

## Sliding wear characteristics of BasaltFiber with GE/Epoxy/Al<sub>2</sub>O<sub>3</sub>/SiC hybrid Composites for Journal bearing material using Fish Oil Lubricant

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**Abstract:** This paper presents the wear behaviour of Basalt fiber reinforced with silicon carbide (SiC) and aluminium oxide (Al<sub>2</sub>O<sub>3</sub>) composite using fish oil as lubricant. The test specimens are prepared and tested as per ASTM standard. The experiments are conducted by using a pin on disc wear tester. The results indicated that the wear resistance of the hybrid composite is better than that of the basalt fiber with GE (Glass Epoxy). The fracture surface of composites shows the ductile tear ridges and cracked SiC and Al<sub>2</sub>O<sub>3</sub> particles indicating both ductile and brittle fracture mechanism. In this study, different combinations based composite materials were comparatively investigated under actual loading, sliding distances and time frame to configure best suitable bearing materials. The hybrid composite are proven for clean functioning and shows remarkable life.

**Keywords:** Hybrid composite; Basalt reinforced fiber; wear rate; Sliding wear, Friction, Fish oil.

### 1.Introduction

The sliding metal-to-metal contact wear can be observed in cams, gears, bearings, clutches and other applications involving sliding contact or rolling contact [1]. Composites is widely used in many automobile, aerospace and mineral processing components because of their excellent combination of low density and high thermal conductivity [2]. However, they suffer from poor wear properties. To overcome this, hard reinforcement phases, such as particulates, fiber, and whiskers (short fiber) which are well known for their high-specific strength, have been uniformly distributed [3]. Here the good ductility of the matrix material is retained while the modulus and strength of the composites have increased because of the reinforcement phase. Composite material structures are a synergistic combination of two or more reinforcements (constituents) that differ in physical form, chemical combination and are insoluble in each other. The objective of having two or more reinforcements is to take advantage of the superior properties of both materials without compromising on the weakness of either [4]. In most cases, hard ceramic particulates such as Zirconia, alumina (Al<sub>2</sub>O<sub>3</sub>) and silicon carbide (SiC), have been introduced into aluminium-based matrix in order to increase the strength, stiffness, wear resistance, corrosion resistance, fatigue resistance and elevated temperature resistance. Among these reinforcements, SiC is chemically compatible with aluminium (Al) and forms an adequate bond with the matrix without developing inter-metallic phase and has other advantages such as excellent thermal conductivity, high machinability, good workability and low cost [5–8].

The demand for lightweight, inexpensive and energy efficient materials has led to the development of aluminium matrix composites containing hard ceramic dispersed [9,10]. The results from the previous studies

indicated that wear increases with the applied load. The composites failed under certain combination of load and speed. The load that caused failure during sliding is not fixed at a particular critical value but varied with respect to speed [11]. Sahin [12] indicated that the introduction of SiC particle into the aluminium exert a greater effect on wear, followed by applying load. The sliding distance is found to have a much lower effect. In addition, the interactions of SiC reinforcement/applied load and SiC reinforcement/sliding distance had a moderate influence on the abrasive wear while the interactions of reinforcement/ abrasive size, applied load/abrasive size, applied load/sliding distance and abrasive size/sliding distance had no significant effect.

## 2. Experimental

### Fabrication Process

1. The major component of Basalt fiber is Epoxy LY556 (Resin).
2. Hardener HY951 is used for hardening and support.
3. Resin + Hardener are mixed in the ratio of 10:1 and the mixture made up is called MATRIX.
4. Basalt fiber of 0.29mm thickness is used.
5. Tool is prepared by standard method.
6. Apply the matrix on fiber cloth which is wrapped around the mandrel.
7. Ensure proper weighing is done.
8. Clamp the tool die for 2 hrs at ambient temperature condition.
9. The sample is then furnace heated at 100celcius for 2 hrs for hardening.
10. Take out and cool the specimen until room temp. is achieved.
11. Flash is removed from the sample.
12. Demoulding i.e. clamp is removed from the specimen.
13. Cut to appropriate dimension as per experimental needs
14. Emery paper of grade 60 is used to provide necessary surface finish.

The Figure1, Figure 2 and Figure 3 shows the short glass with basalt fiber, mould cavity and hot air oven for preparing specimen.



**Figure 1.Short glass fiber and Basalt Fiber**



**Figure 2. Mould Cavity**

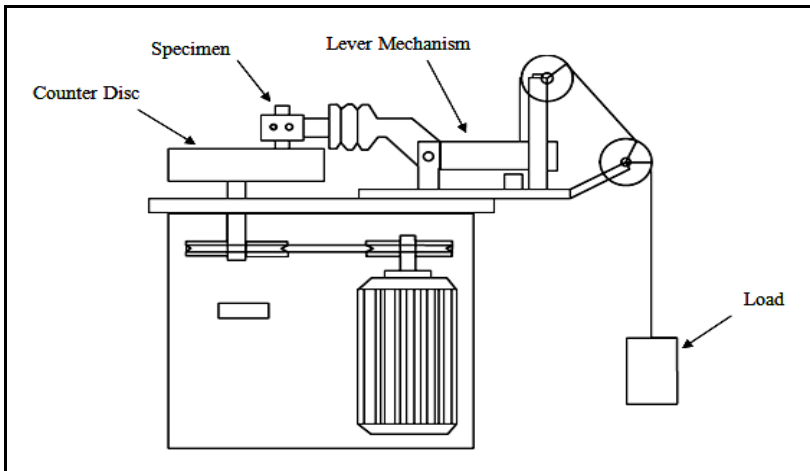


**Figure 3. Hot Air Oven**

### Experimental Setup

This test method describes a laboratory procedure for determining the wear of materials during sliding using a pin-on-disc test rig shown in Figure 4. Materials are tested in pairs under nominally non-abrasive

conditions. A pin on disc is an instrument that measures tribological quantities, such as coefficient of friction, friction force, and wear volume, between two surfaces in contact.



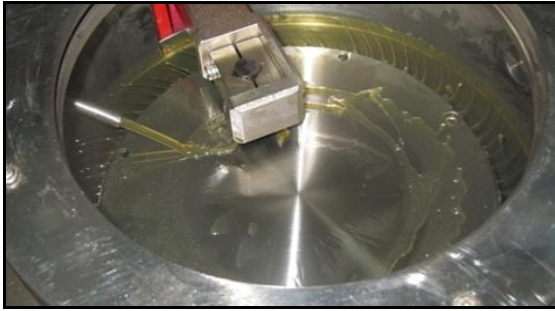
**Figure 4. Pin-on-Disc Test Rig**

**Table 1 Test Rig Parameters**

S.No	Description	Details
1	Speed	Min 200 rpm, max 2000 rpm
2	Normal Load	200N max
3	Frictional Force	200N max
4	Wear	± 2mm
5	Wear Track Diameter	Min 50mm, max 100mm
6	Sliding Speed	Min 0.3m/sec, max 10m/sec
7	Preset Timer	99/59/59 hr/min/sec
8	Specification Size (Pin)	Ø3,4,5,6,8,10 & 12mm
9	Wear Disc Size	Dia 165mm X 8mm Thick, EN-31 Hardened To 60hrc, Ground To Surface Roughness 1.6Ra
10	Environmental Chamber	This chamber prevents oil spillage and collects debris after test
11	Software	Winducom 2010
12	Software Interface	Comport

## Procedure

A pin-on-disc test setup was used for slide wear experiments. The surface of the sample (5mm X 5 mm) glued to a pin of dimensions 10 mm diameter and 30 mm length comes in contact with a hardened disc of hardness 60 HRC. The counter surface disc was made of En31 steel having dimensions of 165 mm diameter, 8 mm thick and surface roughness (Ra) of 1.6 µm. The test was conducted on a track of 115 mm diameter for a specified test duration, load and velocity. Prior to testing, the test samples were rubbed against a 600-grade SiC paper. The surfaces of both the sample and the disc were cleaned with a soft paper soaked in acetone before the test. The pin assembly was initially weighed using a digital electronic balance (0.1 mg accuracy). The test was carried out by applying normal load (50 N to 150 N) and run for a constant sliding distance (5000 m) at different sliding velocities. At the end of the test, the pin assembly was again weighed in the same balance. A minimum of three trials was conducted to ensure repeatability of test data. The friction force at the sliding interface of the specimen was measured at an interval of 5 minutes using a frictional load cell. The coefficient of friction was obtained by dividing the frictional force by the applied normal force. Experiments were done in two groups. The aim in the first group is to investigate the effect of load and velocity on tribological behaviours while the aim in the second group is to investigate the effect of sliding distance and sliding time. The bearing velocities are kept in between 2.5-3 m/s and the bearing loading upto 150N. The Figure 5. shows the sliding test with fish oil lubricant.



**Figure 5. Sliding Test with Fish oil Lubricant**

### 3. Results and Discussion

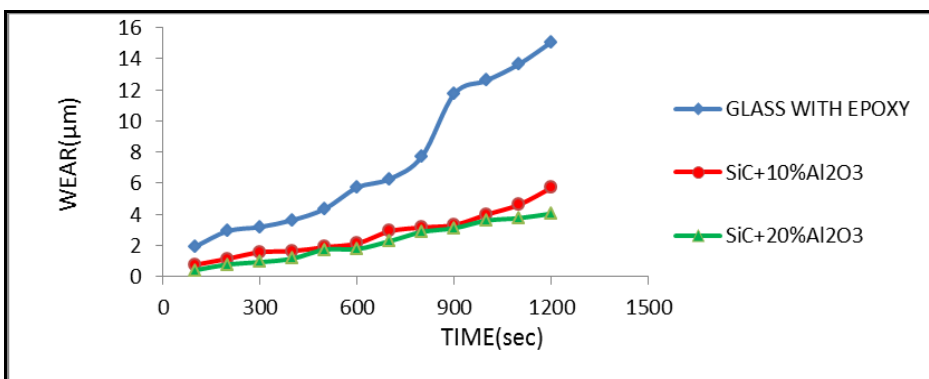
#### Results Related To Friction

1. At the beginning, the friction coefficient increases with the operating time, but after some time it reaches a stable value and this does not change considerably.
2. With increasing sliding distance, the friction coefficient values changes in close periphery and values lies in higher order for dry conditions.
3. Friction coefficient increases as working load increases, but this increase slows down as load increases.
4. Friction coefficient increases as the velocity increases. But this increase in the friction coefficient slows down as the velocity increases. The time needed to reach a stable value of friction coefficient does not depend on bearing pressure.
5. For dry testing conditions, coefficient of friction value ranges within 0.5 to 0.8 for different loading conditions and sliding distances.

#### Results Related To Wear

1. At the beginning of operation, wear increases quickly with the operating time. These times corresponds respectively 4.610 km sliding distance.
2. Under lubricated testing condition wear pattern increases considerably with sliding distanceWear rate increases as working load increases, but this increase is not gradual as load increases.
3. Wear increases as the velocity increases. But this increase in the wear rate slows down as the velocity increases.
4. For lubricated testing conditions, wear value ranges up to 210 $\mu\text{m}$  for different loading conditions.

The Figure 6, Figure 7 and Figure 8 show that as the load increases, the wear with respect to time also increases. The wear is more for basalt fiber with Epoxy(GE) when compared to GE filled with  $\text{Al}_2\text{O}_3$  and SiC.



**Figure 6. Lubricated, Load - 50 N, Speed - 572 Rpm, Duration - 20 Min**

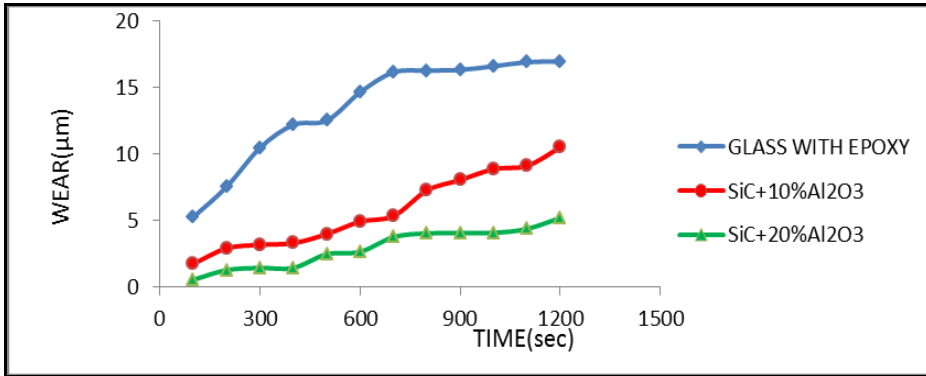


Figure 7. Lubricated, Load - 100 N, Speed - 572 Rpm, Duration - 20 Min

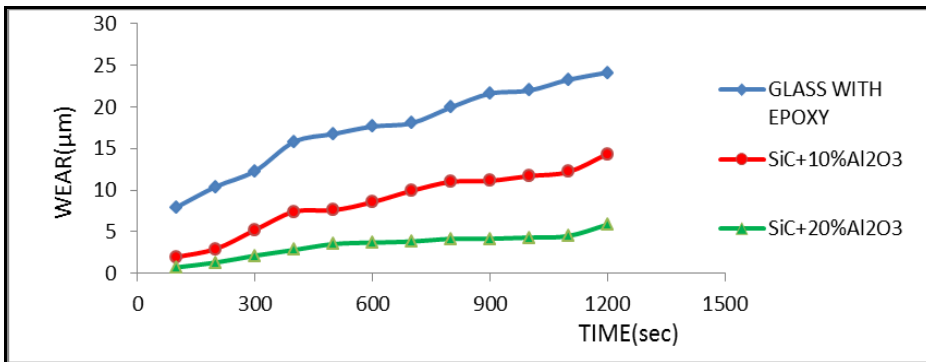


Figure 8. Lubricated, Load - 150 N, Speed - 572 Rpm, Duration - 20 Min

The Figure 9, Figure 10 and Figure 11 show that as the load increases, the coefficient of friction with respect to time also increases. But, the wear is more for basalt fiber with epoxy when compared to GE filled with 10% of Al<sub>2</sub>O<sub>3</sub> and SiC and 20% of Al<sub>2</sub>O<sub>3</sub> and SiC. This shows that as the composition increases wear and coefficient of friction are get decreased.

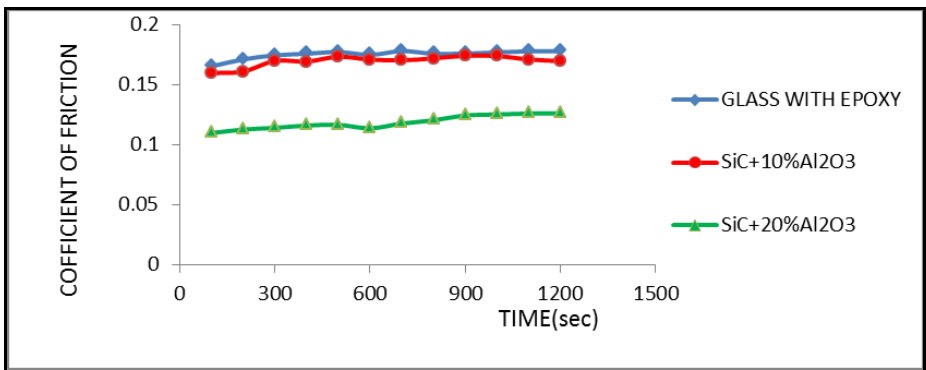


Figure 9. Lubricated, Load - 50 N, Speed - 572 Rpm, Duration - 20 Min

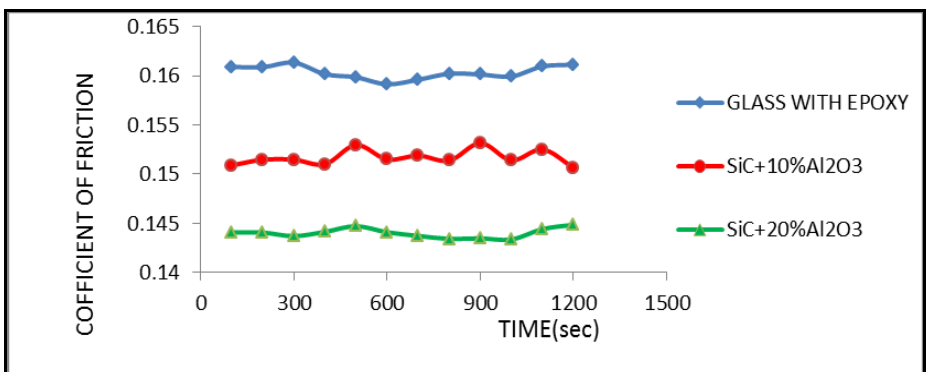


Figure 10. Lubricated, Load - 100 N, Speed - 572 Rpm, Duration - 20 Min

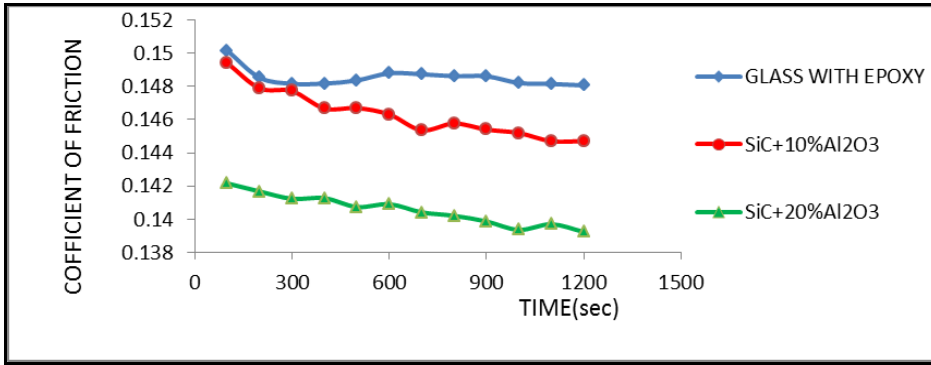


Figure 11. Lubricated, Load - 150 N, Speed - 572 Rpm, Duration - 20 Min

The Figure 12, Figure 13 and Figure 14 show that as the load increases, the wear with respect to time also increases. But, the wear is more for basalt fiber with epoxy when compared to fiber filled with 10% of Al<sub>2</sub>O<sub>3</sub> and SiC and 20% of Al<sub>2</sub>O<sub>3</sub> and SiC. This shows that as the composition increases wear is get decreased.

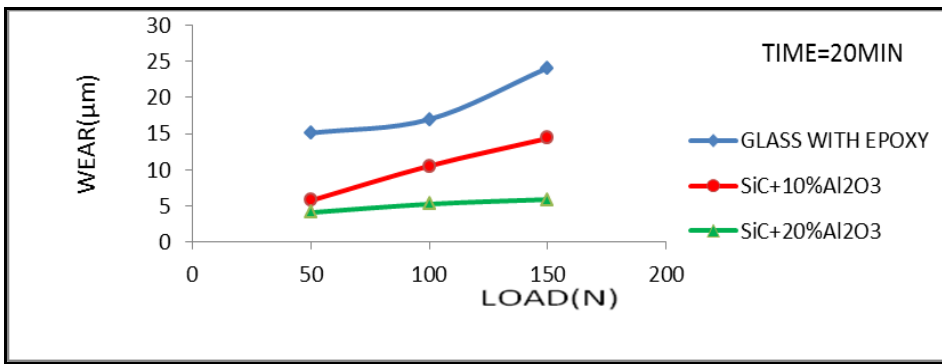


Figure 12. Lubricated, Speed - 572 Rpm, Duration - 20 Min

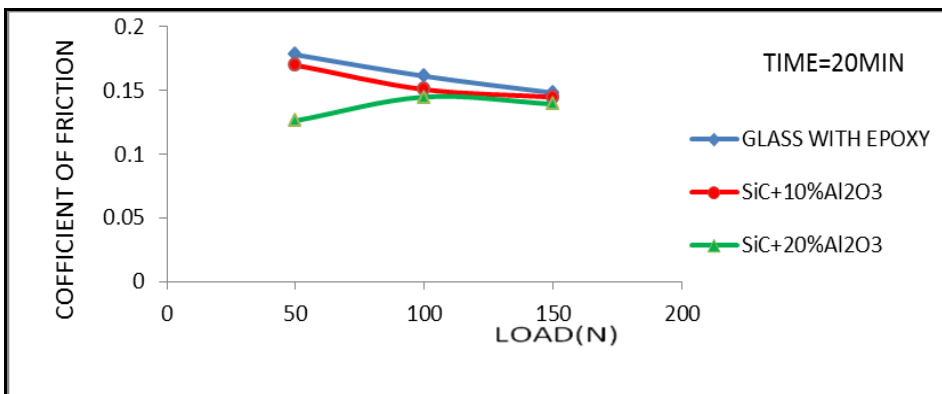


Figure 13. Lubricated, Speed - 572 Rpm, Duration - 20 Min

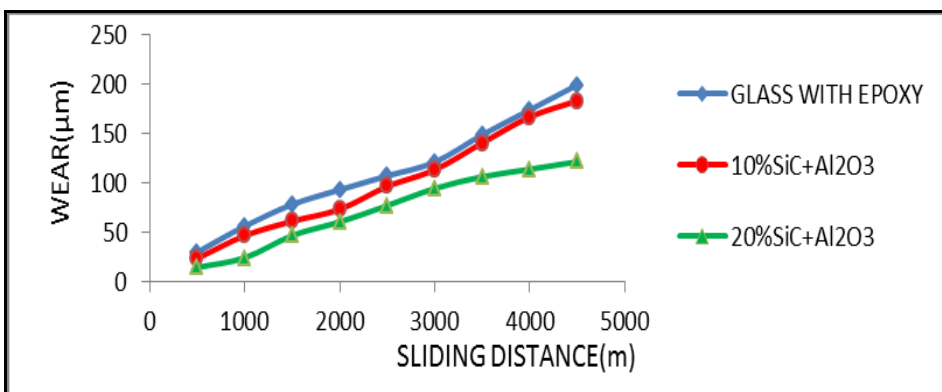


Figure 14. Lubricated, Load - 50 N, Speed - 572 Rpm, Velocity=2.9m/S



The Figure 15, Figure 16 and Figure 17 show that as the sliding increases, the wear also increases. But, the wear is more for basalt fiber with epoxy when compared to GE filled with 10% of Al<sub>2</sub>O<sub>3</sub> and SiC and 20% of Al<sub>2</sub>O<sub>3</sub> and SiC. This shows that as the composition increases wear is get decreased.

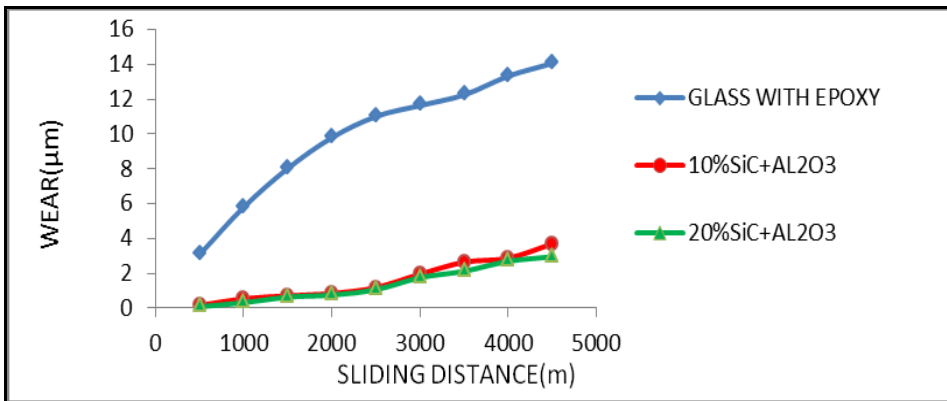


Figure 15. Lubricated, Load - 50 N, Speed - 572 Rpm, Velocity=2.9m/s

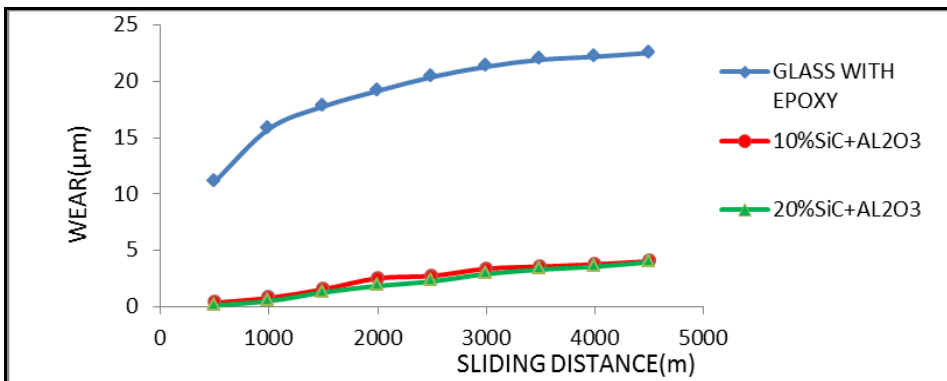


Figure 16. Lubricated, Load - 100 N, Speed - 572 Rpm, Velocity=2.9m/s

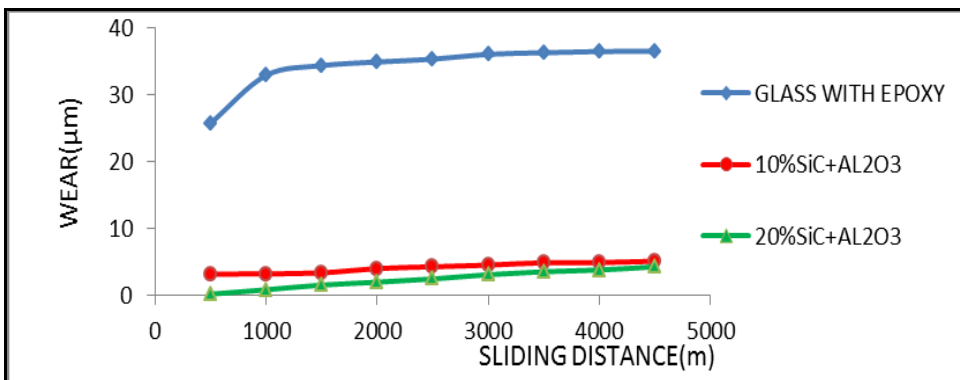


Figure 17. Lubricated, Load - 150 N, Speed - 572 Rpm, Velocity=2.9m/s

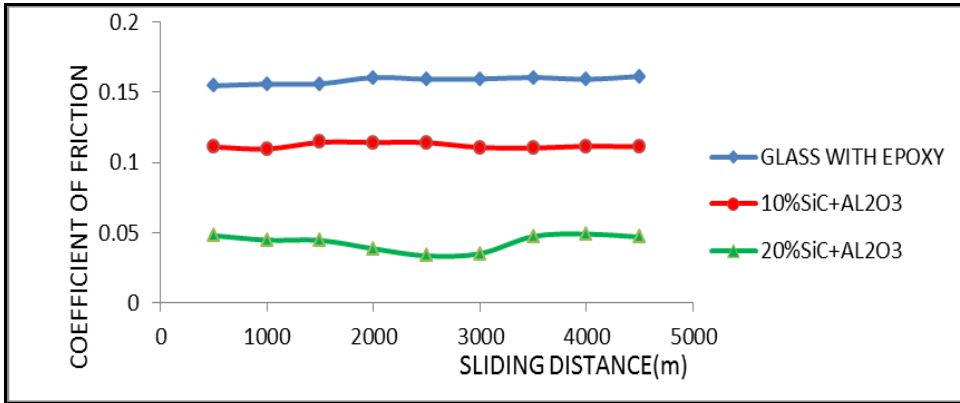


Figure 18.Lubricated, Load -50 N, Speed - 572 Rpm, Velocity=2.9m/s

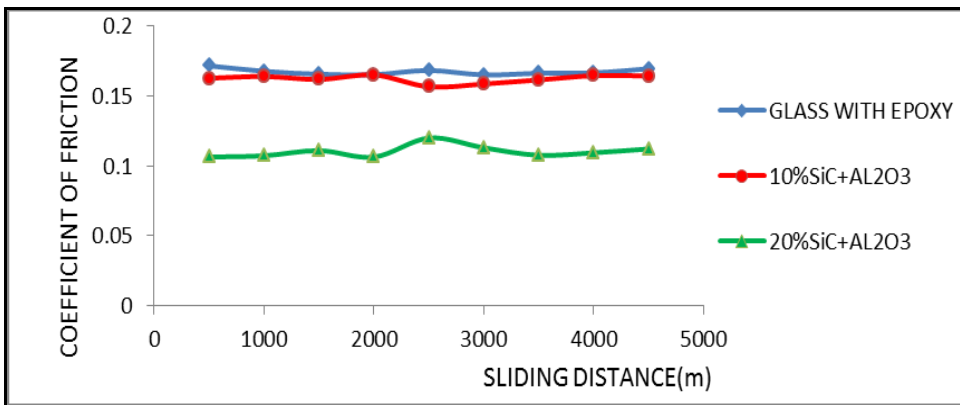


Figure 19.Lubricated, Load -100 N, Speed - 572 Rpm, Velocity=2.9m/s

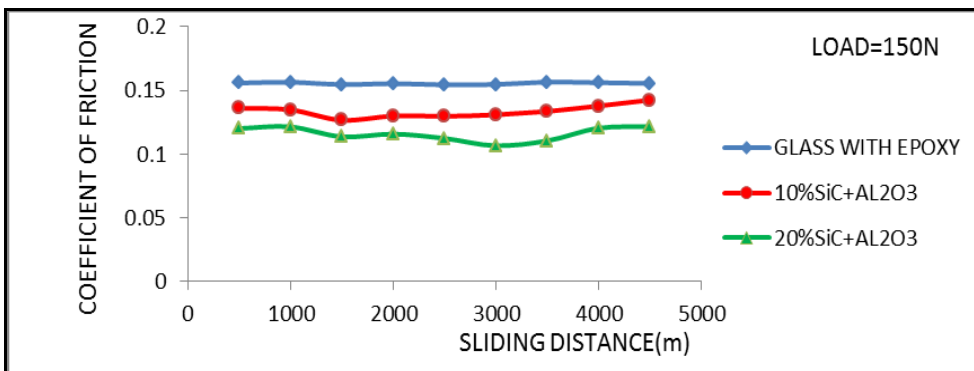


Figure 20.Lubricated, Load -150 N, Speed - 572 Rpm, Velocity=2.9m/s

The Figure 18, Figure 19 and Figure 20 show that as the sliding distance increases, the coefficient of friction with respect to load also increases. But, the wear is more for basalt fiber with epoxy when compared to GE filled with 10% of Al<sub>2</sub>O<sub>3</sub> and SiC and 20% of Al<sub>2</sub>O<sub>3</sub> and SiC. This shows that the composites having excellent self-lubricating property.

The Figure 21 Shows 3D Plot of Wear Vs Volume Fraction Vs Sliding Distance and Figure 22 Shows 2D Plot of Wear Vs Volume Fraction Vs Sliding Distance. From the plots, it finds that wear is less, when the volume fraction is increased.



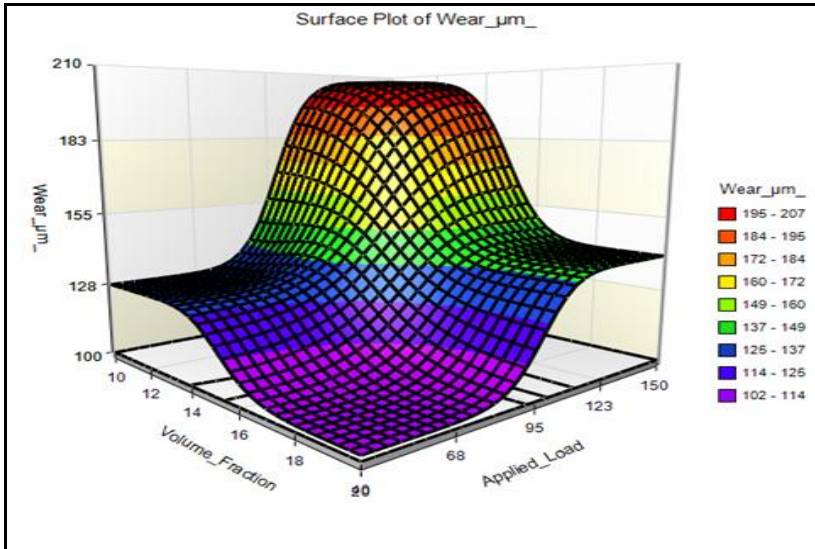


Figure 21. 3D Plot of Wear Vs Volume Fraction Vs Sliding Distance

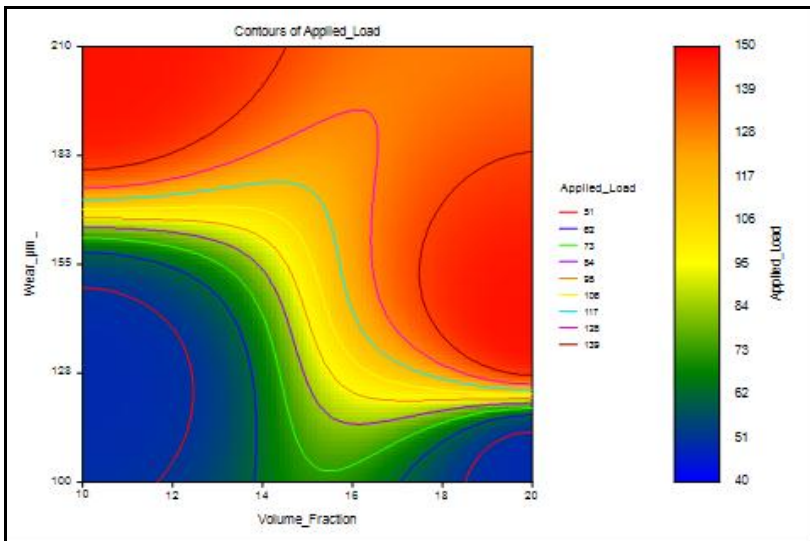


Figure 22. 2D Plot of Wear Vs Volume Fraction Vs Sliding Distance

## 5. Conclusion

An attempt has been made in this paper. The following points are drawn from the above study.

- Inclusion of Graphite,  $\text{Al}_2\text{O}_3$  and SiC particulate fillers contributed significantly in reducing friction and exhibited better wear resistant properties.
- $\text{Al}_2\text{O}_3$  and SiC particulate carbide filled G-E composite shows higher resistance to slide wear compared to plain composites.
- There has been an observed marked improvement in wear resistance as seen in  $\text{Al}_2\text{O}_3/\text{SiC}$  composite sample compared to plain G-E sample.
- Composite shows highest coefficient of friction compared to the other two samples.
- Increased wear resistance and reduced coefficient of friction are positive traits, which make the composite suitable to be used as liners in bearings and coal handling equipment's.

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