Track: -1 Machine Design

Stacking sequence effect on dry sliding wear behavior of hybrid Basalt/Glass fiber reinforced epoxy composite

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Abstract

This study examined the dry sliding wear behavior of Basalt/Glass fiber hybrid laminate composites under various stacking sequences. The usual hand-lay-up technique associated with heat gun to avoid possible entrapment of air bubbles during fabrication has been utilized to fabricate the composite laminates. The abrasive wear behavior of the composite samples for different sequences (BBBB, BGGB, BGBG, GBBG) were investigated on a pin-on-disc machine using 400 grade abrasive paper. Experiment were conducted with applied normal loads of 10N, 15N, and 20N with sliding velocities of 1m/s, 2m/s, and 3m/s for a fixed sliding distance of 1000m. The experimental analysis reveals wear resistance enhancement with reinforcement of basalt and glass fiber as compared to neat epoxy composite. It was also observed that GBBG hybrid composite shows maximum wear resistance in comparison to other sequenced hybrid composite, irrespective to normal loads and sliding velocities. The failure mechanism of fractured and worn surface were also analyzed by Scanning Electron Microscope (SEM) and reported in this paper.

Keywords: Hybrid composite, Basalt fiber, Stacking sequence, wear, SEM

1.Introduction

In context to environment, economic competition, and sustainable growth, the researchers and the industrialist are looking for an environmental friendly material to match the environment standard. Therefore, there is great need to develop composite that should be environmentally friendly and also low cost. A composite material is a non-uniform solid produced by combining two or more materials that are mechanically bonded together. Each material in a composite retains its properties, and when combined, their combined properties improves their properties as individual solids [1–5]. In general, composites are composed of two phases, the matrix and the reinforcement. The matrix serves to bond the reinforcements, which in turn, increase the strength of the composite [4,6,7]. Now a day industries are started gaining interest in mineral fiber reinforced polymer composites (MFRPCs) because of its low density, high specific strength, high heat resistance which make MFRPCs an appropriate material for tribology application. The tribological performance of any composite depends on the characteristics of its reinforcement. Among the various available reinforcement glass fibre reinforcement is usually used is dry sliding wear components like bearings, belt drive etc. Wear is defined as the removal of material from a solid surface by mechanical action exerted by another solid material, when two solid body have relative motion with respect to each other, then due to friction the body start removing material and the phenomena is called wear. The presence of wear may be good or bad like friction. Controlled wear can be found productive in many mechanical operations like machining, grinding, polishing. But in most of the technology application occurrence of wear is undesirable and it is an expensive problem because it leads to deterioration or even failure of the components. Wear is classified as abrasive, adhesive, surface, erosive, corrosive wear. Among all form of wear, abrasive wear is most important wear because it contributes almost 63% of total cost of wear. Abrasive wear occurs when hard particles are forced against and moved against a solid surface. There are two form of abrasive wear, first one is two-body abrasive wear which occur when hard particle remove material from other surface and the second one is three-body abrasive wear in which particles are not constrained, and are free to roll and slide between the surfaces.

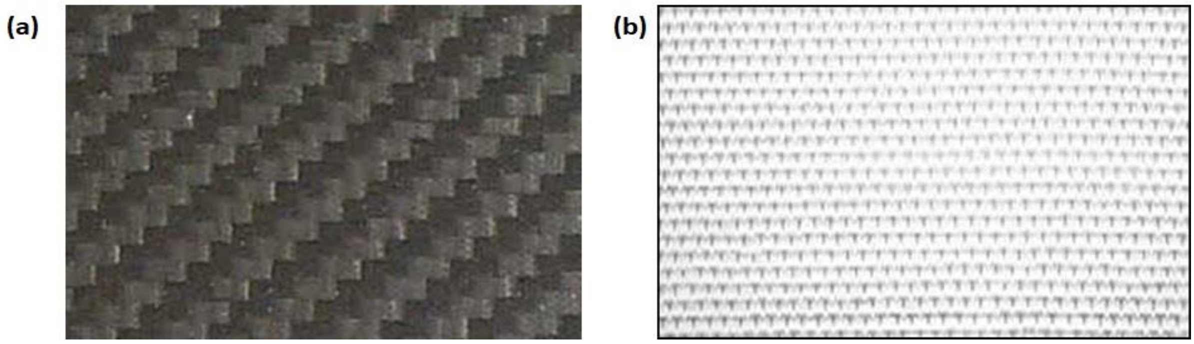
Now a day's basalt fiber has become more popular than other fiber because of its low cost, superb mechanical properties, good abrasive resistance. Several work has been done in the improvement of basalt-fiber reinforced epoxy composites. Basalt fiber is the most preferred fiber among the available natural fiber because of its low cost and excellent wear property.

In recent year much research was done in the development of basalt fiber and many researchers was studying to find out its more advantages over conventional materials. One such matrix is an epoxy resin which is extensively studied because of its low cost, excellent mechanical property. The wear property of basalt-glass epoxy composite, determine its acceptance in tribological applications. In this regard the aim of this article is to study the dry sliding wear behavior of basalt-glass fiber reinforced epoxy composite. Therefore, the basalt have become the most popular and are widely applied in various types of industries [8–12].

2. Materials and Methods

2.1 Materials

Basalt is obtained by melting the volcanic rocks and from basalt, basalt fiber is obtained.
The fiber used here is basalt of density 2.65 g/cm^3 and reinforcement used here is E-glass of density 2.54 g/cm^3. The epoxy matrix used here is of medium viscosity epoxy resin (LY556) with density of 1.15-1.20 g/cm^3 and a hardener of (HY951) which can be cured at room temperature, both the epoxy resin and the hardener is supplied by CIBA GEIGY Ltd. Which is a Switzerland based pharmaceutical company. The composite consists of bidirectional woven basalt and glass fiber which is labeled uniform is shown below.



2.2 Composite Preparation

The composite was fabricated by using hand-layup techniques by using heat gun to remove the air bubbles present in epoxy. First the mold of dimension $300\times 100 \times 3$ mm^3 was prepared by using wood. The composite preparation involves the mixing of epoxy resin with hardener in 10:1 ration, which means for 10 party of epoxy resin only 1 part of hardener was used. The perplex sheet of size $400mm \times 200mm$ was used as base, the mold was cleaned using acetone to ensure that no dust particle present in the mold.

The first layer of matrix was put in the mold and with the help of brush it is uniformly distributed and then heat gun was applied to remove the air bubble present in matrix and then the first layer of fiber was placed, after that a roller was applied on the fiber to get uniform thickness. After the first layer was completed the second layer of matrix was applied on the first layer fiber. Then with the help of brush the epoxy is uniformly distributed and then heat gun was applied to ensure there is no air bubbles, after that the with the help of roller the fiber is pressed by using hand to get uniform thickness. The above process was repeated until we get the four-layer composite. After all the layers of fiber was placed in mold, a top layer of perplex sheet was put over the mold very carefully to ensure that no air trap inside the perplex sheet. After that load was applied over the fabricated composite and keep it aside for 72 hours to cure. Finally, the laminated composite was taken out from mold and trimmed to the required dimension.

Composites of different stacking sequence of basalt and glass fiber was fabricated by following the steps discussed in above paragraph.

First composite sequence consists of all the four layer of basalts fiber – BBBB

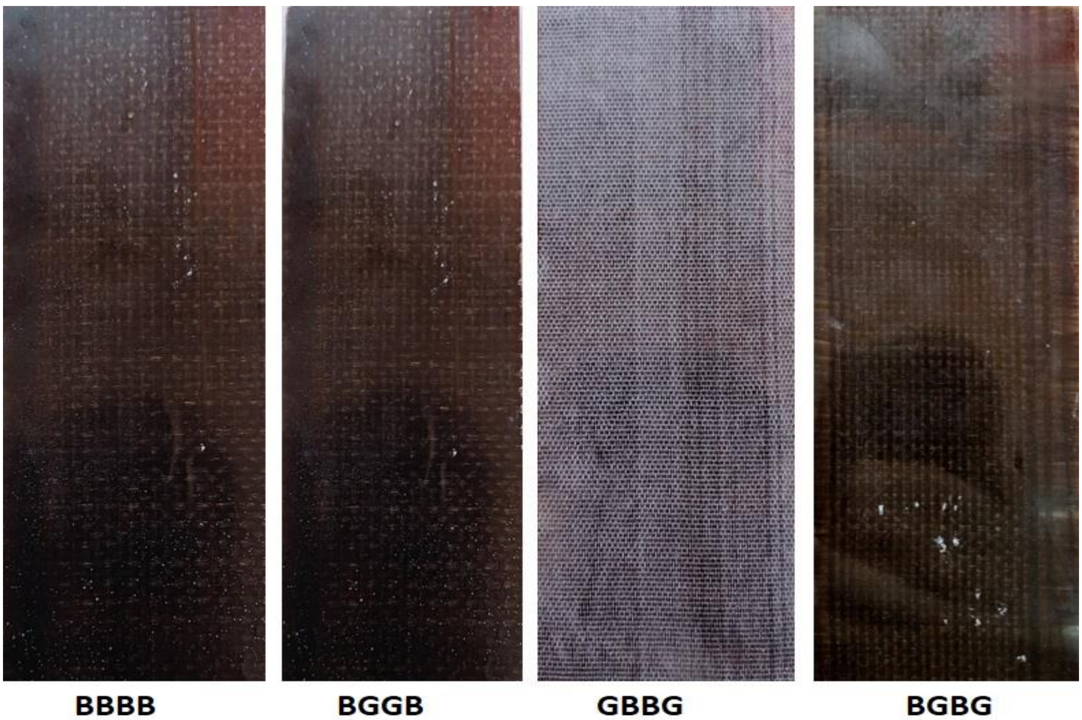
Second composite sequence consists of top and bottom layer basalt fiber and middle two-layer fiber glass –BGGB

Third composite sequence consists of consecutive layer of basalt and glass fiber –BGBG

Fourth composite sequence consists of top and bottom layer glass fiber and the middle two-layer basalt – GBBG

The last composite is Neat Epoxy whose results is compared with the hybrid basalt-glass reinforced composites.

Figure:- 1 shows the images of the fabricated composites samples



2.3 Dry Sliding Wear Experiment

The dry sliding wear experiment was conducted on pin-on-disc machine (as pes ASTM G 99 standard) shown in figure.

The test specimen of dimension $20mm \times 10mm \times 4mm$ was cut from the samples by using Scroll Saw machine. The surface which was going to be rubbed was made uniform by polishing it with SiC paper of 600 grade and then cleaned with soft paper soaked in acetone and thoroughly dried before the test. The specimen weight was measured before the experiment by using an electronic weight measuring device. The specimen was put inside the sample holder and then the specimens were abraded against the Silicon carbide(SiC) abrasive paper of 400 grade at a constant running speed in multipass condition. The hard surface of SiC abrade the surface of test sample. The experiment were conducted at an applied normal loads of 10N, 15N, and 20N with sliding velocities of 1m/s, 2m/s, and 3m/s for a fixed sliding of $1000m$. The weight and height of test samples were measured before the experiment and then immediately after the experiment, and then the weight loss and height loss were calculated. The specific were rate (Ks) of the composite samples were calculated as:

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

Where ΔV is the change in volume loss (m^3), L is the load in (N), and D is the sliding distance in (m). The worn surface of the test samples was gold sputtered before using scanning electron microscope. The SEM images of the worn surface is shown if figure.

3.RESULTS AND DISCUSSION

3.1 Effect of Sliding Distance and Velocity on Friction Force:

Figure shows the plot of friction force versus sliding distance for BBBB, BGGB, BGBG, GBBG, and NEAT EPOXY composite. The abrasive wear data of basalt-glass hybrid epoxy composite and the neat EPOXY for the total sliding distance of 1000m was noted. The figure shows that the friction force attains the steady state-state value immediately after the start of the experiment. As the load and sliding velocity increase the friction force also increases. The increment in friction force was about 20% when the load increased to 15 N from 10 N, similarly when the load was increased to 20 N from 10 N the increment if friction force was about 60% at a constant speed of 1 m/. Friction force plays an important role in the wear of polymer matrix composite. The sliding distance and the normal load are the main parameter on which abrasive wear depend. When the load and sliding velocity increases, the pressure on the face disc increases and hence the friction force increases. Thus the wear rate also increases.

It was observed that the friction force of neat EPOXY composite was higher as compared to basalt-glass hybrid composite at all normal load and sliding velocity. It was also observed from the figure that the limiting friction force for BGBG sequence composite is lowest compared to other sequence layer irrespective to load and sliding velocity.

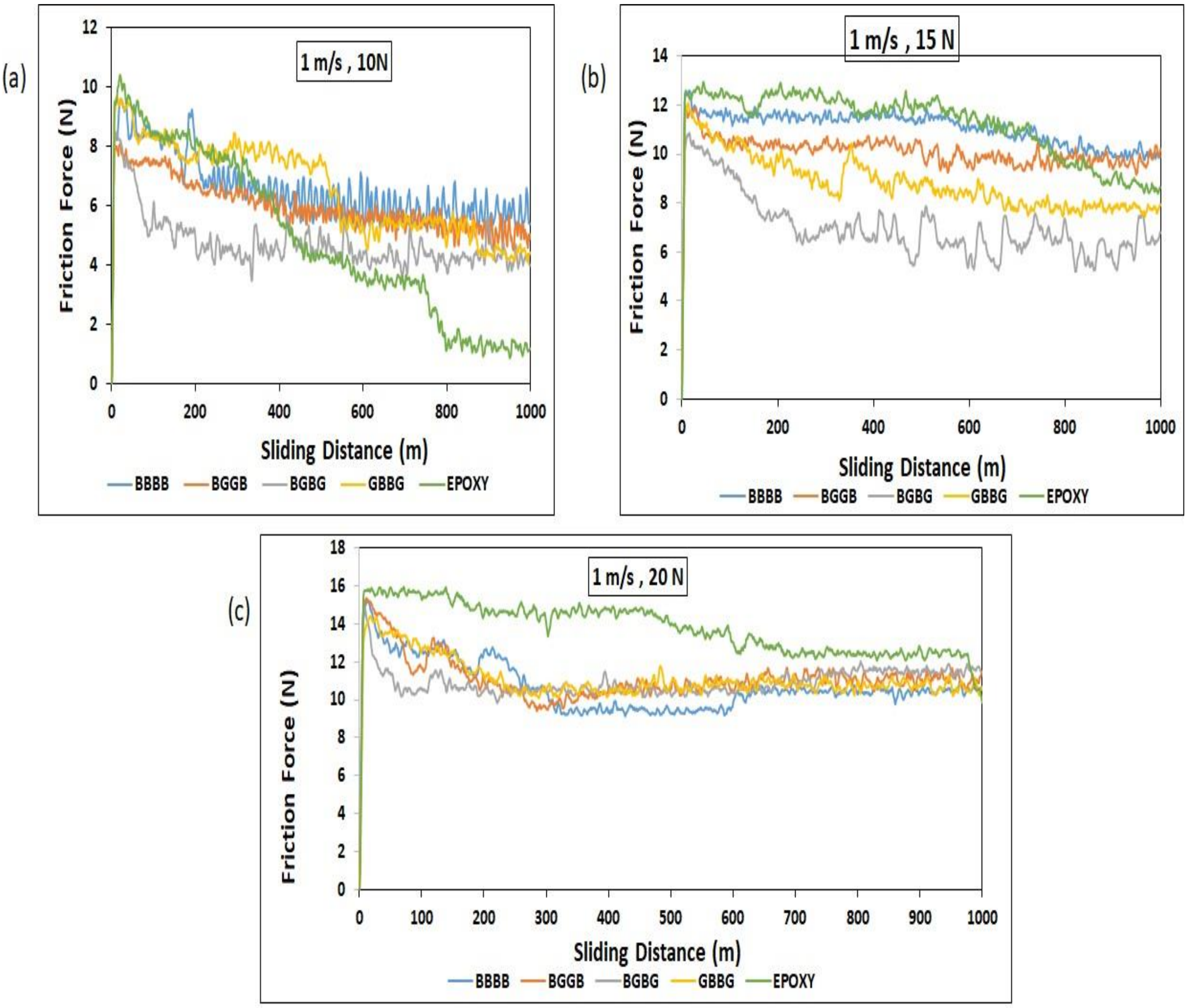


Fig: -2 Effect of sliding distance on friction force at a normal load of (a) 10 N load, (b) 15 N load, (c) 20 N load for Neat EPOXY and Basalts-Glass Hybrid composites

Fig: -3 Shows the variation of friction force with sliding distance for normal load of 10 N, 15 N, and 20 N

From fig.3 it can be understood that the friction force goes on increasing with load, as we increased load to 20 N from 10 N the friction force has increased by 75 %.

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3.2 Specific Wear Rate of Basalts-Glass Hybrid Composites

Generally, composites have superior tribological property than any other conventional materials. Therefore, to improve its tribological property it if usually reinforced with different material. During the two-body abrasive wear experiment it was observed that the neat EPOXY composite was having highest wear rate compared to basalt-glass hybrid composite. SWR of neat Epoxy and the basalt-glass composite are shown in figure. Figure shows the variation of specific wear rate with respect to sliding distance. In general process it was also seen that the normal load plays an important role in distortion and deterioration in the neat EPOXY and basalt-glass hybrid epoxy composite. On increasing sliding velocity, normal load, sliding distance the values of SWR varies. It was seen that the trend of SWR is higher for the load of 30 N. This can be possible because of the axial thrust load of

30 N. At higher load the debris of neat Epoxy and the composite were deforming plastically and a new layer of thin neat Epoxy or composite comes in contact with the abrasive paper.

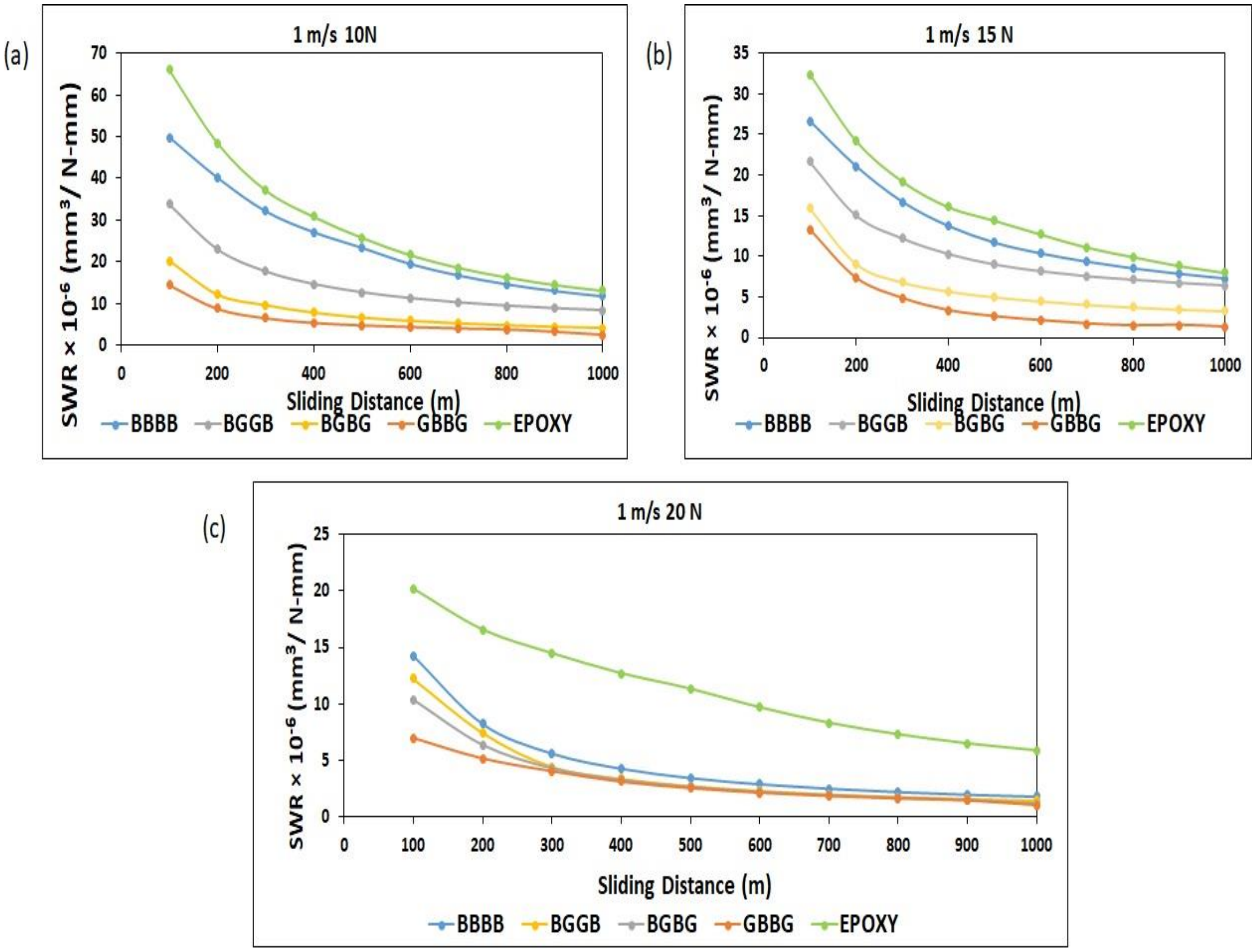

Figure: - 4 shows the variation of SWR with respect to sliding distance

Conclusion

The following conclusion were drawn from the experimental study on two body dry sliding wear behavior of basalt glass reinforced hybrid epoxy composite.

- A good bonding between basalt fiber and the matrix has a positive influence on the behavior on the abrasive were behavior
- Basalt fiber prove to be effective in increasing the wear resistance of the composites.
- Glass composites are detrimental to abrasive wear due to poor bonding between fibers and resins.
- The analysis of the worn surface of glass composites revels that the matrix was, breakage of fiber, and fiber pull out due to the abrasive wear of the SiC particle.
- The output of the result suggest that basalt fabric resin forced epoxy composites has the possible application in the abrasive wear situation, owing to its better abrasive wear resistance and good mechanical property. However, this situation may differ from other.

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