Frictional Effects and Sliding Pressure on the Wear Behaviour of Glass-Basalt Composites

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Abstract - Thermoplastic polymer composites are very promising materials for structural and friction related applications. Thermoplastic blend hybrid composites are used for the study. The blend polyamide 66 / polypropylene (PA66/PP) is reinforced with short glass (SGF) and basalt fibers (SBF). The composites are developed by melt mixing process using twin-screw extruder. The composites used for the study are blend (PA66/PP), Blend/SGF, Blend/SBF and Blend/SGF/SBF. The frictional effects and sliding pressure on the wear performance of thermoplastic blend composites reinforced with glass and basalt fibers are studied using pin-on-disk system as per ASTM G99. It has been noticed from the investigation that the wear loss of composites is totally influenced by the sliding pressure. The composites exhibit better wear resistance characteristics by the addition of fibers. Hybrid fibers reinforced composite demonstrated much greater wear resistance than individual fiber reinforced and thermoplastic blend composites. The reduction in the frictional constant has been noticed by the addition of fiber reinforcement into the blend.

Keywords - Frictional constant; Sliding pressure; PA66/PP; SGF; SBF;

1. INTRODUCTION

Polymer materials are most widely used in modern industries. The synthetic polymers are made with a wide – range of rigidity, strength, heat resistance and cost [1–4]. The amount of polymer materials used annually is more than steel [5]. Polymer mixing is the effective process for enhancing the wear and frictional properties of homo polymer. Several researchers have discovered that the wear and frictional performance of polymer blend mixtures are the roles of blend compositions. The performance of the polymer blend is much better than the polymer component [6-9]. Wang et al documented the mechanical and tribo activities of polyamide 66 / high molecular weight polyethylene blends [10]. They found that the wear volume rate of the blend decreased apparently with the rise of UHMWPE percentage. The mechanical and tribological performance of PA6/UHMWPE blend was studied by Liu and Ren [11]. They discovered that the tribological properties of the blend are affected by the sliding distance, surface roughness, sliding speed and the load. They concluded that the roughness of the surface and load are the major factors for blend wear. The wear characteristics of natural fiber reinforced PLA composites was reported by Pramendra Bajpai et al[12]. The results showed that natural fiber reinforcement into the PLA matrix greatly improves the wear performance of neat polymer. Guijun Xian et al [13] studied PEI matrix composite sliding wear: short carbon fiber reinforcement effect. The results showed that the addition of 5 to 20 volume percentage of short fibers decreases the friction coefficient and improves wear resistance. It is evident from the literature that much less research has been done on thermoplastic blend hybrid fibers composites. The good balanced properties of glass and basalt fibers made them most widely used fibers in thermoplastic matrix composites. Due to the sizing, the fibers provide a very good bonding with matrix materials. Polyamide 66 is a high performing thermoplastic engineering polymer and Polypropylene is a thermoplastic crystalline polymer. Not as much data on the impact of hybrid fibers on the sliding wear characterization of Polyamide 66 and Polypropylene blend were recorded. Considering the above factors, the dry sliding wear activity of short fibers (SGF / SBF) reinforced 80 wt. percentage of Polyamide 66 and 20 wt. percentage of Polypropylene [14] blend composites.

2. MATERIAL SYSTEM AND PROCESSING OF COMPOSITES

A. Material System

Material system used for this analysis are shown in table I. Table I also tabulates the descriptions of the material system and their properties. Table II lists the material compositions, along with the material definition, depending on weight percentage.

TABLE I. DETAILS OF THE MATERIAL SYSTEM

Material System	Shape	Size	Melting Temperature (⁰C)	Density (g/cm3)
Polyamide 66	Particles	15-20 µm	255	1.14
Polypropylene	Particles	12-15 µm	130	0.9
Short glass fibers	Cylinder-shaped	1-3 mm	1000	2.54
Short basalt fibers	Cylinder-shaped	1-3 mm	1500	2.65

TABLE II. COMPOSITE FORMULATIONS BY WEIGHT PROPORTION

Composition of Composites	Mt. ID	Wt.%			
		PA 66	*PP*	*SG Fibers*	*SB Fibers*
Blend (PA66/PP)	Blend	80	20	--	--
Blend/glass fibers	Blend/SGF	80	20	10	--
Blend/basalt fibers	Blend/SBF	80	20	--	10
Blend/glass/basalt fibers	BG Hybrid	80	20	10	10

B. *Processing of Composites*

The weight percentage of polymers and fibers as shown in table II is dried out at 85^{0}C for 48 hrs to prevent plasticization, and hydrolyzing effects from moisture to achieve high homogeneousness. The material system as per the table II were prepared and the aggregate was extruded using a twin screw co-rotating extruder. (Brand: CMEI, 16 CME, SPL, 70 cm3 chamber size). The particulars of composites processing using extrusion technique have been addressed elsewhere [15].

C. *Sliding - Wear Measurement (ASTM- G99)*

The composite's dry-sliding wear behavior was calculated in compliance with G99 (ASTM standard). The Pin on disk machine was the experimental setup used for the research. The test samples were cut into 8 * 8 * 3.2 millimeter sizes that are rubbed against the 600 grit silicon carbide paper to ensure a uniform surface for the specimen. The test was carried out on loads of 20, 30, 40 and 50 N and the distances selected for the test were 1000, 2000, 3000 and 4000 metres, with a velocity of 2.5 m/s. The equipment's disk is made of E-52100 steel, hardened to 62 HRC, 165 millimeter diameter and 6 to 8 millimeter in thickness with a surface roughness of 0.82 µm Ra. Test samples were fixed using appropriate adhesive to 8 millimeter diameter steel pins and their initial weights are determined by high accuracy electronic weighing system (0.0001 grams). Before the test, the steel disc surface was washed using a soft paper and acetone. After the proper positioning of the specimen and the disk, a standard load on the pin was applied through the pivoting lever as depicted in figure 1. Once the experiment was completed, the specimen's final weight was noted down along with the pin using electronic weighing system. The initial and final weight of the specimens was reported for all the cases, and the weight loss of the specimen was measured. The composites wear volume loss was evaluated using the equation $\Delta V = W/\rho$ where the weight loss of composites is represented by 'W' and the density by 'ρ'. To obtain steady values, a total of three experiments are performed, and the results were considered to reflect an average value.

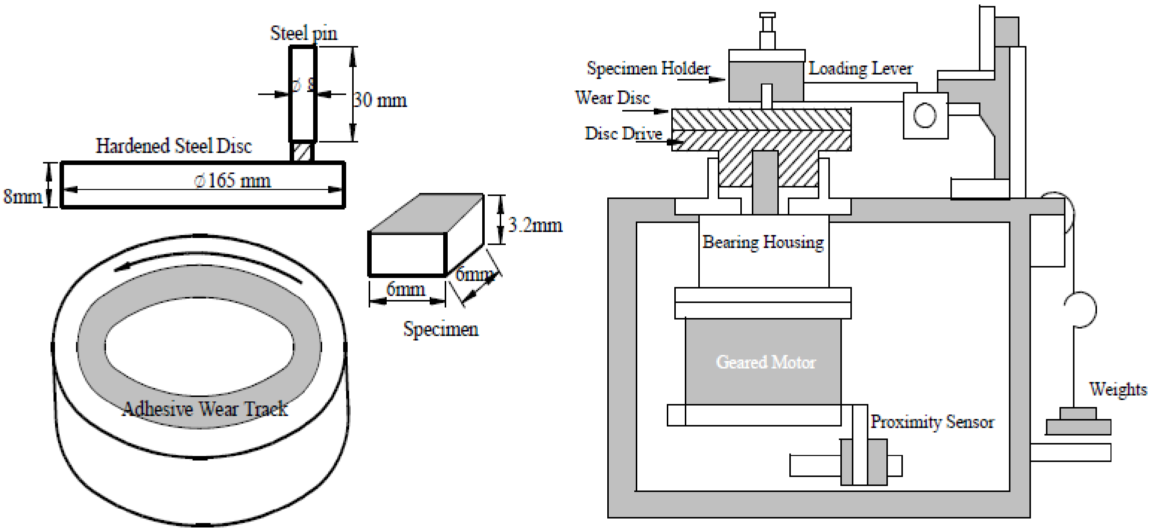

Figure 1. Pin on Disc equipment and components

3. Results and Discussion

D. Sliding Wear Performance of Fiber Filled Composites: Influence of Sliding Pressure

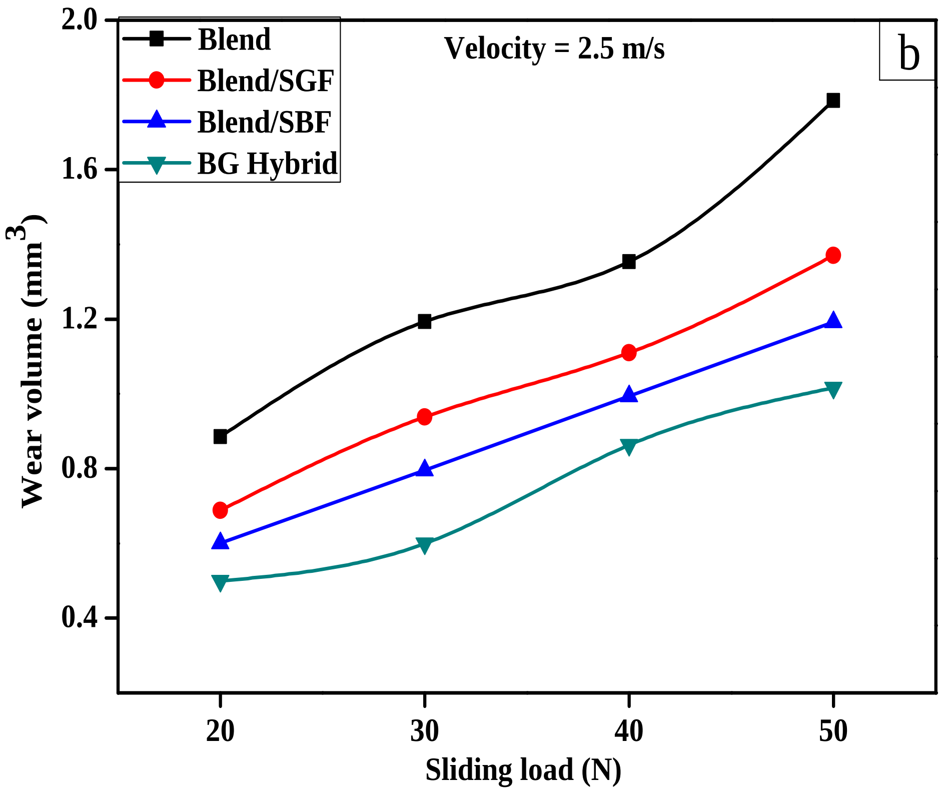

Figure 2. Wear volume of composites under the action of sliding load

The volumetric loss of fiber filled composites under the influence of sliding pressure is depicted in figure 2. The wear performance of composites was evaluated at a velocity of 2.5 m/s for 20 min. It is clear from the graph that; the composites volumetric loss depends on sliding pressure. The volumetric loss of studied composites has been enhanced with rise in sliding pressure. The sliding wear behavior of fiber filled composites has been studied against the blend PA66/PP. The blend exhibited the highest loss of wear among all the composites studied at different applied loads. The maximum loss of wear for the blend is because of increase in frictional shear at the sliding surface. The frictional and wear performance of Polyamide 66 and Polypropylene blend is significantly influenced by the strength of polymer transfer film which is formed on steel counter surface [16].

The influence of SGF addition into the blend reduced the wear loss of composites irrespective of loading conditions. The strong polymer film was formed on the steel surface by the reinforcement of 10 wt. percentage SGF into the polymer blend. The shearing force has been resisted by SGF filled composites at lower load. Yet at higher load, the SGF resists the sliding load by providing good resistance to wear. In this situation, fiber sliding wear is more dominant than matrix wear [17]. Therefore, low wear loss of short glass fiber filled composites.

The influence of SBF addition into the blend exhibits better wear resistance than SGF filled composites. This is due to good load carrying capacity of SBF. At initial load, the matrix wear followed by its melting occurs. But at higher load, when SBF has been exposed to sliding load, resist the wear volume loss. The SBF can retain their strength at higher temperature than SGF.

The effect of fiber hybridization is most important in enhancing composite wear resistance. The BG hybrid composites exhibited minimum loss of wear among all the composites. The collective influence of SGF and SBF, enhanced the wear resistance of hybrid composites. In hybrid composites, SBF has regulated the thermal resistance and restriction of wear growth in composites. Secondly, hard glass fibers minimized the penetration of hard steel asperities and protected the part of the load applied against wear loss of composites. The failure mechanisms such as microcutting and microploughing actions can be reduced [18]. The wear of matrix in more than the fiber wear in composites. Hence, hybrid fibers resist the loss of wear in composites during the sliding.

E. Frictional Behavior of Fiber Filled Composites

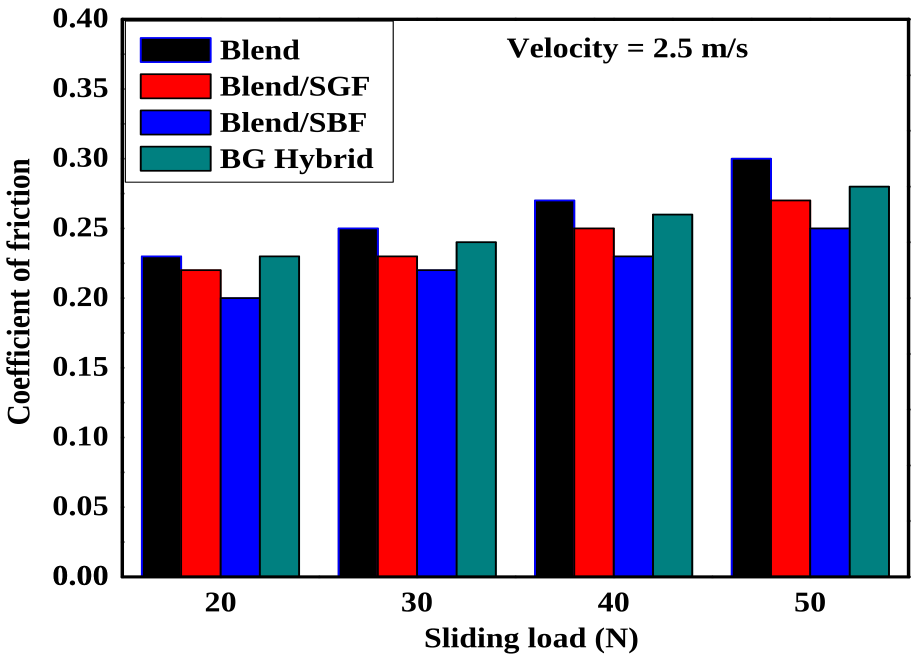

Figure 3. Frictional behavior of composites: Effect of sliding pressure

The frictional behavior of fiber filled composites under the influence of sliding pressure is shown in figure 3. A small change in the frictional constant was observed as the sliding load increased. The increase in sliding load raises the frictional force at the interface, resulting in an increase in the frictional constant. From the experimentation, it is clear that the blend Polyamide 66/Polypropylene exhibited the highest frictional coefficient. This is due to the fact that the shear of transfer film at the steel interface is very severe. Therefore, frictional contacts have been established between the composites and the steel surface. The influence of fiber reinforcement into the blend PA66/PP reduced the frictional constant irrespective of load applied. The fibers SGF and SBF exposed at the sliding surface acts as self-lubricating agents there by reducing the frictional force at the interface. Further, the effect of hybridization of fibers increased the frictional force at the interface due to the more fibers exposure.

F. SEM Examination

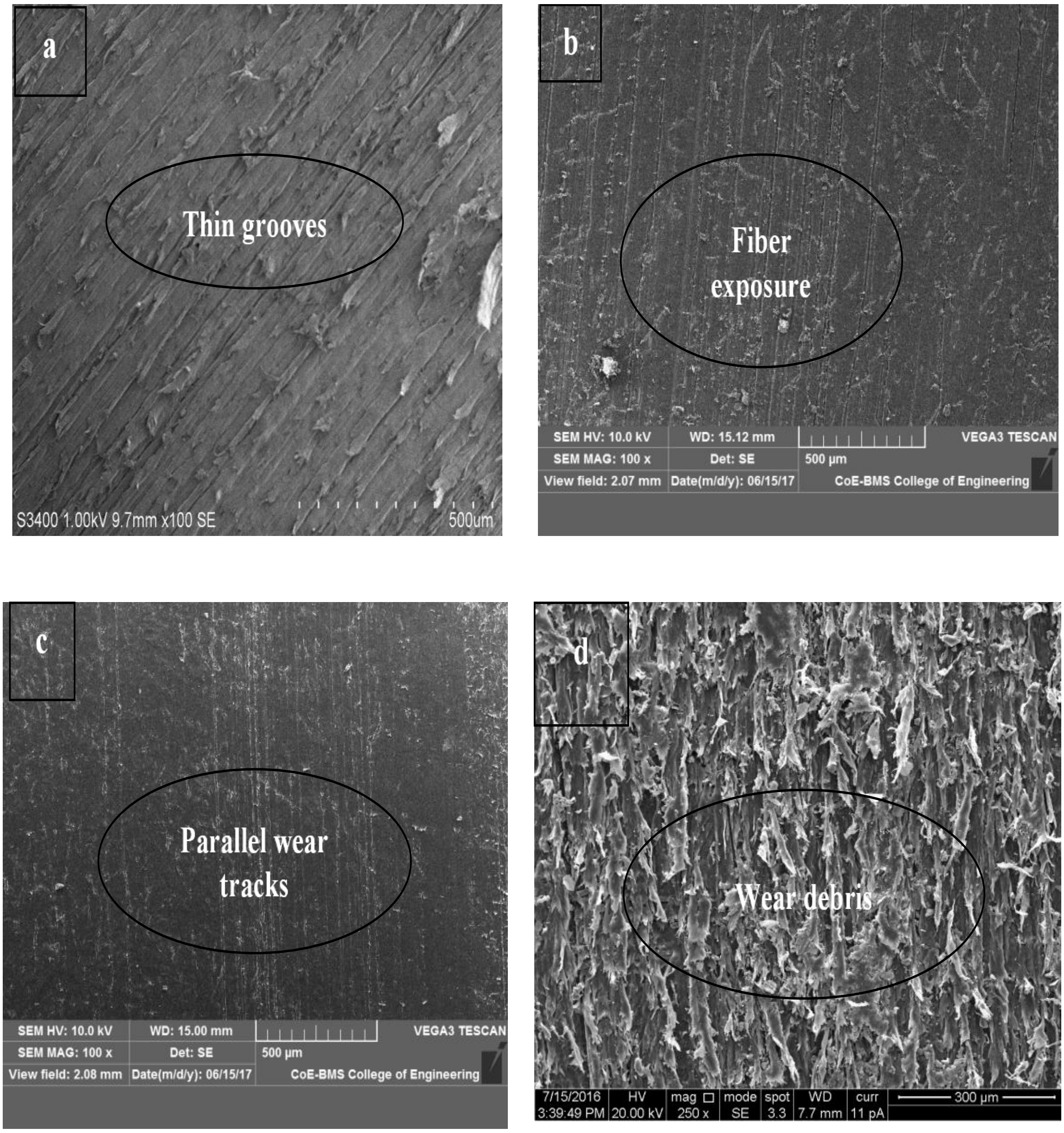

Figure 4. SEM pictures of worn out surfaces of composites: (a) Blend, (b) Blend/SGF, (c) Blend/SBF (d) BG Hybrid

The SEM photographs of worn out surfaces of fiber filled composites under the sliding load are shown in the figure 4 (a-d). The uniform wear tracks parallel to the direction of wear is seen in the figure 4 (a). The effect of matrix melt due to high frictional effects is clearly seen in the picture. The severe plastic deformation due to upper load is exhibited by the SEM picture. The fiber volume fraction affected transfer film formation on the steel counter surface [19, 20]. The fractured glass fibers under the action of sliding load is shown in figure 4 (b). Such fractured fibers plunged into the matrix and surmounted it under greater frictional force. The melted matrix surmounts the fibers and acts as abrasives for the wear resistance. The SEM images of SBF filled composites is depicted in figure 4 (c). The high thermal behavior of basalt fibers regulates the wear behavior of SBF filled composites. SEM photographs of the worn out surfaces of BG hybrid composites is depicted in figure 4 (d). The mutual effect of hybrid fibers supported the applied load resulting in lower wear volume loss. The fiber wear is less when compared to the matrix wear. The wear debris at the surface is seen in figure. The micro cracking, micro cutting and fracture of fibers are some of the failure mechanisms noticed in the course of investigation.

4. Conclusions

The influence of hybrid fibers on the sliding wear performance under the action of sliding pressure of thermoplastic blend composites have been studied. Following are the important facts drawn from the study.

- The composites wear loss depends on the sliding pressure
- The better sliding wear characteristics was exhibited by the fiber reinforced composites
- The sliding wear performance of hybrid composites is greatly improved by reinforcing hybrid fibers under sliding pressure
- The SEM photographs revealed that micro cutting, microploughing, fiber fracture and fiber pullout are some of the failure mechanisms identified in the tribological study of worn surfaces

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