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ADHESIVE AND FRICTIONAL BEHAVIOUR OF POLYMERIC COMPOSITES BASED ON KENAF FIBRE

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ABSTRACT

This paper presents an attempt to use kenaf fibres as a reinforcement for tribo-polyester composite for bearing applications. Kenaf fibres reinforced epoxy (KFRE) composites were fabricated using a closed mould technique associated with vacuum system. Adhesive wear and frictional behaviour of the composites were studied against polished stainless steel counterface using Block-On-Disc (BOD) machine at different applied loads (10-100N), sliding distances (0-5km) and sliding velocities (1.1-3.9m/s). Furthermore, the effect of the fibre orientations, with respect to the sliding direction, were considered, i.e. Parallel (P-O), Anti-Parallel (AP-O) and Normal (N-O). The morphology of the worn surfaces of the composites was studied using a scanning electron microscope (SEM). The result revealed that the presence of kenaf fibres in the composite enhanced the wear and frictional performance of the epoxy. Applied load and sliding velocity have less effect on the specific wear rate of the composite in all the three orientations. The composite exhibited better wear performance in P-O and AP-O compared to N-O.

INTRODUCTION

Recently, the interest in using natural fibres as a reinforcement for polymeric composites is increased due to their properties such as lightweight, renewability, low density, high specific strength, non-abrasivity, combustibility, non-toxicity, low cost and biodegradability.

With regards to the usage of natural fibres as reinforcement for tribo-polymeric composites, few works have been attempted on polyester composites using oil palm, jute and sugarcane fibres [1-4]. In spite of the poor interfacial adhesion of those fibres, promising results were reported.

The potential of using high interfacial adhesion, kenaf fibres, as reinforcement for tribo-polymeric composites has not been explored yet. This motivates the current work on the effect of kenaf fibres on the tribological properties of polymers. Adhesive wear and frictional characteristics of neat epoxy and its composites based on kenaf fibres were evaluated using Block-On-Disc machine against smooth stainless steel considering three different orientations of fibres. The tests were conducted at different sliding distances (0-5km), 2.8m/s sliding velocity and 50M applied load.

MATERIAL AND EXPERIMENTAL

Raw kenaf fibres were supplied by Malaysian Agricultural Research and Development Institute (MARDI). The fibres were uniformly cut into a length of 300mm, and then placed into a metal mould in the size of 300mm x 200mm x 20mm in an unidirectional form. The epoxy resin (DER 331) and hardener (JOINTMINE 905-3S), with 2:1 of ratio, was uniformly mixed using electric stir and poured into the mould. The mould was placed in a vacuum chamber (MCP 004PLC) with 0.5bar pressure to get rid of the air bubble which trapped in the mould in between the fibres. The vacuumed block was kept for curing at room temperature for 24 hr.

The diameter of the fibre is in the range of 0.25mm to 0.4 mm. Some of the mechanical properties of the neat epoxy and KFRE composite are listed in table 1. The prepared composite was machined into small specimens in the size of 10mm x 10mm x 20mm and the tribological tests were conducted on 10mm x 10mm apparent contact area. Three different orientations of fibres, with respect to the sliding direction of the counterface, were considered. These orientations are namely parallel, anti-parallel and normal (P-O, AP-O and N-O, respectively). Schematic drawing illustrates those orientations in figure. 1.

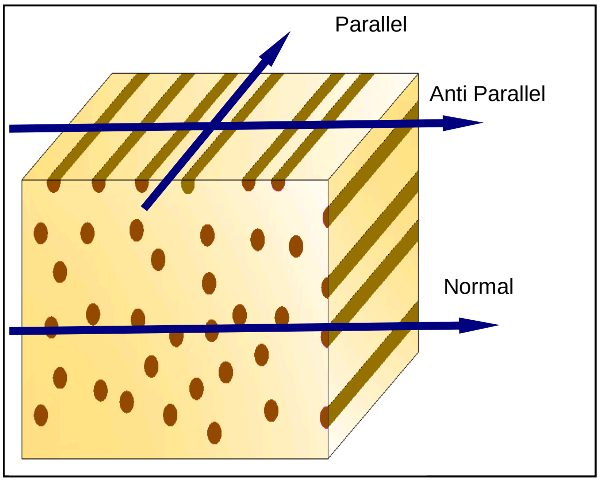


Figure 1 Fibre orientations with respect to the sliding direction

EXPERIMENTAL PROCEDURE

Pullout tests

Samples for single pullout tests were fabricated using a metal mould with dimensions of 50mm × 10mm × 10mm, figure. 2. The embedded length of fibres in the matrix was 20 mm and the free one was about 30 mm. The specimens were tested using the universal test system (100Q Standalone) with a loading speed of 1 mm/min.

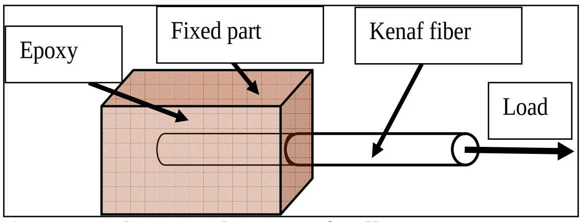


Figure 2 Schematic diagram of pullout test

Tribological experimental procedure

The experiments were conducted using a Block-On-Disk (BOD) machine as illustrated in figure.3. The counterface was made of stainless steel (hardness = 1250 HB, Ra=0.1µm). Before each test, abrasive paper (Sic G2000) was used to polish the counterface and the prepared composites surfaces. The roughness of the composite surface was varied in each orientation. In P- and AP-orientations, the average of 5 measurements in different regions was about 0.30µm. Meanwhile, in N-O, the composite roughness values were in an average of 0.70.1µm.

Figure 3 Schematic drawing showing the developed Pin-On-Disc (POD) machine

The initial weight of the specimens was measured using Setra weight balancer (±0.1mg). During the tests, friction force was measured by load cell which was fixed in the mid of the lever as shown in figure 3. An infrared thermometer (Extech 42580) was used to measure the initial interface temperature and calibration was made to determine the real interface temperature. The composite surface morphology was studied using an SEM (JEOL, JSM 840). Before using the SEM machine, the composite surfaces were coated with a thin layer of gold using an ion sputtering device (JEOL, JFC-1600). Each tribological test was repeated three times and the average of the measurements were determined.

PULL-OUT AND TRIBOLOGICAL RESULTS

The pull-out tests revealed that the interfacial adhesion property of kenaf fibres with the epoxy matrix is high. In other words, the failure mechanism of the pull-out test samples was due to the breakage of the fibres, which is not due to the pull out. The stress/strain results showed similar trend to the one for the single fibre tensile result. The higher interfacial adhesion of the kenaf fibres could make it over the other natural fibres such as sugarcane [3], oil palm [1,2] and coconut [4].

Regarding the tribological behaviour of the epoxy and its composite, figure 4 illustrates the trend and variation of the specific wear rates against the sliding distances. The figure shows that the specific wear rates display a relatively steady state after 2.5km sliding distance. NE denotes the highest specific wear rate at all sliding distances while the composite in N-O possesses the highest wear resistance. In other words, kenaf fibres assist to reduce the *Ws* of the epoxy especially when the fibres were oriented in N-O. In this orientation (N-O), the wear performance of the neat epoxy was enhanced by about 85% when it was reinforced with kenaf fibres. The higher wear resistance of the composite in N-O is in highly agreement with other published work [5]. This is due to two reasons. Firstly, the fibre is deeply embedded in the matrix, where it is not easy to be pulled out. Secondly, the higher interfacial adhesion of the fibres contributes in preventing the pull-out of the fibres. This can further explain with the assistant of the surface SEM observations.

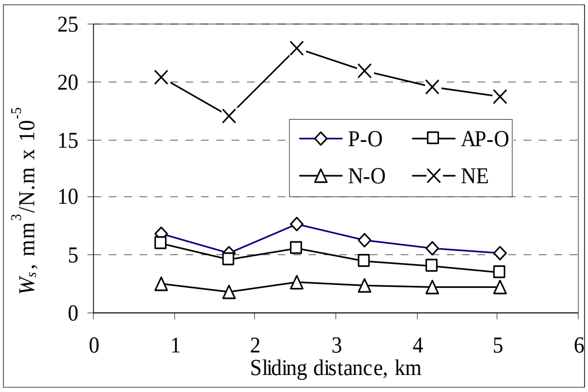
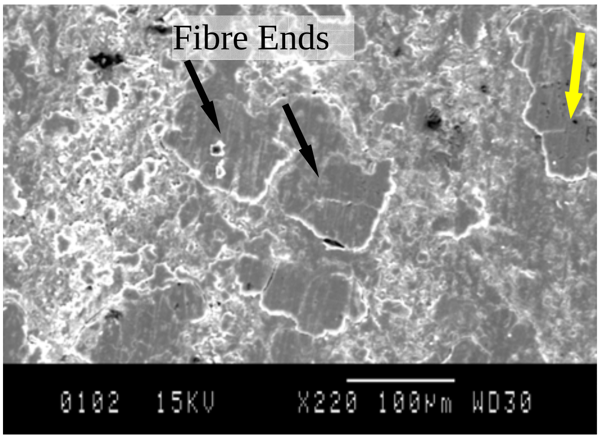
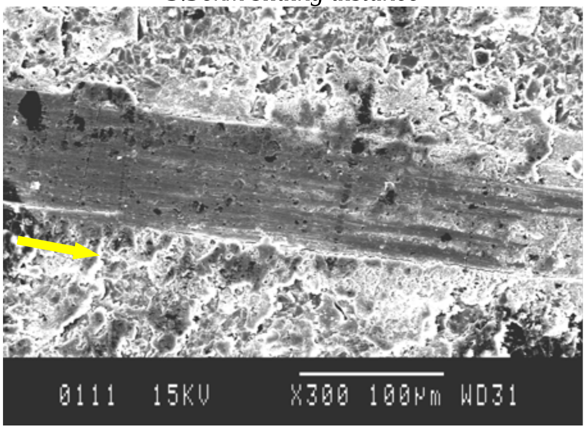


Figure 4 Specific wear rate versus sliding distance at 50N applied load.

The micrographs of the worn surfaces of the composite in N-O and P-O are shown in figure 5 a & b, respectively. The wear mechanism of the composite in N-O is predominant by deformation in the resinous regions. It can be seen a sign of back film transfer from the counterface to the composite. Furthermore, the fibres' end is covered by epoxy layer. This indicates that some of the removed material in the resinous regions transferred onto the fibres end, i.e. not worn away. This could be the reason of the lower Ws of the composites in N-O. On the other hand, when the fibres are parallel to the counterface and the sliding direction (P-O), the possibility of transfer some of the removed epoxy debris to the fibrous regions is weak. This is confirmed in figure 5b, where it seems that the resinous regions are highly deformed and become rough. However, there is no sign of delamination or debonding. This could explain the results shown in figure 4.



a) At 50N applied load and 2.8m/s sliding velocity for 3.36km sliding distance



b) At 50N applied load and 2.8m/s sliding velocity for 3.36km sliding distance

Figure 5 Worn surface of the KFRE composite tested in N-O at different operating parameters.

The friction coefficient versus the sliding distance of the neat epoxy and its composite (in P-, AP-, and N-orientations) is shown in figure 6. From the figure, there is no steady state of friction coefficient can be seen for all the materials. Higher friction coefficient exhibits by neat epoxy (NE). Meanwhile, the composite in the three orientations gives similar values. In other words, there is significant effect of the fibre orientation on the frictional result of the composites.

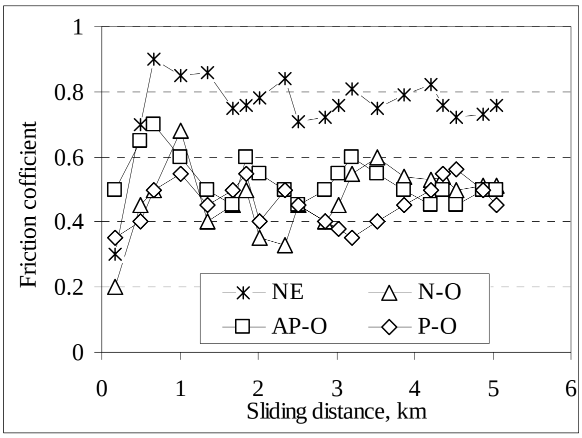


Figure 6 Friction coefficients versus sliding distance for NE and KFRP composite.

In comparison to other published works [1-4], epoxy composite based on kenaf fibres introduces low friction coefficient, where polyester composite based on sugarcane, oil palm or coir fibres exhibited very high friction coefficient. This could be due to the differences in the film transfer characteristics generated on the counterface by rubbing those composites. The back film transfer on the epoxy composite (cf. figure 5a) could contribute to the lower friction coefficient of this composite compared to the others. However, further study on the effect of the composite sliding on the counterface is needed, i.e. modification on the hardness, roughness and film transfer characteristic (SEM).

CONCLUSIONS

From the results obtained and observation made on the surface morphology few points can be concluded as follows:

1. Presence of kenaf fibres oriented in N-O enhanced the wear performance of the epoxy by about 85%. Moreover, the friction coefficient of the composite was significantly lower than the neat epoxy.
2. The wear mechanisms of the composite were predominated by back film transfer (in N-O) and high deformation (in P-O) in the resinous.
3. In comparison to other published works, kenaf fibres give better wear and friction support to the matrix compared to oil pal, sugarcane and coir fibres.

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