

Three Body Abrasive Wear Behavior of Glass-Basalt PA66/PTFE Hybrid Composites in Multi pass Condition

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ABSTRACT

The three body abrasive wear (3-BAW) of Glass – Basalt hybrid composites is studied. The PA66/PTFE blend(80/20 wt.%), Blend/Short glass fiber(SGF), Blend/Short Basalt fiber(SBF),Blend/10 wt.% SGF/10 wt.% SBF (GB) were the composites selected for the investigation. These composites were fabricated using twin screw extrusion and then subjected to injection molding. The experimentation has been carried out for different load (20 and 30 N) with varying distance through constant velocity (2.5 m/s) as per ASTM G65 method. It is revealed from the experimentation that the fiber filled composites exhibited better abrasion resistance. The hardness of composites, abrasion resistance of fibers and binding energy between the blend associates were found to resist the failure of composites in three body abrasion. Further, the Glass – Basalt composites (GB) exhibits good wear resistance because of their excellent Ratner - Lancaster factor ($\sigma\epsilon$). It is observed that the high crystallinity of GB hybrid composites has supported the abrasion resistance. The hardness ratio between the rubber wheel and the composites is quite greater than unity. On the other hand, plastic deformation, fiber pull out and agglomeration of sand particles along with wear debris were some of the observations made during morphology of hybrid composites through SEM pictures.

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1. INTRODUCTION

The usage of polymers in industries is increasing day by day. Polymers are light in weight with good specific strength and specific modulus. Even though with their good regime, they are facing tough situations in industrial applications. The abrasive wear is one of the critical form of

wear in the field of polymer tribology [1]. There were situations in chute liners, roller guides, automobile reciprocating parts, agricultural equipments, cams and clutch accessories etc., where the effect of three body abrasion is severe. Three body wear is the wear where the critical wear volume loss is contributed by all the three bodies (Rubber wheel, sand particles

and material under test). This mode of abrasion is called three body abrasion. This is most significant in polymer composites. Further, the situation demands for the composites with good strength and tribological resistance. The wear loss during this mode is most significant as it accounts for 30% of the total wear [2]. Some of the important bodies acts as the counterpart are fine sand particles, rubber wheel, brake liners, coal, belts along with lubricants in roller mills etc. The complexity of abrasion resistance is more in polymer composites compared to any other materials [3]. This can be achieved using the concept of polymer blend. The performance of polymer of blend is most promising than the homopolymer in abrasion wear. Some of the polymer blend composites used are PA66/PPS, PEEK/PTFE, PA66/PP, PA66/PAEK and PA66/POM. Many research works revealed that the reinforcement of fibers along with the fillers plays the major role in wear resistance. Further, it was reported that these reinforcements influences the abrasion wear resistance of polymers [4]. Therefore, definite response of fibers on three body abrasion of fiber filled composites must be discussed critically. The 3-BAW behavior of Polyamide 66/Polypropylene nano composites has been reported by Ravi Kumar et al. [5]. Three material systems were selected for the study: Blend PA66/PP, Nano clay filled blend and SCF reinforced nano clay composites. It was showed that the inclusion of SCF into blend was detrimental to 3-BAW resistance of composites. The blend PA66/PP exhibited the better abrasive wear resistance.

The 3-BAW behavior of Polyaryletherketone (PAEK) and its composites has been reported by Harsha et al. [6]. They reported the hybridization effect of short fibers and solid lubricants on abrasive wear behavior. Angular silica sand was used as the third body for the test. They showed that the fiber loading was unfavorable to the abrasive wear resistance of PAEK composites. Further, the synergism between fillers and fibers is more detrimental to the abrasive wear behavior. The hybrid effect of micro particulates on 3-BAW behavior of fillers loaded glass vinyl ester composites has been reported by Suresha et al. [7]. Three material systems were selected for the study: glass -vinyl ester, glass-vinyl ester with SiC particulate, hybrid composite of SiC, graphite filled glass - vinyl composites. They showed that the abrasion volumetric loss of

composites was increased with the raise of abrading distance and load. The hybridization effect of fillers and fibers on 3-BAW behavior of Polyaryletherketone (PAEK) composites was studied by Harsha and Tewari [8]. It was reported that the volumetric loss of composites is greatly affected by abrading distance, load and grain size both in 3-BAW and 2-BAW behavior. They also stated that the synergistic effect of SCF or SGF and fillers increased the wear volume loss of composites. PAEK/20 wt. % SCF exhibited the excellent abrasion resistance among the composites tested for abrasion. The effect of particles on 3-BAW properties of glass fiber loaded epoxy composites has been reported by Patnaik et al. [9]. The fillers used for the study are Alumina, SiC along with pine bark dust. The glass fiber of 10 wt. % was used as reinforcement in composites. The pine bark dust filled Glass epoxy composite exhibited excellent abrasion resistance among the composites studied. The three body abrasion effect of glass fibers (long and short) reinforced epoxy composites has been reported by agarwal et al [10]. They reported the influence of load, velocity and particle size. They suggested that the wear resistance has been decreased with increase in speed and particle size but improved up to 40 wt. % of fiber with increase in speed irrespective of geometry of fibers. The influence of fiber loading on three body abrasion effect of PA66/PP composites has been studied by Lingesh et al [11]. They suggested that the effect of fiber loading improved the abrasion resistance in three body wear mode. They also stated that the glass fiber filled composites exhibits the better resistance in abrasion. The tribological response in three body abrasion of PA66/PTFE blend has been reported by Rudresh et al. [12]. They investigated the influence of abrading load with varying distance through constant velocity of 2.5 m/s. They proved that the addition of PTFE in different weight composition improved the abrasion resistance of composites under lower abrading load. The materials used in agricultural rollers, rotor gears, plastic screws, conveyors are subjected to wear severely under the action of abrasives and metal parts. The knee cap which is designed for medical applications will wear repetitively in three body mode. Therefore, three body wear behavior in multipass condition must be studied systematically.

From the above literature observations, it is believed that the effect of fiber loading on three

body abrasion has mixed response. Further, the abrasion behavior of fiber filled composites in three body mode is very limited in supply. Therefore, systematic investigation is required for the composites. Further, 3-BAW of thermoplastic is very rarely reported. In addition, effect of hybridization of fibers is not reported. Keeping this in view, the 3-BAW behavior of PA66/PTFE blend along with Glass-Basalt hybrid composites has been studied for different load (20 and 30 N) with varying distance at constant velocity of 2.5 m/s. Based on the previous work of authors [11,12,16,17], the weight fraction percentage of fibers and matrix is selected.

2. MATERIALS, PROCESSING AND TESTING

2.1 Materials

The materials used for the production process are PA66, PTFE, Short glass fibres and Short basalt fibres. The material details have been reported in the Table1. Further, the composite material system in weight percentage is also recorded in Table 2.

Table 1. Data of the materials used in the production.

Materials	Properties of Materials			
	Form	Size(μm)	Trade Name	Density (g/cc)
PA66	Granules	---	Zytel 101L NC010	1.14
PTFE	Powder	12-14	MP1000	3.2
Short glass fibers	Cylindrical	Length = 3-4 mm Diameter = 10-20	----	2.45
Short basalt fibers	Cylindrical	Length = 5-6 mm Diameter = 10-20	-----	1.74

Table 2. Composite formulation in weight percentage.

Composite systems	Weight Percentage			
	PA66	PTFE	SGF	SCF
Blend (PA66/PTFE)	80	20	---	----
Blend/Short glass fibers	80	20	10	---
Blend/Short basalt fibers	80	20	---	10
Blend/SGF/SBF	80	20	10	10

Table 3. Factors controlling abrasive wear behaviour [16,17].

Particulars	Blend	Blend/SGF	Blend/SBF	Hybrid (GB)
Ultimate tensile strength (σ)	66.5	76.81	60	88.5
% elongation (ϵ)	16	14.45	12	14
Fracture energy ($\sigma\epsilon$)	10.64	11.09	7.2	12.39
Hardness, H	69	72	60	75
$1/\sigma\epsilon$	0.0939	0.0901	0.133	0.0807
$1/H\sigma\epsilon$	1.362e-3	1.25e-3	2.31e-3	1.76e-3

2.2 Production of hybrid composites

The known weight percentage of PA66, PTFE and short glass and basalt fibres were dried in the heating oven at about 80 °C for 48 hours to relieve them from the effect of moisture and plasticization. There are two stages of production. In the first stage, the blend PA66/PTFE has been subjected to extrusion process to obtain the pellets. In the second stage, all these compositions along with the fibres has been mixed thoroughly in the mixer and subjected to extrusion process. The twin screw extruder chamber consists of five heating zones to heat the material to melt mix uniformly. The temperature maintained in all these zones were 220, 230, 245, 260 and 267 °C respectively. Further, the die has been maintained at a temperature of 65 °C. The feed rate of 5 kg/s with a screw speed of 100 RPM has been used for the production process. The melt mix of composites has been extruded in the cylindrical form through quenching followed by pelletization. The obtained pellets are then subjected to normal heating process before subjecting them to injection molding. The injection molding machine consists of two chambers where the temperature of 60 °C and 70 °C is allowed. The injection pressure of 700 bar along with 2 s ejection time, 10 s cooling time and 5 s ejection time has been permitted to obtain the specimens as per ASTM methods. All the checked specimens were subjected to testing and the defective ones are rejected for the process.

2.3 Three body abrasive wear test (ASTM G65)

The three body abrasive wear (3-BAW) behaviour of polymer composites has been evaluated using rubber wheel abrasion tester as

per ASTM G99 method (Fig. 1). The test sample (First body) has been cut into the required size (25 mm x 75 mm) (Fig.1) and then it is fixed to the place meant for it. The second body (Rubber wheel) and the specimen were fixed in such a way that the proper contact between wheel and the specimen is maintained. The fine silica sand grains of grade AFS 60 with density of 2.4 g/cm³ and knoop hardness of 875 is used as abrasives for the test. The abrasives were supplied to the junction as third body to the path of sliding between rubber wheel made of chlorobutyle-rubber with hardness 58-62 (Shore D) and the specimen. The abrasives are fed at a rate of 275 ±5 g/min. The initial weight of the specimen before abrasion is measured using suitable high precision balance (0.1 mg accuracy). The rubber wheel diameter is 220 mm. The specimen is so fixed that there should be close contact between rubber wheel and contacting specimen. The direction of the wheel and the grains was in the same direction. For the better accuracy, the flow rate of fine grains must be maintained consistently. The flow rate of abrasives has been maintained consistently for better accuracy of results. The final weight of the specimen after rubbing against the rubber wheel is measured. The loss in weight of the specimen (W) is then calculated and this weight loss has been converted to wear volume loss (ΔV) using experimentally determined density (ρ).

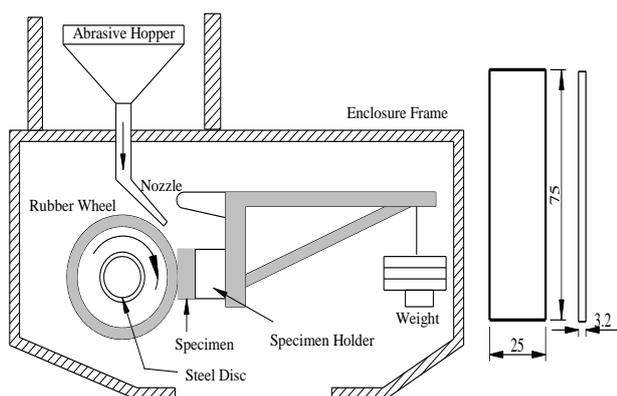


Fig. 1. The experimental set up used for abrasion wear in three body mode (RWAT Machine) (Magnum Engineers, Bangalore).

The wear volume loss ‘ΔV’ and specific wear rate ‘Ks’ polymer composites are calculated using the following equations 1 and 2:

$$\text{Wear volume} = \Delta V = W/\rho \text{ mm}^3 \quad (1)$$

$$\text{Sp. wear rate} = K_s = (\Delta V/ (F*D)) \text{ mm}^3/\text{N-m} \quad (2)$$

where: ρ = density in gr/cm³, F the experimentally applied load in N and D, the sliding distance (m). The details of experimentation for 3-BAW of composites is shown in Table 4.

Table 4. Experimental parameters for three body abrasive wear test (ASTM G65).

Experimental Parameters	
Sliding load (N)	20 and 30
Sliding velocity (m/s)	2.5
Sliding distance (m)	500, 1000, 1500 and 2000

3. RESULTS AND DISCUSSION

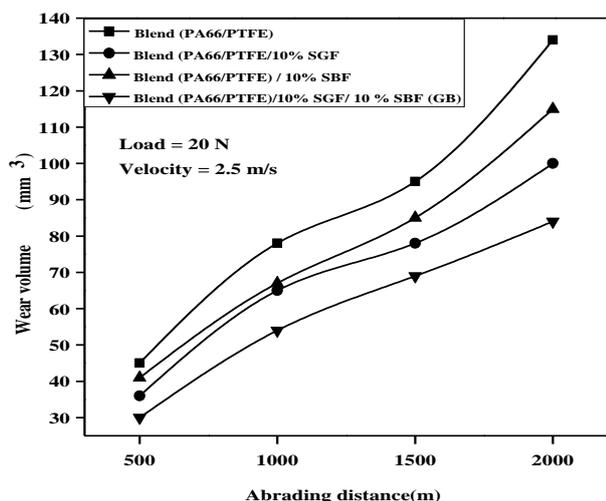
The 3-BAW behaviour of fiber filled composites as per ASTM G65 method has been studied using abrasion testing (RWAT) machine. The experimentation is conducted for a load of 20 and 30 N for a varying sliding distance of 500, 1000, 1500 and 2000 m under the influence of 2.5 m/s sliding velocity with the abrasive particles (Silica sand grains: 200 to 250 μm size)(Table 4). The investigation showed that the influence of hybrid fiber reinforcement promoted the 3-BAW resistance of composites. Some of the important results of 3-BAW are discussed in the following section.

4.1 Tribological response of Glass- basalt (GB) hybrid composites under the action of load and distance : 3-BAW

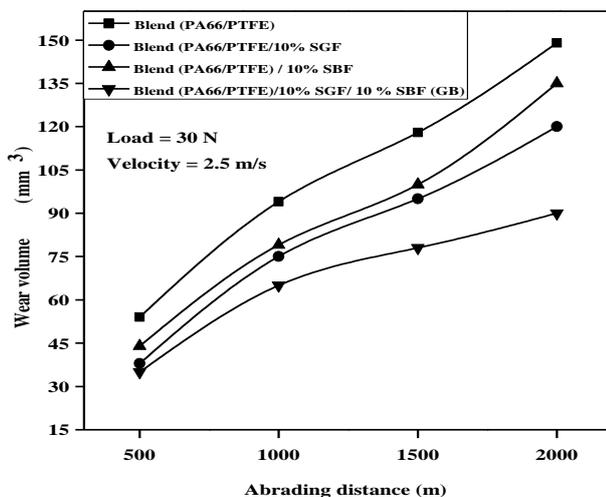
The Influence of abrading load and distance on the volumetric loss of GB hybrid composites in 3-BAW behaviour is shown in Figs. 2a and 2b. It is indicated from the figure that the abrasion wear volume loss in three body mode is a function of load and distance. The volumetric loss of composites increases with the abrading distance. Similarly, higher volumetric loss of GB hybrid composites is obtained because of higher abrading load. The promotion in wear volume loss due to increase in abrading load is attributed to the plastic deformation of composites under the influence of varying abrading distance. Increase in load increased the contact stresses between abrasive wheel and the polymer surface under the influence of sand grains.

The influence of abrading distance on wear volume loss lower abrading load (20 N) is

depicted through the Fig. 2a. The wear volume loss of blend PA66/PTFE is more when compared to other composites tested. At lesser distance, the wear volume loss is 45 mm³. When the distance was increased, the wear volume loss followed the increasing trend. At higher abrading distance of 2000 m, the blend yielded a wear volume loss of 134 mm³ which is 197 % increase over the wear volume loss at lower distance.



(a)



(b)

Fig. 2. The influence of abrading distance and load on the volumetric loss of 3-BAW behaviour of composites: a) Abrading load: 20 N and b) Abrading load: 30 N.

Under low stress, the abrasive grains received the energy from the rubber wheel and then penetrated the polymer surface resulting in the formation of pits [5]. The abrasive particles embedded in the rubber wheel converts 3-BAW behaviour to 2-BAW behavior with multipass condition [13]. These abrasive grains rolled at the interface causing the plastic deformation of matrix. Similar observations are made for other fiber filled

composites at the same load (20 N). The wear volume loss ranging from 36 to 100 mm³, 41 to 115 mm³ and 30 to 84 mm³ for SGF filled, SBF filled and GB hybrid composites respectively.

The reduction in wear volume loss of 20%, 9% and 33.3 % is obtained for glass fiber, basalt fiber and GB hybrid composites at lower abrading distance over the blend respectively. But with increase of 300% abrading distance, 25%, 14% and 37% reduction in wear volume loss of SGF filled, SBF filled and GB hybrid composites were noticed over the blend. It is clear from the above observations that the wear volume loss of composites studied is strongly depends on abrading distance, load and compositions of blend. But the reinforcement effect of fibers is most beneficial for all fiber filled composites.

Similar trend is observed for composites for an applied load of 30 N (Fig. 2b). The higher volumetric loss is exhibited by all the composites at higher load. This is due to high contact stresses of abrasive sand particles against soft polymer surface. The high wear volume loss of blend is due to severe pressure exerted by the rubber wheel along with angular sharp sand particles against flat smooth surface of blend. At the beginning of the process, less number of abrasion particles were in touch with wheel and plastic material [14]. The exerted high stress on smooth flat surface has been shared only by few abrasive sand grains owing to high contact stresses at the interaction region. Hence, these penetrating stresses are more than enough to achieve the failure of matrix and results in more volume loss of blend composites. Further, the hardness ratio between abrasive particles and polymer surface is extremely higher than unity [14]. This resulted higher matrix damage and more wear volume loss. After certain traverses, when the wear track is generated, PTFE present in the blend had smoothed the surface of track by its fibrils to form smooth sliding surface. As the abrading distance was increased, the wear volume loss of composites increased slightly and reached the saturation stage as a result of slight destruction of smooth polymer surface by abrasive sand grains [5,6]. This made the composites to loose more volume of material in later stages.

A unique observation is made from the composite filled with SGF. The SGF filled composites is

characterized by higher hardness. The ratio between hardness of abrasive grains and SGF filled polymer surface found to be little more than unity [8,14]. The sand grains along with rubber wheel failed to get rid of SGFs from composites because of hard fibers which were embedded in the matrix. The bond strength between glass fibers and resin matrix is more effective because of silane coating. On the other hand, when the depth of wear track is more due to increase in distance, more volume of abrasive sand particles were present at the contact surface. Hence, more load shared by more number of sand particles at the contact surface. The contact surface behaves as abrasive surface rubbing against the abrasive grains [6,14]. The energy gained by the abrasive particles was insufficient to remove glass fiber from composite surface. Hence, high wear resistance of composites.

But the wear volume loss of SBF filled composites is more than SGF filled composites. This is purely attributed to lesser hardness of SBF filled composites. Also, basalt fibers are rich in abrasive silica compounds which are responsible for abrasive wear behaviour [7,8]. Therefore, less wear volume loss of composites. When SBF has been exposed to abrasive surface, the silane coated fibers and silica rich surface offered resistance against the abrasive surface. Hence low wear volume loss. But the lesser hardness of composites leads to wear more.

The combined effect of both SGF and SBF played the major role in supporting the abrasive grains load even at higher load and higher distance. As usual, at lesser sliding distance, the wear volume loss is more due to the penetration of fresh polymer surface. More number of abrasive grains penetrated the surface and results in more wear volume loss [14]. The fracture energy ($\sigma\epsilon$) (Ratner-Lancaster factor) of GB hybrid composites is more compared to other fiber filled composites [11,12] (Table 3). The hardness ratio is much greater than unity when compared to all the composites tested [12]. Here the sliding layers of fibers offered resistance to applied load. When the hybrid fibers were exposed to abrasive wheel surface, the abrasive grains who received the energy from the rubbing wheel slid against the exposed fiber surface [8].

The geometry of fibers and interfacial bond between fibers and the matrix were responsible for good wear resistance of fiber filled composites.

The rubber wheel along with abrasive grains ploughed the matrix filled with fibers at high velocity. Due to the difference in hardness between two rubbing surfaces (fiber surface and abrasive wheel surface), the energy imparted by rubbing wheel to abrasive particles was not enough to pull out the fibers from the matrix even at higher velocity [14,15]. The interfacial friction between SGF and SBF has fractured the fibres as an effect of abrasion thereby modifying the smooth surface with full of abrasives and broken fibres. This is the condition of two body abrasive wear (2-BAW) with multipass condition [9]. This result in high wear volume loss at lesser abrading distance. The wear volume loss increases as the abrading distance increases and later it was stabilized to a constant value. The depth and width of wear track has been defined by wheel, abrasive grains, composition of blend and the applied load. The geometry of wear track of GB hybrid composites is small when compared to all other composites. The findings of this investigation are in good agreement with the work of others [14].

Specific wear rate of GB hybrid composites (K_s) is depicted in Figs. 3a and 3b. From the figure, it is found that ' K_s ' of composites depends on distance, load and composition of composites. The wear rate of composite decreases with the promotion of abrading distance and abrading load. The K_s of GB hybrid composites at lesser load (20 N) is shown in Fig. 3a. The K_s of the blend at lower sliding distance is $45 \times 10^{-4} \text{ mm}^3/\text{N-m}$.

The K_s of composites studied was decreased with the rise of abrading distance. It is around $30 \times 10^{-4} \text{ mm}^3/\text{N-m}$ at higher sliding distance which is 33 % decrease. Similarly, the K_s of $36 \times 10^{-4} \text{ mm}^3/\text{N-m}$ to $25 \times 10^{-4} \text{ mm}^3/\text{N-m}$, $41 \times 10^{-4} \text{ mm}^3/\text{N-m}$ to $26 \times 10^{-4} \text{ mm}^3/\text{N-m}$ and $30 \times 10^{-4} \text{ mm}^3/\text{N-m}$ to $21 \times 10^{-4} \text{ mm}^3/\text{N-m}$ was exhibited by glass filled, basalt filled and GB hybrid composites. This is purely attributed to hardness ratio of abrasive wheel and the polymer surface. Initially, the abrasive ploughing of soft polymer surface by hard abrasive wheel resulted more penetration of abrasive grains into the soft surface, thereby removing more amount of material.

The geometry of wheel track increases with increase in sliding distance and more number of abrasive grains embed in the track would roll instead of penetrating on to the surface. This mechanism reduces the wear rate of composites.

But in case of fiber filled composites, the hard fiber surface exposed to wheel track provides the resistance against cutting and ploughing action of abrasive grits [6]. As a result, the frictional sliding between fibers enhanced the opposing capacity of composites against the abrading load. Among the composites studied, the PA66/PTFE blend composites exhibits the highest specific wear rate whereas GB hybrid composites experienced the least wear rate.

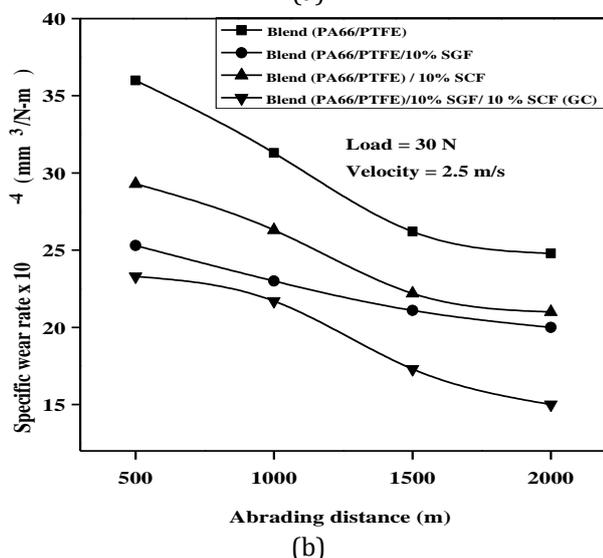
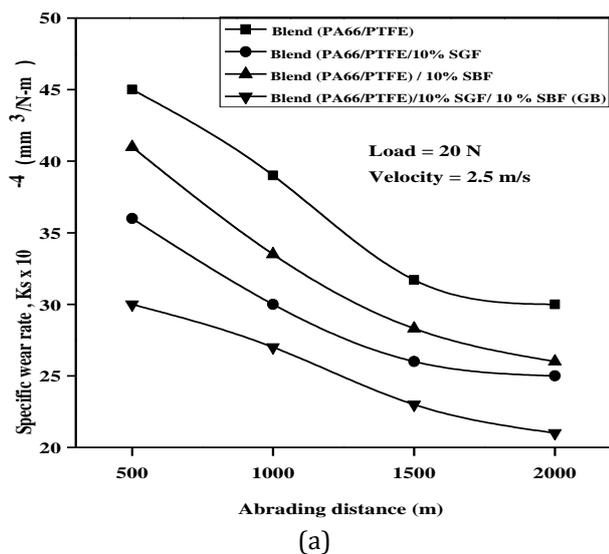


Fig. 3. The effect of abrading load and abrading distance on the specific wear rate of composites in 3-BAW behaviour: a) 20 N, and b) 30 N.

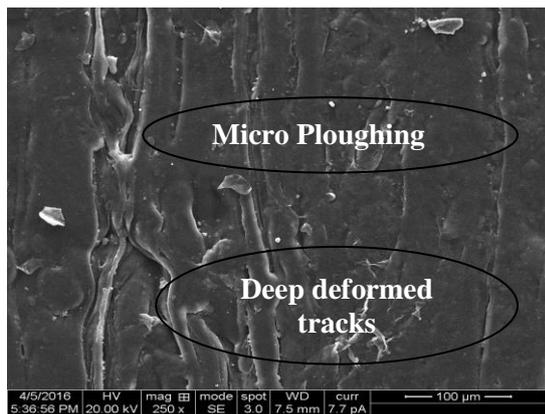
Similarly, at higher load (30 N), the 'Ks' of composites deteriorates with the raise of applied load (Fig. 3b). This is due to the fact that at higher load, the depth of penetration of sand grains on smooth polymer surface is more in the beginning. When the distance is increased, the material removal rate is also decreased due to

rolling action of abrasive grains on the wear track. In this stage, more number of fibres was exposed to abrasion action.

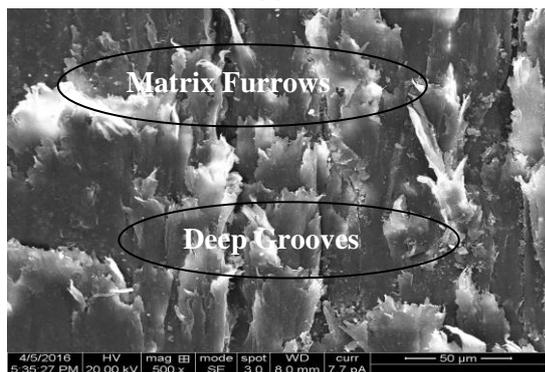
Due to higher hardness of fibers, an appreciable resistance was offered by these fibers against the applied load. Further, the abrasive sand particles require more energy to fail fiber filled composites. Hence, the wear rate of composites is decreased with increase in distance and abrading load. The range of wear rate of fiber filled composites at 30 N was 25×10^{-4} to 20×10^{-4} mm³/N-m, 29×10^{-4} to 22.5×10^{-4} mm³/N-m and 23×10^{-4} to 15×10^{-4} mm³/N-m respectively for glass fiber, basalt fiber and GB hybrid composites. The exhibited results of composites match with the published work [6,14,15].

4.2 Analysis of abrasion effect in three body mode on the abraded surfaces using SEM images

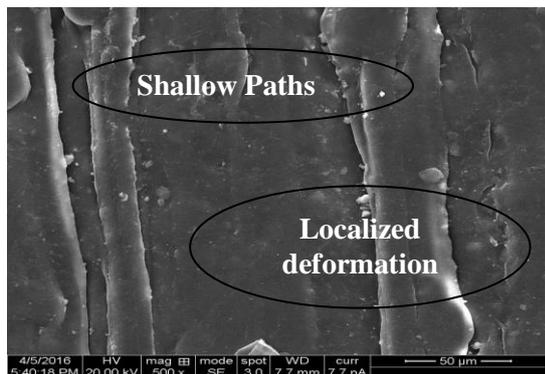
The morphology of abraded surfaces in three body abrasion due to effect of abrasion load and distance of GB hybrid composites has been studied using scanning electron microscope images (SEM). The abraded distance of 500 m and 2000 m were selected for the study under the influence of applied load of 30 N. The SEM images of abrasion surfaces of blend PA66/PTFE under the influence of varying distance is shown in Figs. 4a and 4b. Small parallel tracks are seen due to the influence of abrasives on worn surface of the blend (Fig. 4a). The ruptured sand grains dipped into soft polymer matrix acts as anti-wear agents. Under higher abrading distance, the matrix deformation along with wear debris is seen on the surface. The matrix furrows are resulted as an effect of repetitive stresses on the soft polymer surface. The abrasive grains which were embedded in soft polymer matrix made the surface with full of abrasives and furrows (Fig. 4b). The SEM images of SGF filled composites under the action of sliding distance are depicted in Figs. 4c and 4d. At lower sliding distance, the severe matrix damage and disposition of glass fibers due to abrasion action is seen in Fig. 4c. The fiber fracture and their removal are also seen on the surface. At the beginning of the process, the fresh polymer surface interacted with the third body abrasive sand particles resulting in high frictional shear at the contact surface [14].



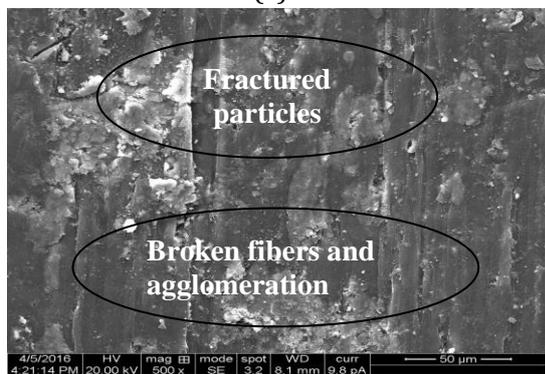
(a)



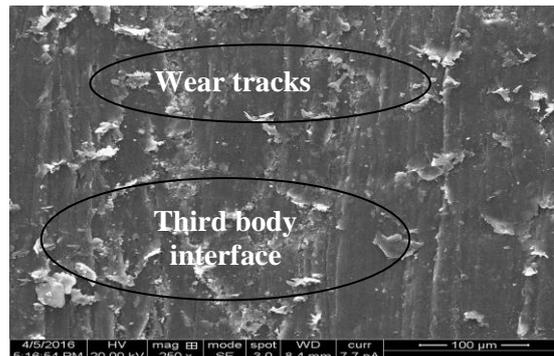
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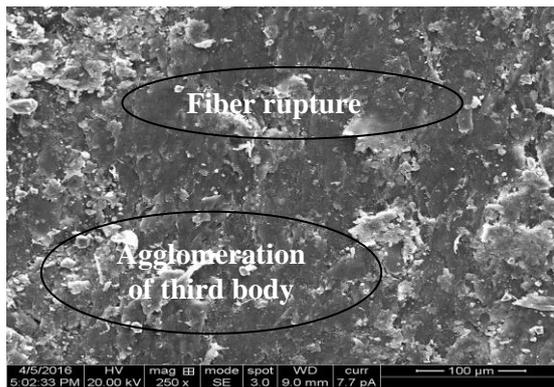
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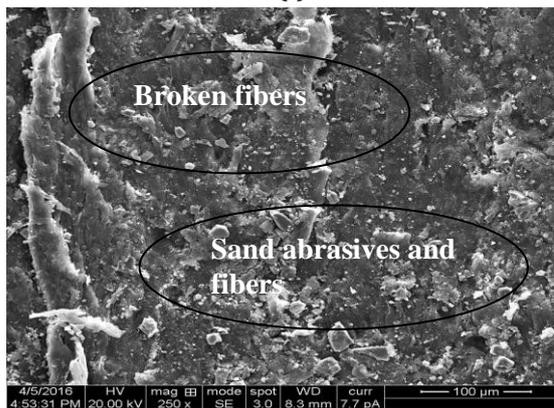
(d)



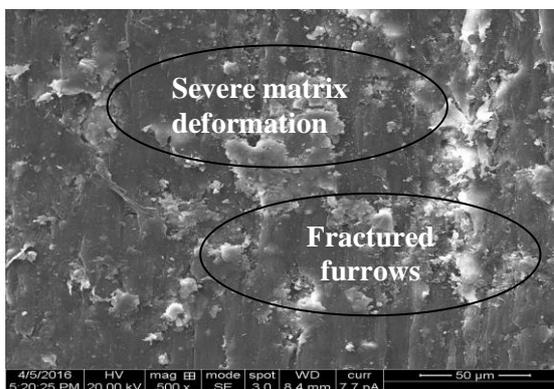
(e)



(f)



(g)



(h)

Fig. 4. SEM images of the worn surfaces of composites studied under the influence of 30 N and varying distance (3-BAW): a) blend (PA66/PTFE) (500 m), b) blend (PA66/PTFE) (2000 m), c) blend (PA66/PTFE)/SGF (500 m), and d) blend (PA66/PTFE)/SGF (2000m).

Fig. 5. SEM images of the worn surfaces of composites studied under the influence of 30 N and varying distance (3-BAW), e) blend (PA66/PTFE)/SBF (500 m), f) blend (PA66/PTFE)/SBF (2000 m), g) GB hybrid composites (500 m), and h) GB hybrid composites (2000 m).

In this situation, more volume of glass fibers were disposed along with the matrix. Hence, low wear volume loss of composites. In addition, glass fiber interaction either physically or chemically is strong with the matrix (Fig. 4d). The same SEM image witnessed the interfacial compatibility of fiber with the matrix.

The SEM images of SBF filled composites under the action of sliding distance is depicted in the Figs. 5e and 5f. The SEM image presents matrix damage followed by its removal due to materialization of micro and macro cracks at the surface (Fig. 5e) [14,15]. This has weakened the toughness of composites. During the initial abrading distance, the deformation of matrix was more. As the distance increases, the severity of abrasion effect increases and due to this the basalt fibres were exposed on the polymer surface.

Therefore, fiber fracture and fiber pull out are observed in the picture. But at higher sliding distance, due to repetitive stresses by the applied load, the hard phase of matrix exposed by the polymer track is exhibited in Fig. 5f.

The SEM images of GB hybrid composites under the action of sliding distance are depicted in the Figs. 5g and 5h. The SEM image exhibits the severe matrix damage followed by deformation due to micro and macro cracks at the surface (Fig. 5g). But the overlapping of fibres is seemed to be less in the picture at lower abrading distance. The abrasion effect has failed to pull the hybrid fibres from the surface. Therefore, less damage to fibres is seen on the surface. The fracture of fibre and their pull out is very less at higher sliding distance. But at higher sliding distance, the hard phase of matrix is slightly exposed by the polymer path. This is exhibited in Fig. 5f.

4. CONCLUSION

The following conclusion has been drawn from the investigation of three body abrasion of Glass-Basalt hybrid composites:

1. The blend (PA66/PTFE) was found to be the suitable base material for glass basalt hybrid composites in 3-BAW process.
2. The 3 - BAW behaviour of fibre filled composites is better than neat blend (PA66/PTFE).

3. It is observed that PA66/PTFE/SGF composites seemed to be promised composites for three abrasion resistance among the single fibre reinforced composites.
4. The hybrid Glass-Basalt composites exhibits the superior three body abrasion wear resistance irrespective of sliding load among the composites studied.
5. Good fracture energy and hardness of hybrid composites promoted their abrasive wear resistance.
6. The three body abrasive wear behaviour of composites studied agrees with the abrasion wear models.
7. The Matrix deformation, severe matrix ploughing, fibre pull out and third body penetration are the impact on the performance of composites.

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