Influence of Counter Surface Topography on the Tribological Behaviour of Carbon-filled PPS Composites in Water

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This study is aimed at investigating the influence of counter surfaces’ topography on tribological behaviour of several carbon-filled polyphenylene sulfide (PPS) composites in water lubricated contacts. The results of this study showed significant increase in wear rate of pure, graphite and/or multi-walled carbon nanotubes filled PPS composites with increase in mean slope of profile along the sliding direction (Δαy). This is while short carbon fiber (SCF) filled PPS composites exhibited 1-3 orders of magnitude lower wear rate with little dependence on counter surface roughness characteristics. Among the roughness parameters studied, RpÄ and lay orientation played a more significant role in friction, and RpÄ and Δαy were found to correlate best with the wear rate of the composites not containing SCF in their matrices.

Keywords: Polyphenylene sulfide, Roughness; Polymer; Friction; Wear.

1. Introduction

It is very well known that the roughness characteristics of the metallic counter surfaces play an important role in the tribological behaviour of polymeric materials (1, 2, 3). However, little efforts have been carried out to experimentally investigate the influence of various counter surface roughness parameters on the friction and wear of polymers (4, 5). This is especially true for lubricated conditions where the initial topography of the metallic counter surfaces is only marginally affected due to obstruction of the polymer transfer film formation in presence of the lubricant. The present study is aimed at investigating the tribological behaviour of several carbon filled PPS composites with variation in counter surface roughness parameters and lay orientation in water lubricated sliding contacts. An attempt has been made to statistically correlate the friction and wear behaviour of the polymeric materials to the counter surface roughness parameters and/or lay orientation using a multi-linear regression analysis technique.

2. Experimental work

Tribological studies were carried out using single-, dual- and multi-modal reinforced PPS composites. The reinforcements utilized for the PPS matrix in this study included MWNTs, short carbon fibers and graphite flakes. Fixed loadings of short carbon fibers (15wt. %), graphite (10wt. %) and multi-walled nanotubes (3wt. %) were utilized throughout this study. Polymer pins (4×4×4 mm3) were cut from extruded and injection molded polymer bars. The Inconel plates were initially mirror polished using #1200P SiC papers and subsequently were roughened to the desired topography using #60P, #100P or #400P SiC abrasive papers. The experiments were carried out using a Cameron-Plint tribometer (Plint-TE77) with a polymer pin on Inconel plate configuration. The experimental conditions are detailed in Table 1 and a schematic diagram of the test configuration is shown in Figure 1.

Table 1: Experimental Conditions

<table>
<thead>
<tr>
<th>Load</th>
<th>128 N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Apparent Contact Pressure</td>
<td>8 MPa</td>
</tr>
<tr>
<td>Stroke length</td>
<td>8 mm</td>
</tr>
<tr>
<td>Frequency</td>
<td>3 Hz</td>
</tr>
<tr>
<td>Test Duration</td>
<td>30 min - 20 h*</td>
</tr>
<tr>
<td>Total Sliding Distance</td>
<td>86.4-3456 m*</td>
</tr>
<tr>
<td>Temperature</td>
<td>R.T. (21-23 °C)</td>
</tr>
<tr>
<td>Lubricant</td>
<td>Distilled Water</td>
</tr>
<tr>
<td>Counter surface grinded by</td>
<td>#60P, #100P or #400P</td>
</tr>
<tr>
<td>Counter surface lay orientation</td>
<td>Parallel or perpendicular</td>
</tr>
</tbody>
</table>

Figure 1: Schematic diagram of test configuration

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3. Results

The results of the wear measurements are shown in Figures 2-3. Multi-linear regression analysis was utilized in order to statistically investigate the effect of various fillers and roughness parameters on the tribological behaviour of the polymer composites investigated. These analyses were carried out using commercially available statistical software (Minitab 16).

![Figure 2: Average steady state wear rate of polymers sliding against counter surfaces with lay orientation parallel to the sliding direction.](image)

![Figure 3: Average steady state wear rate of polymers sliding against counter surfaces with lay orientation perpendicular to the sliding direction.](image)

4. Conclusion

- Incorporation of SCF in the PPS matrix resulted in 1-3 orders of magnitude reduction in wear of PPS composites. No improvement in wear resistance of PPS could be observed with an incorporation of Gr and/or MWNTs only.
- The friction and wear behaviour of SCF filled PPS composites showed marginal variation with change in topography of the Inconel counter surfaces with regard to roughness parameters and/or lay orientation. On the other hand, the composites without SCF exhibited up to two orders of magnitude increase in wear rate with sliding against rough counter surfaces.
- Among the roughness parameters, \( R_{pk} \) and lay orientation played a more significant role in friction of the non-SCF filled PPS composites, where an increase in \( R_{pk} \) and lay orientation perpendicular to the sliding direction resulted in reduced friction.
- Among the roughness parameters, \( R_{pk} \) and mean slope of the profile along the sliding direction (\( \Delta \alpha_y \)) played a more significant role in wear of the non-SCF filled PPS composites, whereby an increased \( R_{pk} \) and reduced (\( \Delta \alpha_y \)) resulted in reduced wear rate.
- Irrespective of the initial topography of the counter surfaces, pure PPS as well as Gr and/or MWNT filled PPS composites resulted in marginal wear of the Inconel counter surfaces. However the wear of the Inconel plates were significantly influenced by their initial surface roughness and/or lay orientation when experiments were carried out against SCF filled PPS composites.

5. Acknowledgements

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6. References