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EVALUATION OF MECHANICAL AND TRIBOLOGICAL CHARACTERIZATION OF GLASS-BASALT HYBRID COMPOSITES

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ABSTRACT

Fiber reinforced polymer composites (FRPCs) are used in almost all type of advanced engineering structures like aircraft, boats, ships and, helicopters, automobiles, sporting goods, chemical processing equipment etc. In the field of composite materials the fiber reinforced composite consisting of one fiber is used for long time. The results would have appeared for certain area. This is because use of single fiber consisting of limited property. To overcome this problem the use of another fiber is made. This results in the form of hybrid composite. In this paper glass and basalt fibers are used in the form of hybrid composite. The characteristics of both the materials are discussed here.Epoxy binders are widely used as matrix in many FRPCs. They are a class of thermoset materials provide a unique balance of chemical and mechanical properties. For epoxy based fiber laminates, the typical reinforcements are glass, carbon, aramid and basalt fibers have been used to improve the overall properties of the composite laminate. By adding the filler to the composite material we can further improve the performance of composites. The filler use in this paper is the silicon carbide. The silicon carbide is known for its high hardness. Now a days hybrid composites used in the high level applications.

KeyWords: *Composite materials, Hybrid composite, silicon carbide, Basalt fibers, Glass fibers.*

1. INTRODUCTION

A composite is a structural material that consists of two or more combined constituents that are combined at a macroscopic level and are not soluble in each other. One constituent is called the reinforcing phase and the one in which it is embedded is called the matrix. The reinforcing phase material may be in the form of fibers, particles, or flakes. They consist of mainly three different types. Among them polymer matrix composite (PMC) and metal matrix composite (MMC) are the commonly used in large scale. Fibers place an important role in the field of industries, automobile, military applications.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.

Fiber reinforced polymer composites (FRPCs) are used in almost all type of advanced engineering structures like aircraft, helicopters, boats, ships and off-shore platforms, automobiles, sporting goods, chemical processing equipment etc. A key factor driving the increased applications of composites over the recent years is the development of new advanced forms of FRPCs. These include developments in high performance resin systems and wide variety of fabric reinforcement.

Due to environmental issue natural fibers are widely used as reinforcement for polymer composites. Despite the advantages of natural fibers over traditional ones (low cost, low density, acceptable specific strength properties, reduced tool wear and biodegradability), they suffer from several drawbacks, such as their hydrophilic nature the scattering in mechanical properties and the low processing temperature required. A possible solution that takes into account the environmental issues is represented by the use of mineral fibers like basalt. Since deep studies on this material are only recent, in the last 10 years, number of researchers has been investigating properties and behaviour of various composites made of continuous or short basalt fibers. These emerging mineral fibers are natural, safe and easy to process also at the recycling stage. Basalt fibers are continuously extruded from high temperature melt of selected basalt stones, which are volcanic, over-ground, effusive rocks saturated with 45–52% SiO_2. These fibers show high modulus, excellent heat resistance, heat and sound insulating properties, good resistance to chemical attack and low water absorption. These 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. As a consequence, over the last year's basalt fibers have been studied extensively as reinforcement in thermosetting matrices.

2. MATERIALS AND METHODS

2.1MATERIALS

The composites were made from E-glass fiber, basalt fiber and commercially available ARALDITE (L-12) along with hardener K-6, Silicon Carbide (Sic) powder was used as filler materials. Silicon carbide particles are commonly used filler, it is also known as carborundum is a compound of silicon and carbon.it is well known for its hardness. it is a black powder with specific gravity of 3.21. Silicon carbide as reinforcement are improved stiffness, strength, thermal conductivity, wear resistance, fatigue resistance, reduced thermal expansion and dimensional stability.

Basalt Fiber is an environmentally friendly high performance fiber, it is an ideal low cost fiber to instead of carbon and aramid fiber, Basalt Chopped Strand is chopped from continuous basalt fiber as per indicated length, this product have chemical resistant, high strength, high modulus, wide range of work temperature, magnetic wave passable, similar coefficient of thermal expansion with concrete, mainly used for concrete reinforcement, it can improve the concrete defect when temperature is not good, and also improve the impact resistant and compressive resistant properties, prevent water penetration, thus can increase the concrete service life, this basalt chopped strand can be also used in FRP and friction products, with the properties of high strength, high modulus and resistance to friction.

Figure 1: Silicon carbide, Glass fiber, Basalt fiber, and Epoxy

2.2 PREPARATION OF COMPOSITE SPECIMEN

Table 1.Composition of Composite materials

SL NO	MATRIX	FIBER	FILLERS	COMPOSITE
1.	45%	55%	-	100
2.	43%	55%	2%	100
3.	41%	55%	4%	100
4.	39%	55%	6%	100

In the present investigation composite materials are fabricated by hand layup process. Basalt and glass fibers were cut into the dimensions of length and breadth is of 300×300mm was used to prepare the specimen. The wax is applied on a Teflon plane sheet, to easy removal of composite. The composite specimen consists of totally 4 layers of glass fiber and 4 layers of basalt fibers for the preparation of different samples. A measured amount of epoxy is taken for different volume fraction of fiber and mixed with the hardener in the ratio of 10:1 and Silicon carbide filler is added into that mixer (unfilled, 2,4,6 wt.%) in a clean bowl. The layers of fibers were fabricated by adding the required amount of epoxy resin. The glass fiber is mounted on the table and then epoxy resin is applied on it. Before the resin gets dried, the second layer basalt fiber is mounted over the glass fiber.

Table 2. Physical properties of Glass fiber

Properties	Glass Fiber
GSM	360 GSM
Density	2.58 gm/cc
Tensile Strength	3450 Mpa
Elastic Modulus	80Gpa

Table 3. Physical properties of basalt fiber

Properties	Basalt fiber
GSM	360 GSM
Orientation	Plain-Woven Fabric
Density	2.65 gm/cc
Elastic Modulus	90-110 Gpa

Table 4. Properties of silicon carbide

Physical property	Silicon carbide
Density	3.1(gm/cc)
Hardness	2800 (kg/mm^2)
Elastic Modulus	410 (Gpa)
Flexural strength	550 (Mpa)

The process is repeated alternatively till four layers of glass fiber and four layers of basalt fiber got over. The epoxy resin applied is distributed to the entire surface by means of a roller. The air gaps formed between the layers during the processing were gently squeezed out. The processed wet composite were then pressed hard and the excess resin is removed and dried. Finally these specimens were hydraulic pressed to force to remove the air present in between the fibers and resin, and then kept for several hours to get the perfect samples. After the composite material dried completely, take out from the press and put the specimens into the hot oven for a hour at 120^0C. The composite material was taken out from the oven and rough edges were neatly cut and removed as per the required ASTM standards. Two types of composites were prepared one is with addition of silicon carbide filler (2, 4, 6 wt. %) and another one is without addition of silicon carbide filler.

3. TESTING

3.1 TENSILE TEST

The specimen is prepared according to the ASTM D638 standard. The testing is carried out in tensile testing machine with displacement velocity at 2 mm/min. The gauge length for testing specimen is 80 mm. Initially the breadth and width of specimen is observed and the area of cross section is calculated. The output result is a load displacement curve, from this the ultimate stress, elongation percentage and break load is calculated. Two specimens are tested for each fiber resin composition ratio.

Figure 2. Tensile test specimen.

Figure 3. Tensile testing setup

3.2 FLEXURAL TEST

The specimen is prepared according to the ASTM D790 standard. Three point bending method is followed. The testing is carried out in flexural testing machine with displacement velocity at 2 mm/min. The gauge length for testing specimen is 50 mm. Initially the breadth and width of specimen is observed and the area of cross section is calculated. The output result is a load Vs displacement curve, from this the ultimate stress and break load is calculated. two specimens are tested for each fiber resin composition ratio.

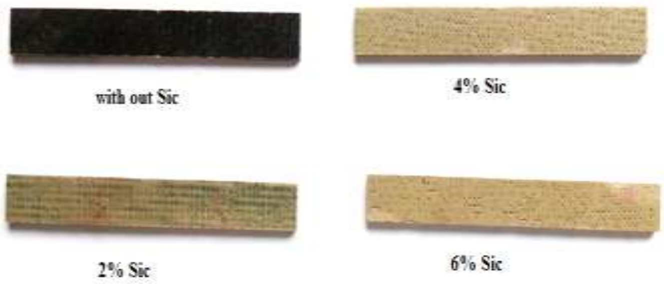


Figure 4. Flexural test specimen.

Figure 5. Flexural testing setup

3.3 WEAR TEST

The wear test was performed on Pin-on-Disc apparatus shown in figure. The specimen is prepared according to the ASTM G99 standard.In this test the flat end of cylindrical specimen 8 mm in diameter and 3 mm height was attach to the steel pin by gum. Its initial weight was determined in a high precision digital balance (0.0001accuracy) before it was mounted in the sample holder, and fixed in chuck jaws to prevent specimens from rotation during the test.The test specimen was pressed against the rotating disc at a specified force by means of lever arm. Each specimen was weighed before the experiment with pins and after it by a digital balance having sensitivity of 0.0001gm. The tests were conducted at a rotational speed of 2 m/s (764 rpm).At the end of a set test duration, the specimen was removed, thoroughly cleaned and again weighed (final weight). The difference in weight before and after dry sliding was determined.

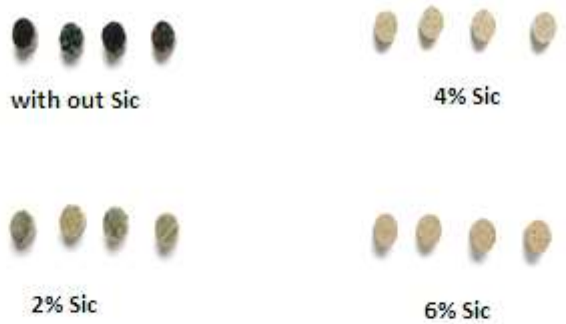


Figure 6. Wear test specimen.

Figure 7. Wear testing setup

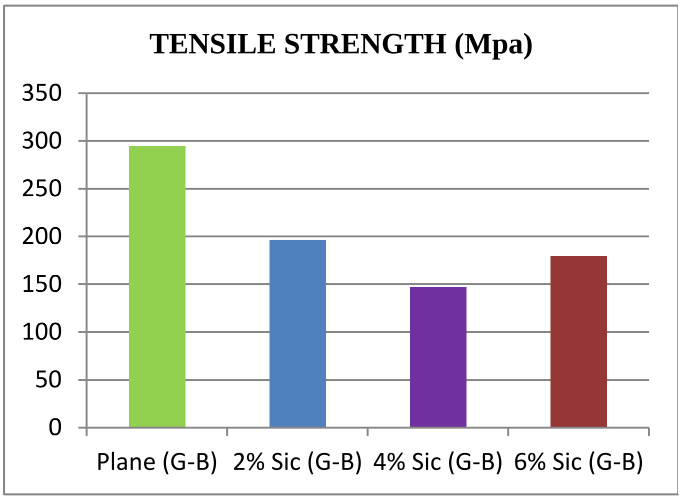
4. RESULTS AND DISCUSSION

4.1 TENSILE STRENGTH

Table 5. Test results of specimens

Sample (Wt %)	Tensile strength [N/mm²]	Tensile modulus [N/mm²]	Flexural strength (Mpa)	Flexural modulus [N/mm²]
Without Sic	294.8	7640	256.8	9129
2 % Sic	196.6	8846	294.2	15220
4 % Sic	147	9240	299.4	16260
6 % Sic	179.6	10800	300.2	21410

The composite samples were tested in the universal testing machine (UTM) and load-displacement curve was plotted. The typical graphgenerated directly from machine for tensile test for glass-basalt composite without silicon carbide filler and glass-basalt with silicon carbide filler composites plotted in Fig 9.The results show that the tensile strength for the composite without silicon carbide is higher than the composite with silicon carbide filler.



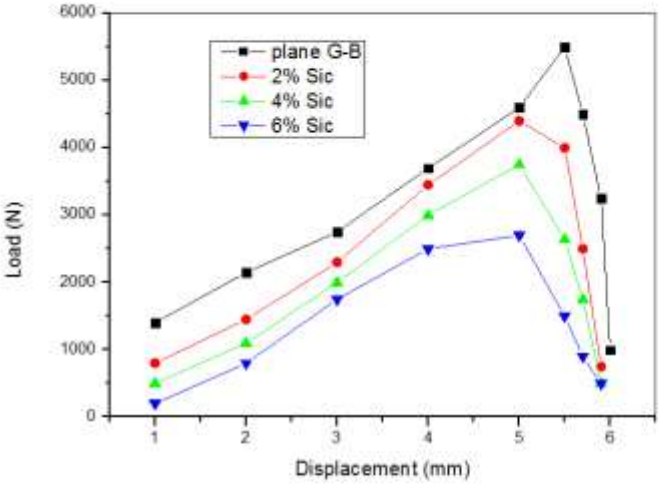
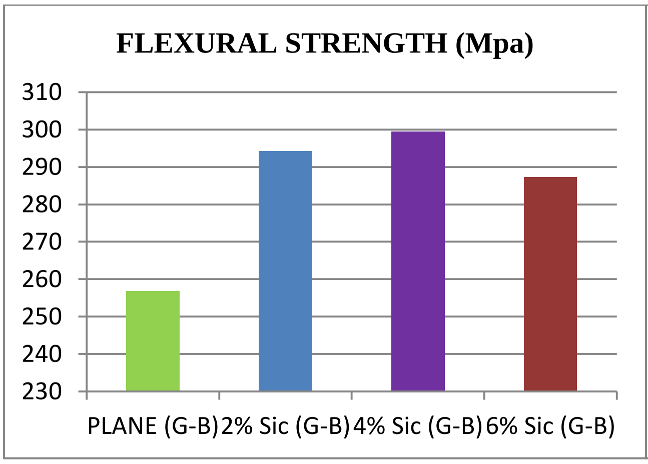


Figure 8. Tensile strength of G-B fiber reinforced epoxy resin composite

Figure 9. Load vs displacement curves

4.2 FLEXURAL STRENGTH

The composite samples are tested in the universal testing machine (UTM) and load-displacement curve is plotted. The typical graphgenerated directly from machine for flexural test for glass-basalt composite without silicon carbide filler and glass-basalt with silicon carbide filler composites plotted in Fig 10. Flexural properties of different composite samples are tested and results are plotted. The results show that the flexural strength for the composite with silicon carbide of 4% filer is higher than the other composite with silicon carbide filler and withoutsilicon carbide filler.



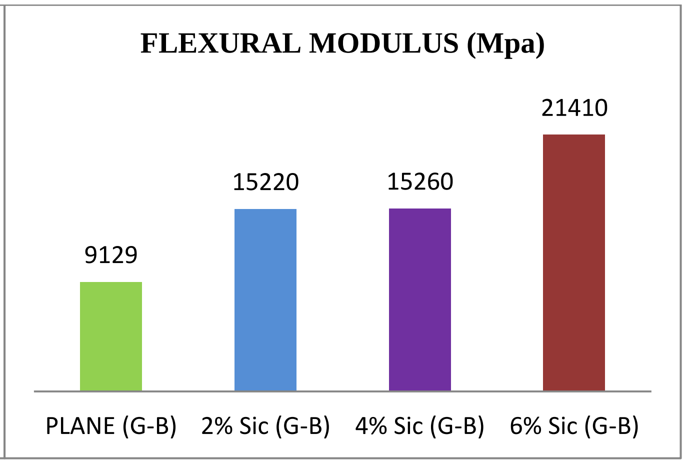


Figure 10.Flexural strength of G-B fiber reinforced epoxy resin composite

Figure 11. Flexural modulus

4.3 SPECIFIC WEAR RATE

Figures 12, 13 show the wear loss in mass of the samples at 10N and 20N loads, respectively. It was clear from these figures that for all the polymer composites used in this study there was a linear wear mass loss with sliding distance. It indicates a steady state wear with a constant wear rate. The highest wear mass loss was for unfilled glass-epoxy composite and the lowest was for glass-Epoxy filled with 6% of Sic composites. In these figures for glass-Epoxy filled with 2% of Sic and glass-Epoxy filled with 4% of Sic composites there was an average increase in sliding resistance.

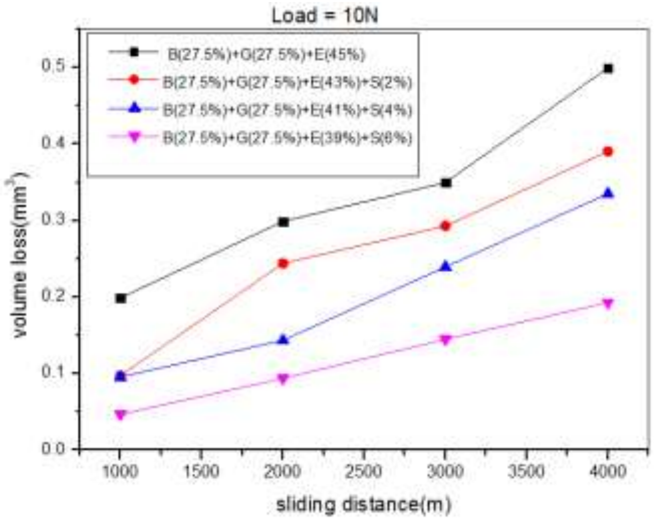


Figure 12. Volume loss vs slide distance curve for 10N

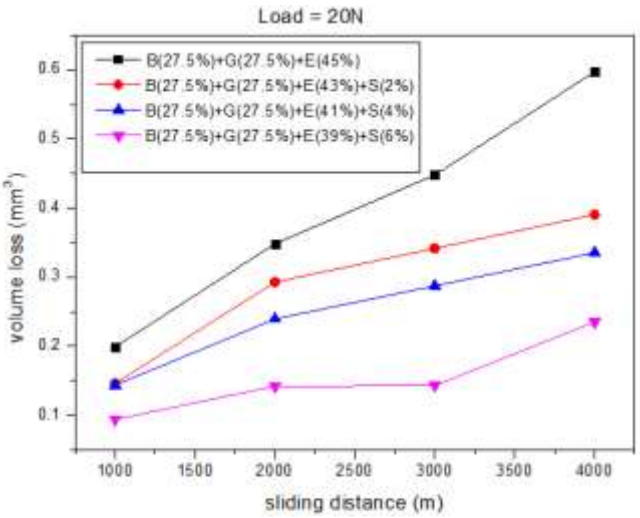


Figure 13. Volume loss vs slide distance curve for 20N

Figures 14, 15 show the variation of specific wear rate in unfilled GB-epoxy, GB-epoxy with 2% Sic, GB-epoxy with 4% Sic, GB-epoxy with 6% Sic composites. At all sliding distances, the lowest specific wear rate was for GB-epoxy with 6% Sic composite with a value of 0.047 x 10^{-4} mm^3/(N-m) and the highest value at 0.199 x 10^{-4} mm^3/N-m for GB-Epoxy FILLED 6% of Sic composites. For all composites of this study, the specific wear rate drops with increase in sliding distance. The specific wear rate for unfilled Sic composites varies between 0.116 x 10^{-4} and 0.0.199 x 10^{-4} mm3/(N-m) and for 6% Sic filled composites the value varies between 0.047 x 10^{-4} and 0.0482 x 10^{-4} mm^3/(N-m) as shown in Figure.

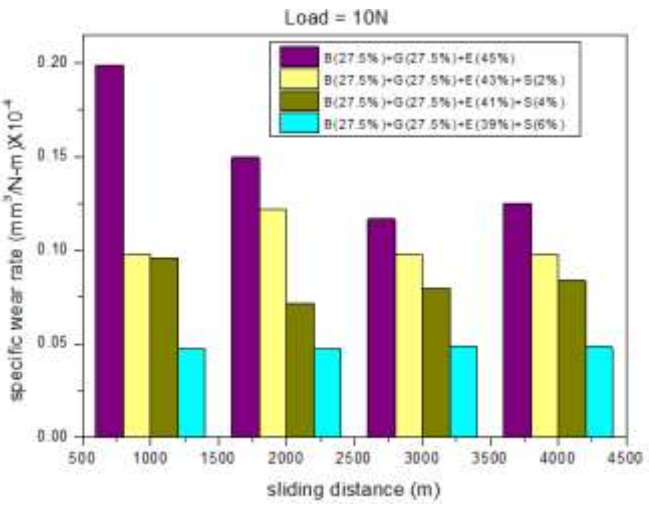


Figure 14. Wear rate vs sliding distance for 10N

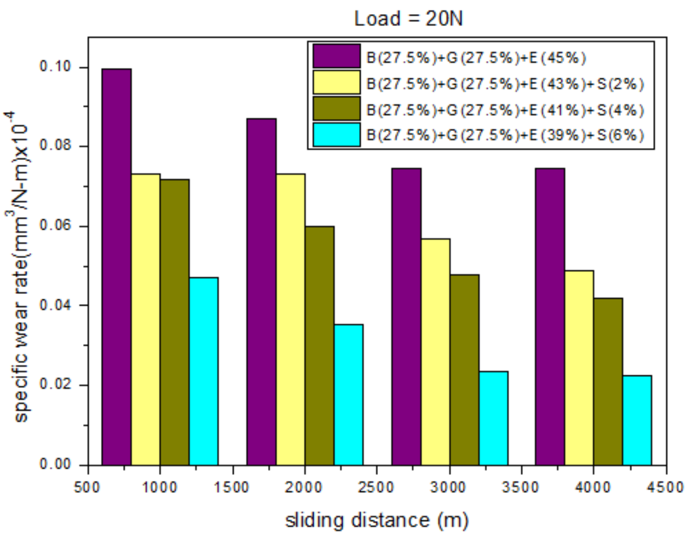


Figure 15. Wear rate vs sliding distance for 20N

5. CONCLUSION

The Tensile strength, Flexural Strength and Specific wear rate of glass and basalt fiber reinforced epoxy resin composite was studied. From the results it was observed that the flexural modulus and flexural strength increased with increasing silicon carbide. The Glass basalt fiber filled with 4% of silicon carbide possesses good flexural strength and can withstand the strength up to 299.4 Mpa. This may be due to complete filling of voids in the matrix by the Sic particles. These Glass basalt composite sample possess good tensile strength and can withstand the strength up to 294.8 N/mm². The tensile strength was decreased with increasing silicon carbide, this is due to increasing of Sic to composite will become brittle in nature.

Specific wear rate decreases with increase in sliding distance for all the samples. However G-B with 6% Sic showed better dry sliding wear resistance. Specific wear rate was higher in un-filled glass fiber-reinforced epoxy composites.

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