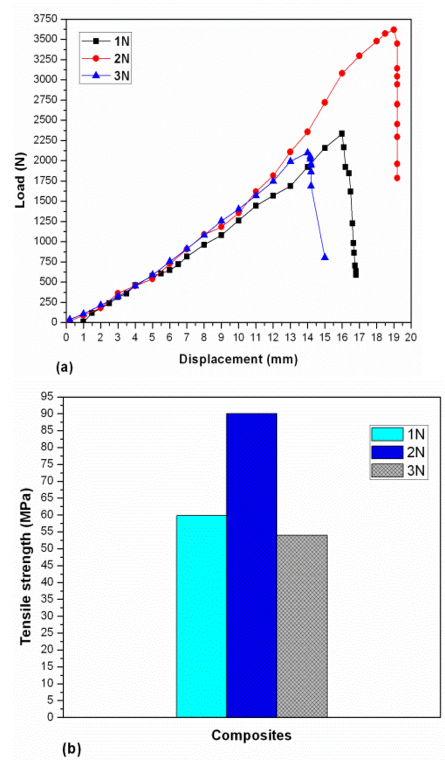
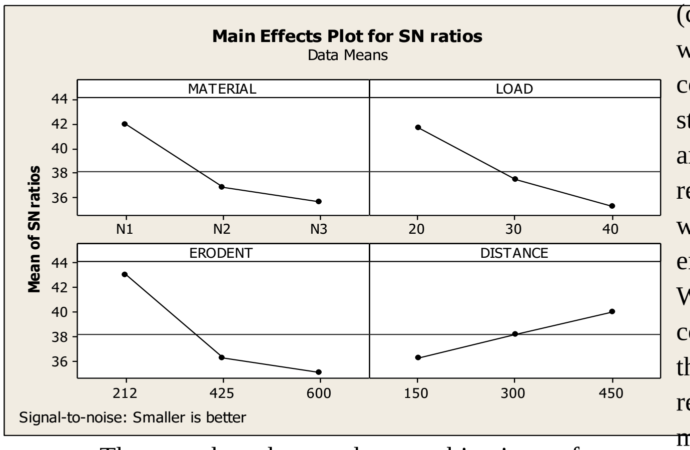


Fig. 3(a) an 3(b) Variation in Mechanical properties of PA66/Teflon blend reinforced with short glass, and micro inorganic fillers : (a) Typical tensile test curve: (b) Tensile strength Variation with composites.

Table 3: Testing Condition used for Three body Experimentation

Sl No	Control Factors	Levels		
		A	B	C
1	Material	N1	N2	N3
2	Abrasive particle size (µm)	212	425	600
3	Load (Newton's)	20	30	40
4	Distance (Meter)	150	300	450

From the figure it is clear that polyblend (PA-66/PTFE) composite shows better wear resistance as compared to other composites. Addition of fiber and fillers in the matrix resulted in lower wear resistance compared to unfilled one.



The graphs shows the combination of parameters giving the optimum performance, i.e. minimum wear is observed when experimenting with sand size of 212 mesh, 20N load and 150 m of abrading distance. High contact pressure transferred to the abrasive has been shared by few sand particles, leading to maximum stresses at contact region. This stress produced by an abrasive is sufficient to facilitate failure of matrix, leading to the matrix removal. Wear volume increases with increase in load and abrading distance for all composites, which is manifested by the deeper grooving on the composite surface and more material removal from the composite with increasing load.

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 [7-9]. Budinski [6] 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 [10] 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 [11] 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 [11] 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.

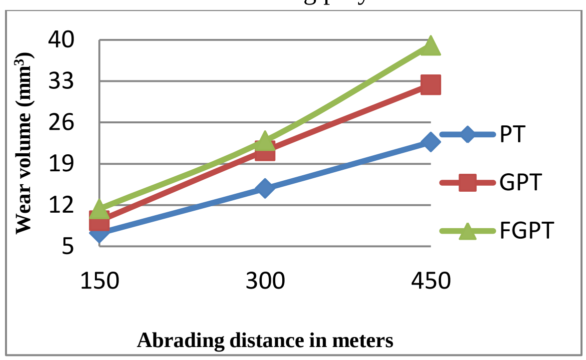


Fig.4. Variation in wear volume against various abrading distance of PA-66 composites at load of 40 N.

IV. CONCLUSION

The polymer blend PA66 with Teflon is one of the good combinations as per this study on the mechanical aspects of the micro composites.

1. 68 wt. % PA66 – 12 wt.% Teflon reinforced with 20 wt.% short glass fiber is the best combination for the good tensile strength of the studied polyblend. When the polyblend was reinforced with short glass fiber alone, the tensile strength and ductility was increased by 50% and 23% respectively.

2. The addition of micro level particulate fillers to the short glass fiber reinforced polyblend (60 wt. %PA66-10 wt.% Teflon) slightly reduces the tensile strength and also the ductility of the polyblend.
3. The specific wear rate (K_s) decreases non linearly with increase in abrading distances for two-body abrasive wear under bi-directional single pass conditions, whereas in case of three-body abrasive wear specific wear rate increases non linearly with increase in abrading distance.
4. In three-body abrasive wear, specific wear rate increases for all the materials with increase in abrading distance.
5. Abrasive wear volume increases with increase in abrading distance/load for all the composites. However, the PA-66/PTFE composite showed better abrasive wear resistance.

REFERENCE

[1]. L. Chang, Z. Zhang, on the sliding wear of nanoparticle filled polyamide 66 composites. Composites Science Technology 66 (2006) 3188-3198.

[2]. Gai Zhao, Irina Hussainova, friction and wear of fiber reinforced polyamide composites. Wear 301 (2013) 122-129.

[3]. Xian Jia, Ruofei Ling, two body free abrasive wear of polyethylene, nylon1010, epoxy and polyurethane coatings. Tribology International 40 (2007) 1276-1283.

[4]. N.S.M. El-Tayeb, B.F. Yousif. Evaluation of glass fiber reinforced polyester composite for multi-pass abrasive wear applications. Wear 262 (2007) 1140-1151.

[5].Gates JD. Two body and three body abrasive wear of polymeric materials. Wear 2003; 255: 742-50.

[6]. A.P. Harsha, U.S. Tewari. Three-body abrasive wear behaviour of polyarylethetherketone composites. Wear 254 (2003) 680–692.

[7] K.G. Budinski, Resistance of particle abrasion of selected plastics. Wear 203–204 (1997) 302–309.

[8] N. Chand, A. Naik, S. Neogi, Three-body abrasive wear of short glass fibre polyester composite. Wear 242 (2000) 38–46.

[9] A.A. Cenna, S. Allen, N.W. Page, P. Dastoor, A polyethylene reinforced polymer composite abraded by bulk solids. Wear 249 (2001) 663–671.

[10]. J.P.Giltrow, Arelationship between abrasive wear and cohesive energy of materials. Wear 15 (1970) 71-78.

[11]. H. Voss, K. Friedrich, On the wear behavior of short fiber reinforced PEEK composites. Wear 116 (1987) 1-18.