TWO-BODY ABRASIVE WEAR BEHAVIOR OF SHORT GLASS FIBER AND PARTICULATE FILLED POLYMETHYLMETHACRYLATE COMPOSITES

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ABSTRACT

The effect of polytetrafluoroethylene (PTFE), short glass fiber (SGF), silicon carbide (SiC) and molybdenum disulphide (MoS₂) on single pass two-body abrasive wear behaviour of Polymethylmethacrylate (PMMA) based composites have been investigated. The two-body abrasive wear tests with different loads and abrading distances were performed at room temperature using a multi-purpose abrasion test apparatus as per ASTM G-99. Wear volume increased with increasing abrading distance and grit size of SiC paper and the specific wear rate decreased with increasing abrading distance for all composites. Among the composite samples tested, PTFE+SGF+SiC+MoS₂ filled PMMA composite showed a promising trend.

Key words: PMMA Composite, Two-Body Abrasion, Sic Grit Paper, Wear Volume, Specific Wear Rate.

1. INTRODUCTION

There is an increasing demand for polymer composites in industrial applications due to its low density, high strength and stiffness. Fabric reinforced plastics (FRPs) are used in various abrasive wear situations such as seals in agricultural, mining equipment, vanes and gears, and pumps handling industrial fluids. Wear is defined as damage to a solid surface, generally involving progressive loss of material, due to relative motion between that surface and contacting substance or substances. The five main types of wear are abrasive, adhesive, fretting, erosion and fatigue wear, which are commonly observed in practical situations. Abrasive wear is the most important among all the forms of wear because it contributes almost 64% of the total cost of wear.

Many researchers have investigated two-body abrasive wear of polymer based composite materials. [1] Polymer composites are subjected to abrasive wear in many applications. Abrasive wear occurs when hard asperities on one surface move across a softer surface under load, penetrates and remove material from the softer surface leaving grooves. [2] Tribological research includes the application of principles of friction, wear and lubrication. Frictional interactions in micro-components are becoming increasingly important for development of new products of modern industry [3]. The tribological performance of composite material is usually related with the properties of their respective reinforcement. One of the traditional concepts to improve the friction and wear behavior of polymeric materials is to enhance their hardness, stiffness and their compressive strength and to reduce adhesion to the counterpart material [4]. A notable advance in the polymer industry has been the use of fiber and particulate fillers as reinforcements in polymer matrices. Many researchers found that glass fiber and carbon fibers were effective reinforcements for distinct effect on the friction and wear behavior of polymer composites[5].
The advantage of glass fiber includes low cost, high strength as well as high chemical resistance. On the other hand, its low modulus, low fatigue resistance, self-abrasiveness and its poor interaction with some matrices, limit this type of fiber for some tribological applications. Carbon fibers not only show a high strength and modulus but also have an excellent heat stability and chemical inertness [6]. It is reported that silane coupling agent promotes the interfacial adhesion and interfacial toughness between glass fibers and polytetrafluoroethylene (PTFE) and largely enhance the tensile and tribological properties of glass–PTFE composites [7]. PMMA resin exhibits better impact, mechanical and physical properties than other polymer materials. [8] Voss et al. Briscoe et al. studied the sliding and abrasive wear behaviour of short glass fibre and CF reinforced PEEK composites at room temperature. [9] Reported abrasive wear behaviour of PEEK filled PTFE and PTFE filled PEEK. Incorporation of PEEK in PTFE reduced wear rate of PTFE while wear rate increased in the latter case.

The main objective of the present work is to study the two-body abrasive wear of polymethylmethacrylate matrix, reinforced with short glass fiber, micro fillers filled with silicon carbide and nano molybdenum disulphide filler. The main reason why polymethylmethacrylate is most widely used is because of its good abrasion resistance, hardness, stiffness and lightweight, nano filler molybdenum disulphide (MoS$_2$) acts as a solid lubricant with low frictional coefficient that reduces the wear.

2. EXPERIMENTAL DETAILS

The details of material composition are listed below:

<table>
<thead>
<tr>
<th>Composites</th>
<th>Designation</th>
<th>Matrix</th>
<th>Reinforcement</th>
<th>Density g/cc</th>
</tr>
</thead>
<tbody>
<tr>
<td>PMMA+PTFE+SGF</td>
<td>1P</td>
<td>PMMA</td>
<td>PTFE GF - -</td>
<td>1.35</td>
</tr>
<tr>
<td>PMMA+PTFE+SiC+SGF</td>
<td>2P</td>
<td>PMMA</td>
<td>PTFE GF SiC -</td>
<td>1.43</td>
</tr>
<tr>
<td>PMMA+PTFE+SGF+SiC+MOS$_2$</td>
<td>3P</td>
<td>PMMA</td>
<td>PTFE SGF SiC MOS$_2$</td>
<td>1.45</td>
</tr>
</tbody>
</table>

2.1 Materials
PMMA bears excellent properties like good abrasion resistance, hardness and stiffness & have excellent scratch resistance and the advantages can be attributed to light weight, easily machinability and are fully recyclable. The PTFE bears properties like it maintains high strength, toughness and self lubrication at up to low temperature of 5K; it was observed that PTFE plays an important role in tensile resistance and wear resistance.

PMMA is reinforced with short glass fibre bearing properties like light weight extremely strong and robust, are improved and it is less expensive. In this Micro SiC is used as a filler material because of low density, high strength, excellent wear resistance and also nano MoS$_2$ is used as filler, it is unaffected by dilute acids and oxygen, MoS$_2$ used as a solid lubricant because of its low friction properties and robustness. The composite material is fabricated by extrusion technique.

2.2 Two-body wear test
The two-body abrasive wear test was conducted by using multi-purpose two-body abrasive wear test rig, as per ASTM – G99. The size of the specimen (6mmx6mmx2.5mm) glued to a pin of dimension 8mm diameter and 25mm length, which comes in contact with water proof Silicon carbide (SiC) abrasive paper. For different abrading distances new SiC abrasive paper has been used, Abrasion wear test was conducted on a track of 270mm×120mm rectangular surface. Composite specimens were abraded against 150& 320 grit size SiC paper at a constant load of 10N &15N at 120 rpm at four abrading distances viz. 1.5, 3, 4.5, 6 meters under single pass condition, Specimen weight is recorded using a electronic balance (0.0001 g accuracy), the difference between the initial and final weight of specimen is measured to find wear loss, and a minimum of three trails for each specimen was conducted to ensure repeatability of test data. Frictional force is measured by a force transducer which displays automatically on screen. The co-efficient of friction was obtained by dividing the tangential frictional force by the applied normal force, the weight loss was converted into volume loss by using a measured density of the specimen. The specific wear rate (Ks) was calculated using following mathematical relation.

Wear loss = Initial weight – Final weight

Wear volume = Wear loss/ Density of material (mm$^3$)

Specific wear rate = Wear volume/ (Load× Abrading distances) m$^3$/Nm
3. RESULT AND DISCUSSION

3.1 Abrasive wear loss

As increase in grit size of abrasive paper there is increase in wear, and here wear loss strongly depends up on grit size, abrasive paper and the load. The graphical plots of two-body wear loss as abrasive wear loss as function of abrading distances of micro SiC filled 2P (PMMA + PTFE + Glass fiber + Sic), without filler 1P (PMMA +PTFE + Glass fiber) and 3P (PMMA +PTFE +Glass fiber + SiC + nano MoS$_2$) abraded against abrasive paper 150 & 320 grit water proof SiC paper are show in fig 2a, 2b and 3a, 3b respectively.

It is obvious that the wear loss of composite increases with increase in abrading distance and load. Increase in abrading distance result in wear debris consisting of shear deformed polymer composite containing broken pulverized glass particle and SiC particle on the counter surface, broken pulverized glass particle can act as a third body abrasive leading to enhanced roughening of the counter surface hence wear loss increases with increase in abrading distances.

Here among 1P, 2P & 3P composites, 3P showed best abrasive resistance property and 3P has nano MoS$_2$ filler material, it acts as a solid lubricant because of its low frictional properties and robustness. The wear volume loss of micro filled composite is much higher than solid lubricating nano MoS$_2$. So the nano filled composite exhibits the higher wear resistance under different abrading condition.

![Fig. 2: (2a, 2b) variation in wear volume of 1P, 2P &3P at (2a) 10N, 150 grit SiC paper and (2b) 15N, 150 grit SiC paper](image)

![Fig. 3: (3a, 3b) variation in wear volume of 1P, 2P &3P at (3a) 10N, 320 grit SiC paper and (3b) 15N, 320 grit SiC paper](image)
3.3 Specific wear rate

Plot of a specific wear versus abrading distances of composite at loads 10N and 15N and abraded against 150 and 320 grit water proof SiC paper is presented in fig 4a, 4b and 5a, 5b respectively. Specific wear rate significantly reduces as increase in abrading distance, load and grit size of SiC paper. Figures clearly shows that there is a linear reduction in specific wear rate with increase in abrading distances among these three composites. The 3P (PMMA +PTFE +Short Glass fibre+SiC +nano MoS$_2$) shows a best specific wear rate compare to 1P(PMMA +PTFE+ Short Glass fiber) and 2P(PMMA +PTFE+ Short Glass fiber+SiC). In single pass, abrasive wear every time surface of specimen has to come across new SiC paper, so there is a linearity in specific wear at every interval of abrading distance, and these results clearly indicate that specific wear rate depends on abrading distance, load and type of abrasive papers.

The highest Specific wear rate ($K_s$) of 1.212 x 10$^{-9}$ m$^3$/Nm for 2P(PMMA +PTFE+ Short Glass fiber+SiC) composite for 150 grit SiC paper load of 15N & lowest specific wear rate ($K_s$) of 0.200x10$^{-9}$ m$^3$/Nm for nano filled 3P(PMMA +PTFE +Short Glass fibre+SiC+nano MoS$_2$) composite at 320 sic grit paper at 10N load were observed.

Fig 4: (4a,4b) The plot of specific wear rate versus abrading distances for 1P, 2P & 3P composites abraded against, (4a) 150 grit SiC paper, load 10N and (4b) 150 grit SiC paper, load 15N

Fig 5: (5a,5b) The plot of specific wear rate versus abrading distances for 1P, 2P & 3P composites abraded against, (5a) 320 grit SiC paper, load 10N and (5b) 320 grit SiC paper, load 15N

4. CONCLUSION

Based on the experimental observation following conclusions are made

- The two- body abrasive wear performance of 1P,2P&3P composite depends significantly on the abrading distance, load and grit size of abrasive paper. The wear loss was found to increase in composites with increase in abrading distance
- The wear volume loss increased in micro filler material with increase in abrading distance as compared to nano filler material
- Among three combinations, the nano filler MoS$_2$ filled material showed better abrasion resistance at different loads and abrading distances. Combination of good fibre and matrix adhesion may be the reason for this improvement in abrasion resistance.
REFERENCES