"EVALUATION OF TRIBO CHARACTERISTICS OF HYBRID FIBER REINFORCED WITH AND WITHOUT PARTICLES"

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ABSTRACT

Enhancements of mechanical properties and wear resistance of epoxy using bi-directional fibers (E-glass and basalt) and fillers namely graphite have been systematically investigated in the present study. Fiber reinforced epoxy (G-B/E) filled with graphite (0%, 2%, 4% and 6%) were fabricated using hand layup technique followed by compression molding. Tensile properties were determined to evaluate the effectiveness of graphite fillers on the mechanical properties. The two body abrasive wear behavior was assessed by using a pin on disc apparatus under different loads (10 and 20 N) and different sliding distances (100, 200, 300 and 400 m). Results show that filler improved the mechanical properties and the improvement is more pronounced with the incorporation of graphite filler. The enhanced performance of filler filled G-B/E composites is due to better adhesion and good dispersion of particulates in the epoxy matrix providing increased surface area for strong interfacial interaction and better load transfer. The wear test results indicate that addition of graphite in G-B/E hybrid composites have significant influence on wear behavior under varied sliding distance/loads. The most important concept of this paper is to strength the importance of integrating fibers and functional fillers in the design of wear resistant polymer matrix composites.

Keywords: G-B/E composites, Graphite Filler, Mechanical properties. Wear properties.

1. INTRODUCTION

Over the past decades, polymer matrix composites are made and most widely used for structural applications in the aerospace, automotive, and chemical industries, and in providing alternatives to traditional metallic materials [1]. The features that make composites so promising as industrial and engineering materials are their high specific strength, high specific stiffness and opportunities to tailor material properties through the control of fiber and matrix compositions. Composites are developed for superior mechanical strength and this objective often conflicts with the simultaneous achievement of superior wear resistance [2]. As a result of this, these materials are found to be used in mechanical components such as gears, cams, wheels, impellers, brakes, clutches, conveyors, transmission belts, bushes and bearings. In most of these services the components are subjected to tribological loading conditions, where the likelihood of wear failure becomes greater.

Basalt is a natural material that is found in volcanic rocks. When used as (continuous) fibers, basalt can reinforce a new range of composites. It can also be used in combination with other reinforcements (e.g. basalt/carbon). Since deep studies on this material are only recent, in the last 10 years, number of researchers has been investigating properties and behavior of various composites made of continuous or short basalt fibers [3–9]. The advantages make basalt fibers a promising alternative to glass fibers as reinforcing material in composites, when considering that the price of basalt fibers lies between that of E and S-glass and that it is continuously dwindling as new market opportunities arise [10]. As a consequence, over the last year's basalt fibers have been studied extensively as reinforcement in thermosetting matrices [11–13]. Fiore et al. [14] demonstrate the feasibility of use of basalt fibers in substitution of glass one. To this aim, hybrid composites were manufactured by means of ply substitution techniques and tested by three point bending and tensile tests. It was shown how the substitution of the most external lamina improves the tensile properties in comparison with glass fibers mat fabric reinforced composite. Moreover, this solution was then applied to a naval bulkhead demonstrating that, considering costs, environment impact, and mechanical performances, this kind of material could substitute the traditional glass fiber composites in naval application. De Rosa et al. [15] confirmed that using the stronger basalt fiber at the top and bottom of the glass laminate improved the post-flexural strength of the hybrids. However, it is difficult to transfer the conclusions from one hybrid to the other, as there is currently no theoretical framework available to assess the importance of the various material parameters.

Apart from fiber reinforced composites, the composites made from both fiber/filler reinforcement performed well in many practical situations. The use of fillers in the matrix, gives rise to many combinations that provide increasing load withstanding capability, reduced coefficient of friction, improved wear resistance and improved thermal properties.

The question of why fibers and fillers usually improve the wear resistance of a polymer matrix has been the subject of intense study in recent years Zhang et al. [16] studied dry sliding friction and wear behavior of PEEK and PEEK/SiC-composite coatings and concluded that the influences of SiC fillers in the composite effectively reduce the plough and the adhesion between the two relative sliding parts. Suresha et al. [17] described the role of SiC and graphite on friction and slide wear characteristics in glass–epoxy composites by adding them separately. They stated that the influence of these inorganic fillers has a significant role in reducing friction and exhibited better wear resistance properties under dry sliding conditions.

The present study focuses on the evaluation of the mechanical and two body abrasive wear behavior of glass–basalt hybrid fiber reinforced epoxy composite with and without filler like graphite. (0, 2, 4 and 6 wt. % each).

2. EXPERIMENTAL

A. Materials

Two types of reinforcement used in the present study are basalt fabrics, 360 g/m^2, plain-weave (warp 5F/ 10 mm, weft 5F/10 mm), tex 330, and E-Glass fabric, 360 g/m^2 , plain-weave (warp 5F/10 mm, weft 5F/10 mm), tex 330 (Suntech fibers Ltd.). The matrix used is an epoxy (LY556) is a bifunctional one that is diglycidyl ether of bisphenol-A (DGEBA) and the high temperature hardener HT972 is a solid, aromatic amine, viz., 4,4' – diamino diphenyl methane (DDM). The resin and hardeners were kindly supplied by M/s. Huntsman Advanced Materials, Mumbai. The wt. % of glass and basalt fibers in the final formulations was varied and is listed in Table 1.

B. Preparation of Composite Laminates

The epoxy resin is mixed with the hardener in the ratio 100:28 by weight. Dry hand lay-up technique is employed to produce the composites. The stacking procedure consists of placing glass and basalt fabric one above the other with the resin mix well spread between the fabrics to obtain hybrid fiber reinforced composites. A porous Teflon film is placed on the completed stack. To ensure uniform thickness of the sample a spacer of size 3 mm is used. The mold plates have a release agent smeared on them. The whole assembly is pressed in a hydraulic press at pressing temperature and pressure of 100^{o}C and 0.5 MPa. The laminate so prepared has a size 500mm X 500mm X 3 mm was kept it in a hot air oven at a temperature of 120^{o}C for 2 h. To prepare the particulate filled fiber reinforced composite graphite powder (average particle size of about 10 µm) is mixed with a known weighed quantity of epoxy resin.

Table 1. Weight percentage of matrix, fiber and filler of prepared composites

S. No	Sample code	Matrix wt. %	Fiber wt. %	Filler wt. %
1	GB-E	45%	55% (50%Glass-50%Basalt)	-
2	GB-E+2Gr	43%	55% (50% Glass-50% Basalt)	2% Graphite
3	GB-E+4Gr	41%	55% (50% Glass-50% Basalt)	4% Graphite
4	GB-E+6Gr	39%	55% (50% Glass-50% Basalt)	6% Graphite

C.Mechanical and wear characterization

Tensile testing was performed according to ASTM D 638 using a universal testing machine. The test was conducted at a crosshead speed of 5 mm/min at room temperature.

A pin-on-disc wear test apparatus was used for the two body abrasive wear experiments (asperASTM-99standard). The test was conducted on a track of 100mm diameter for a specified test duration, applied load and sliding velocity. The surface of the specimen was perpendicular to the contact surface. The surfaces of both the specimen and the disc were cleaned with a soft paper soaked in acetone before the test. The initial and final weights of the specimen were measured by using an electronic digital balance with an accuracy of 0.0001g. The difference between the initial and final weights is the measure of weight loss. The corresponding graph is plotted for weight loss v/s sliding distance.

3.RESULTS AND DISCUSSION

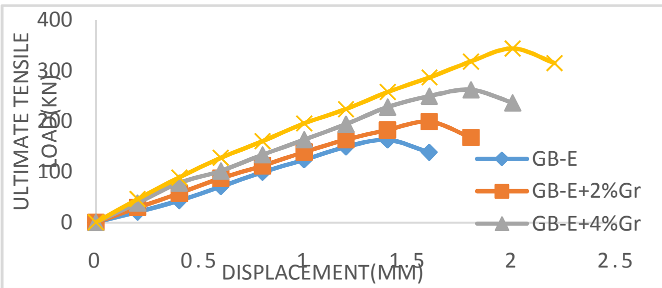
A. Mechanical characterization

Table 2. Mechanical properties of prepared composites

Composites	Tensile strength MPa	% of Elongation	Ultimate Tensile Load(KN)
GB-E	162.98	1.75	6.27
GB-E+2Gr	198.85	1.47	7.65
GB-E+4Gr	261.88	1.13	9.97
GB-E+6Gr	343.51	1.06	13.49

Figure 1. Typical load as a function of displacement of unfilled and filled GB-E composites.

Fig. 1 shows typical tensile load versus displacement curves of glass fiber, basalt fiber and unfilled and filled hybrid (glass-



basalt) fiber reinforced epoxy composites. Here the load linearly increased with increasing displacement until reaching failure of all the samples.
From the result it is observed that basalt fabric type shows an increase of 5% of the tensile strength when compared with glass fabric reinforced composites. Hybridization of glass and basalt fiber (GB-E) showed the tensile strength of 343.51 MPa which is about 13.5% and 8.5% higher than the plain glass and plain basalt fiber reinforced composites as listed in table 2. This is due to positive hybridization between glass and basalt and also the better interfacial bonding between the fiber and matrix. Further incorporation of graphite particles into GB-E composite increases the tensile strength and modulus. This may be due to good particle dispersion and strong polymer/filler interface adhesion for effective stress transfer. But increase in addition of graphite content up to 6% weight to the composites the tensile strengths and modulus is found to be less this is due to more filler material in the composites damages matrix continuity, less volume of fiber and more void formation in the composites. A behavior was observed by Wittek and Tanimoto [18]. The GB-E with graphite particle composites showed a rapid load rise, the highest maximum load, and catastrophic failure. This means that the composite failed in a brittle manner. On the other hand, the GB-E showed a slow load rise, large yield displacement, and the lowest maximum load. This behavior suggests that the composite failed in a ductile manner because of the high elongation property of basalt fiber.
From the obtained result, it is also observed that addition of graphite filler particles enhances the Tensile strength of GB-E composites. Graphite particles filled GB-E composite showed the highest improvement in tensile strength from all the samples. The increased tensile properties signify that graphite particles were homogeneously dispersed in the epoxy matrix.
Table 2 shows that ILSS of GB-E composite is higher than that of pure glass and basalt fiber reinforced composites. This confirms that a good bond exists between the two different fibers and epoxy resin. Further with the incorporation of graphite particles in GB-E composite increases the ILSS. It shows the better graphite particles dispersion in the epoxy matrix. From among the samples GB-E+2Gr showed the best result in the improvement of ILSS.

A. Wear analysis

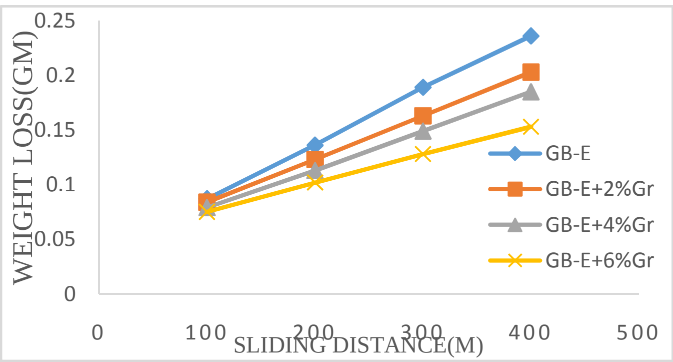


Fig.2 Wear volume loss of unfilled and graphite filled GB-E samples at 10 N.

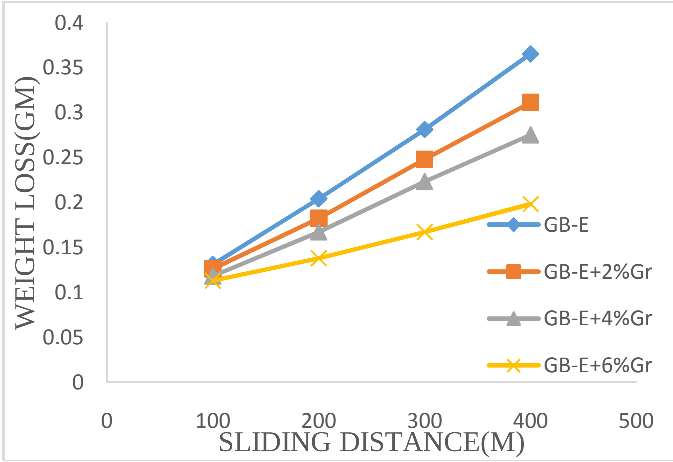


Fig. 3 Wear volume loss of unfilled and graphite filled GB-E samples at 20 N.

Fig. 3 shows the wear volume as a function of sliding distance for unfilled GB-E and Gr and filled GB-E composites at different loads.
The wear data reveal that the wear volume tends to increase near linearly with increasing sliding distance and strongly depends on the applied load for all the composites tested. It was observed that the wear performance is improved for GB-E composite due inclusion of fillers namely Graphite. Among the composites studied, the wear resistance trend occurred in the order: Gr-GB-E > GB–E for two different loads of 10 and 20 N. The variations in the specific wear rate with sliding distance at 20N load are shown in Fig. 3 (a and b), respectively. In the present study, GB–E composite was fabricated by hand lay-up technique followed by compression mouldingcharacterized by the resin rich top layer. Abrasive wear tests were performed on as cast surface of the composite without disturbing its original surface.
Thus, in the initial stage of sliding, matrix is in contact with steel disc and has less hardness compared to that of hardened steel, resulting in severe matrix damage and the rate of material removal is very high. Similarly, when glass and basalt fibers are in contact with steel disc bi-directional fibers provide better resistance to the process of sliding.

The filler such as Graphite was observed to be beneficial to wear performance and shows better wear resistance compared to unfilled and filled GB-E composites at two different loads.

5. CONCLUSIONS

Some important conclusions of this investigation are:

- The incorporation of micron sized fillers improves the mechanical properties such as tensile strength/modulus of GB-E composite. The improvement is more pronounced with the combined addition of graphite microfiller in to the GB-E system.
- The improved results are obtained with 2 wt%, 4 wt% and 6 wt% of graphite filler loading in respect of tensile

properties of GB-E composites. The tensile strength show an increase of 5%, 13.5% and 35% respectively as compared to unfilled GB-E composite. The enhancements in mechanical properties are attributed to the good dispersion of particulates in the epoxy matrix which lead to high surface area for strong interfacial bonding, and better load bearing from hybrid fibres.

- The wear volume was less in the composite material with 6% Graphite filler compared to unfilled composite material, due to high strength and good lubricating characteristics of filler.

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