Specific Wear Rate of Kenaf Epoxy Composite and Oil Palm Empty Fruit Bunch (OPEFB) Epoxy Composite in Dry Sliding

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1.0 INTRODUCTION

Natural fiber usage in industry promotes a sustainable material development through utilization of renewable resources. Composite reinforcement with natural fibres becomes an interest to many researchers and designers because of the positive aspects of the product. Nowadays, all of these natural fibres are beginning to find their way into commercial applications such as in automotive industries, marine hardware and household applications (Maleque and Belal, 2007).

From a mechanical point of view, natural fibres are good substitutes for polymeric composites due to advantageous characteristics in certain aspects such as renewable nature resources, low weight, cost, density and easily available. Another advantage is on the ease of modification chemically and mechanically (Maleque and Belal, 2007; Hanafi et al., 2002). From the tribological point of view, few works have been pursued on kenaf (Sastra et al. 2005), betel nut (Chin and Yousif, 2009; Umar et al., 2010), carbon (Li and Xia, 2010) and E-glass (El-Tayeb and Gadelrab, 1996) fibres and promising results were reported on the use of kenaf as alternative. For instance, the presence of kenaf fibres has enhanced the wear performance of composites (Chin and Yousif, 2009). In another work on epoxy matrix filled with hard powder, it was observed that wear rate increases as the normal load increases (Crivelli et al., 2001).

2.0 WEAR

Wear is defined as the loss of material from one or both of contacting surfaces when subjected to relative motion, while a broader definition of wear include any form of surface damage caused by rubbing processes on one surface against another (Kasolang et al. 2011). Abrasive wear occur when hard particles or hard asperities rub against a surface to cause damage or material removal. From Archard wear model (Archard, 1953), a specific wear rate, $W_s$, can be generally determined

$$W_s = \frac{\Delta m}{L \times \rho \times F}$$

where $W_s$ is wear rate ($\text{mm}^3/\text{Nm}$), $\Delta m$ is weight loss (g), $F$ is applied load (N), $\rho$ is density (g/mm$^3$), and $L$ is sliding distance (m).
3.0 APPARATUS AND EXPERIMENTAL PROCEDURE

3.1 Material

In a current study, raw kenaf fibres were supplied by Malaysian Agriculture Research and Development Institute (MARDI). Kenaf fibres were supplied in long fibres. The epoxy resin was mixed with hardener by composition ratios of 3:1 (by weight) respectively. The kenaf fibre weight fraction of the composite is 20%. In the case of OPEFB, raw OPEFB fibres used in the composite were supplied by Sabutek (M) and the epoxy resin and hardener by Leco (M). OPEFB fibres were supplied in 100, 125, 180 and 250 µm in sizes. As per manufacturer recommendations, resin and hardener were mixed in a ratio of 10.6 parts by volume and was later cured for 8 hours at room temperature. The fibres fraction of the composite is 20% by weight.

3.2 Wear Test

Abrasion Resistance Tester (TR-600) as shown in Figure 1(a) was used for the dry sliding wear tests. Kenaf and OPEFB fibres composite sample was attached to the rotational disc and put in contact with two rotating abrasive wheels made of vitrified bonded silicon carbide. Before each test, abrasive wheels were cleaned from any dust using a dry brush. The size of composite sample is 122 mm in diameter and 5 mm thick. The schematic diagram of the abrasion test apparatus is shown in Figure 1(b).

Summary of the operational conditions was tabulated in Table 1. For each applied load, a new disc sample was used. The amount of weight loss for each sample was measured before and after a test at suitable intervals by weighing the disc sample to an accuracy of ±0.0001g using a precision balance. Specific wear rate at each operating condition was determined using equation (1).

The surface condition of each material sample was analyzed using an optical 3D surface measurement device. From the 3D surface measurements, details of the surface morphology and the surface roughness were obtained.

4.0 RESULTS AND DISCUSSION

The results on the mass loss over distance for both kenaf and OPEFB epoxy composite are shown in Figure 2 and Figure 3 respectively. Generally, Kenaf epoxy composites mass loss is consistently higher compared to OPEFB composites. For the 30N load, the mass loss value of Kenaf epoxy is almost 6 times higher compared to that of OPEFB epoxy composite at 10km distance. In the case of OPEFB composite, at 30N load, it was clear that the mass loss was significantly higher for the smallest fibre size (100µm) examined. The value recorded was more than 6 grams.

At other fibre sizes, the mass loss values were nearly 2 grams.

From the mass loss values, the specific wear rate profiles were produced for both Kenaf and OPEFB composites using equation (1) as shown in Figure 4 and Figure 5 respectively. For kenaf composite, the specific wear rate profile over distance is almost similar in all cases examined. It was noticed that all three cases produced the same wear rate starting at 3km distance. The wear rate starts to converge after 6km distance. This is believed
due to the fiber arrangement in the composite matrix. For the first 5 km distance, the loss was suspected due to epoxy matrix alone on the surface. The values of specific wear rate were later become lower and more consistent as the kenaf fibers being exposed.

Figure 2 Mass loss of Kenaf epoxy composite over distance

Figure 3 Mass loss of OPEFB epoxy composite over distance

Figure 4 Specific wear rate profiles for kenaf epoxy composites over distance

For the case of OPEFB composites, the specific wear rate profiles obtained were different from those of the Kenaf. At 10N load, the specific wear rate profiles over distance were different with no specific trend observed for 100 and 125µm. The specific wear rate for different sizes of fibres at 30N load was pretty much constant beyond 3000m distance. This behaviour could be contributed by the homogeneity of the mixing of fibers and epoxy.

From the results obtained, in the case of OPEFB epoxy composite, it can be safely said that at a higher load, a smaller fiber size (i.e. 100 um) tends to get worn out faster. For the rest of the sizes examined, the specific wear rate is not distinctly different. In the observation of surface morphology, the surface roughness of the sample before and after test was measured. The average surface roughness values for OPEFB composite were tabulated in Table 2.

Table 2 Average surface roughness, Ra values before and after 10km for 10N and 30N loads for OPEFB composite

<table>
<thead>
<tr>
<th>Load 10 N</th>
<th>100µm</th>
<th>125µm</th>
<th>180µm</th>
<th>250µm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Before (µm)</td>
<td>5.502</td>
<td>1.003</td>
<td>2.482</td>
<td>2.073</td>
</tr>
<tr>
<td>After 10km (µm)</td>
<td>0.734</td>
<td>0.951</td>
<td>0.759</td>
<td>0.888</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Load 30 N</th>
<th>100µm</th>
<th>125µm</th>
<th>180µm</th>
<th>250µm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Before (µm)</td>
<td>2.894</td>
<td>1.822</td>
<td>1.289</td>
<td>1.172</td>
</tr>
<tr>
<td>After 10km (µm)</td>
<td>1.020</td>
<td>1.192</td>
<td>1.032</td>
<td>1.069</td>
</tr>
</tbody>
</table>
(2) In the case of OPEFB epoxy composite, at 30N load, the smallest fiber size examined (i.e. 100 µm) produces the highest specific wear rate.

(3) Surface roughness has consistently reduced after 10km in all cases.

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References


4.0 CONCLUSION

Based on the results, the specific wear rate profiles over distance for kenaf and OPEFB epoxy composites were determined. It can be concluded that:

(1) Generally, the specific wear rate for kenaf epoxy composite is higher at the early test and starts to converge to a consistent value after 6km.

Figure 6 Surface morphology of OPEFB epoxy composite captured by 3D microscope imaging at 5000X magnification (a) before test (b) after 10km distance.

From the surface morphology, distribution of fibres orientation can be determined. However, the correlation of fiber orientation to the specific wear rate has not been explored in this study.