STUDY OF THREE BODY ABRASIVE WEAR BEHAVIOR OF NANO PARTICLES FILLED UNIDIRECTIONAL GLASS FIBER REINFORCED EPOXY COMPOSITES

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Abstract-- This paper emphasizes on three body abrasive wear behavior of nano particles filled unidirectional glass fiber reinforced epoxy composites using rubber wheel abrasive test rig (RWAT). For better understanding glass epoxy composites with 3 different compositions were used (GE, GE+Silica, GE+Alumina+Silica, GE+Silica+ Alumina trihydrate). Wear Characteristics were studies for abrading distances of 250, 500, 750, and 1000 m, using 212µm silica sandapplying 20 and 40 N loads. Alumina, silica, and alumina trihydrate nano fillers increased the wear resistance. From the result it is evident that abrasive wear rates were reduced as the abrading distances increased.

Keywords: Glass epoxy, three-body, abrasive wear, wear volume, specific wear rate

I. INTRODUCTION

In material science, wear is erosion or sideways displacement of material from its derivative and original position on a solid surface performed by the action of another surface is related to interaction between surfaces and more specifically the removal and deformation of material on a surface as a result of mechanical action of the opposite surface. Fiber reinforced polymer matrix material play an important role in much industrial application because of their good properties such as high tensile and compressive strength, controllable electrical conductivity, low coefficient of thermal expansion and good fatigue resistance. There are five different types of wear, namely abrasive wear; adhesive wear, surface fatigue, fretting wear and erosion wear [1]. Abrasive wear is typically categorized by the contact environment and the type of contact. The contact type defines the abrasive wear mode. In general there are two types of abrasive wearing i.e. two body abrasive wear and three body abrasive wear. Many scientists have studied the abrasive wear behavior of polymer based composite material. Ranganatha et al. [2] investigated three body abrasive wear of Al2O3 filler on CFRP composites. The materials used in this study are fabricated using hand layup technique. They observed that Abrasive wear loss decreases with increase in the percentage of adding filler alumina to the composites. Ravikumar et al [3] investigated effect of particulate fillers on mechanical and abrasive wear behavior of polyamide 66/polypropylene nano composites.

All particulate-filled PA66/PP composites were prepared using twin screw extrusion followed by injection molding. His results indicate that addition of nanoclay/short carbon fiber in PA66/PP has significant influence on wear under varied abrading distanceeloads. Further, it was found that nanoclay filled PA66/PP composites exhibited lower wear rate compared to short carbon fiber filled PA66/PP composites. In addition, the worn surface morphology of the samples was also discussed. Navin Chand et al. [4] studied the Three-body abrasive wear of short glass fiber polyester composite. They observed that the abrasive wear of the composite shows dependence on all the test parameters like applied load, sliding speed and abrasive particle size. The size of the abrasive particle and applied load tends to increase abrasive wear volume of the composites, whereas wear rate tends to decrease with increasing sliding velocity at constant applied load and particles of size ranging 200–300 µm. Harsha, and U.S.Tewari [5] investigated the “Abrasive wear of glass fiber reinforced polysulfone composites. They observed that their wear resistance deterioted because of fiber reinforcement. With an increase in glass fiber percentage, elongation to break is decreased. This is a controlling factor for abrasive wear performance. Gaurav Agarwal et al. [6] investigated parametric optimization of three-body abrasive wear behavior of bidirectional and short kevlarfiber reinforced epoxy composites. They observed that theoretical values of specific wear rate are calculated based on the given wear model and further compared it with experimental specific wear rate values. The error values for bi-directional Kevlar fiber reinforced epoxy composites lies in the range 0-8%, Whereas, for short Kevlar fiber reinforced epoxy composites error lies is in the range of 0-5%. Suresha et al. [7] studied the Three-body abrasive wear behavior of particulate filled glass–vinyl ester composites, observing that abrasive wear volume increases with increase in abrading distance/loads for all the samples.
However, the SiC-filled glass-vinyl ester composite showed better abrasive wear resistance. Abrasive wear rate is higher in unfilled glass fiber-reinforced vinyl ester composites. The main objective of the present work is to study the three bodies abrasive wear behavior of unidirectional glass fiber reinforced epoxy composite with addition of different fillers (Alumina, Silica, and Alumina Trihydrate).

II. EXPERIMENTAL DETAILS

Using sand/rubber wheel abrasion test rig (RWAT), three body abrasive wear tests were conducted as per ASTM G-65. The wear behavior mainly depends on size and type of abrading particles, abrading distance, rotational speed, type of material.

2.1 CHARACTERIZATION OF THE TEST

Tests were conducted at two different loads (20N and 40N) under four different abrading distances (250m, 500m, 750m, 1000 m) and at a constant speed of 200rpm. Abrading particle used was 212µm silica sand. Wear was measured in terms of mass loss and was converted to wear volume using density equation. Density of the composite was determined using rule of mixture. Specific wear rates were determined using the equation:

\[ K_s = \frac{V}{L \times D} \text{ m}^3/\text{Nm} \]

Where,  
- \( K_s = \text{Specific wear rate (m}^3/\text{Nm}) \)
- \( V = \text{Wear volume (m}^3) \)
- \( L = \text{Load (N)} \)
- \( D = \text{Distance travelled (m)} \)

2.2 MATERIALS USED

Unidirectional glass fiber reinforced epoxy composites with three different compositions (GE, GE + silica + alumina, GE + silica + alumina + alumina trihydrate) were fabricated to study the three body abrasive wear behavior of composite. These composites were manufactured pulltrusion technique. Unidirectional glass fibers were used as reinforcing materials and epoxy as matrix. Fillers like silica, alumina, and alumina trihydrate of nano size were added to improve the wear properties of the composite.

<table>
<thead>
<tr>
<th>MATERIAL:</th>
<th>GE</th>
<th>GEF2</th>
<th>GEF3</th>
</tr>
</thead>
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<tr>
<td>GLASS FIBER</td>
<td>60%</td>
<td>60%</td>
<td>60%</td>
</tr>
<tr>
<td>EPOXY</td>
<td>40%</td>
<td>34%</td>
<td>31%</td>
</tr>
<tr>
<td>ALUMINA</td>
<td>-</td>
<td>3%</td>
<td>3%</td>
</tr>
<tr>
<td>SILICA</td>
<td>-</td>
<td>3%</td>
<td>3%</td>
</tr>
<tr>
<td>ALUMINA TRIHYDRATE</td>
<td>-</td>
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<td>3%</td>
</tr>
</tbody>
</table>

III. RESULT AND DISCUSSION

3.1 WEAR VOLUME

Wear was measured in terms of mass loss and using density equation, it was then converted to wear volume. Figure 2(a) and (b) shows the wear volume of unfilled unidirectional glass fiber reinforced epoxy composite and nano particles filled GE composites for 4 different abrading distances (250m, 500m, 750m, 1000m) at 20N and 40N loads, using 212µm silica sand as abrasive. It is evident from the figure that wears volume increases linearly with increase in abrading distance. As compared to unfilled GE composite, nano particle filled GE composites showed better wear resistance because of debonding at the fiber matrix interface of the unfilled GE and fracture of fibers due to continues sliding of abrasive particles [8]. Fiber matrix bonding was improved as the nano fillers were added, leading to reduced fiber matrix interfacial debonding which in turn resulted in low wear volume loss. This is attributed to better interfacial adhesion between glass fibers and epoxy with nano fillers as compared to the adhesion between glass fibers and epoxy [9].

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3.2 SPECIFIC WEAR RATE (KS)

Figure 3(a) and (b) shows the specific wear rate for the unfilled GE composite and nano particles filled GE composites. It is very clear from the graph that irrespective of type of material specific wear rate has been reduced with increase in abrading distance. This is attributed to exposure of fibers to the abrading phase at higher abrading distances. After the removal of matrix phase, glass fiber which is harder than epoxy offers higher wear resistance resulting in reduced wear rate at greater abrading distances. Maximum wear rate was recorded for the unfilled unidirectional glass fiber reinforced epoxy composite. With the addition of nano fillers like silica, alumina, alumina trihydrate, specific wear rate of GE composite was predominantly reduced. Maximum wear rate was found at a load of 40N.

At 20N load, wear rates were lower and scar length was short at 20N compared to scar length at 40N load [13]. Length and Depth of the scar depends upon the type of polymeric materials and applied load. The wear scar has three different zones: an entrance zone where abrasive particles first come into contact with specimen, central zone in which abrasive particle may roll as well as slide and an exit zone where abrasive particles leave the specimen. The wear rates of all the polymeric materials decreases with increase in abrading distance.
Wear rates of unfilled GE did not show much variation with mass of abrasive at different loads. Whereas other polymeric materials (GE + Silica, GE + Alumina + Silica, GE + Silica + Alumina + Alumina trihydrate) showed relatively high initial wear rate when the surfaces were new, and decreases to an almost constant value with cumulative mass of abrasive.[10, 11, 12].

IV. CONCLUSION

Ceramic nano fillers like silica, alumina, and alumina trihydrate increased the wear resistance of the GE composites. Higher values of wear volume and wear rates were recorded for unfilled GE composite since fiber matrix interfacial debonding and fracture of unidirectional glass fibers by the continues sliding of abrasive particles across the surface of the composite. From the results, it is observed that addition of nano fillers decreased the interfacial debonding by improving the bonding property of epoxy with glass fiber. Wear volume increased with increase in load and abrading distance. Specific wear rate increased with increase in load and decreased with increase in abrading distance. Unidirectional long glass fibers helped in uniform distribution of load throughout the material resulting in steady state abrasive wear, thus leading to reduced wear rate.

REFERENCES