Surface durability of oil palm fiber/epoxy composite at various temperatures

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ABSTRACT – The purpose of this work is to study the surface durability of Oil Palm Fiber/Epoxy (OPF/E) composite at different temperatures. The tribological test was carried out by using a pin-on-disc tribometer in dry sliding conditions. Surface durability was determined by the value of specific wear rate with respect to the temperature. The surface morphology was observed by scanning electron microscopy (SEM). It was found that 30 wt.% have high surface durability compared to 50 wt.% and 70 wt.% which can withstand at a maximum of 80°C before transition to severe wear occur.

1. INTRODUCTION

Natural fibre polymer composites have numerous applications in almost all fields of engineering. Natural fibres offer great potential as reinforcement in polymers for various industrial applications and have a greater impact on socio-economic development [1-2]. The development of high-performance engineering products made from natural resources is increasing around the world because of the issues of low cost with their low density, less damage in processing equipment, good relative mechanical properties and renewable resources as apparently environmentally superior alternatives to glass fibers in composites. Hence, in this present work an attempt has been made in order to emerge to be more environmental friendly and appeared as realistic alternative to become an essential factor used in industrial products and applications [3-5].

There are many situations and development of tribological components made of fiber reinforced polymer composites are under tribological loading conditions and having excellent wear and friction [1,6]. In addition, frictional heating must be considered to avoid the failure of tribological components because it has an important influence on the tribological behavior of so many sliding systems [7]. According to several studies that have been done, understanding the tribological behavior of natural fiber/polymer composites has an equal role to be debated with the mechanical attributes of those materials [4].

Although there were many researches about the influence tribological properties of the polymer composite, study on surface durability on temperature is still not considered yet. This motivates the current work to conduct a series of studies on the effect of temperature on OPF/E composite towards surface durability in tribo-performance.

2. METHODOLOGY

For fiber preparations, the fibers were soaked in 6 vol.% natrium hydroxide (NaOH) solution for 48 hours. Then it was rinsed and dried at room temperature. The prepared fibers of 30 wt.%, 50 wt.% and 70 wt.% were mixed with epoxy at a resin to hardener ratio of 4:1 using hot compaction technique. The sample was formed into a pin with diameter of 10mm and pressed at 2MPa, 80°C.

The tribological test was performed using a pin-on-disc tribometer according to ASTM G99-05 standard at a constant applied load of 49.05N and speed of 1000 rpm. The specific wear rate (Ws) was determined as in Equation 1.

$$Ws = \frac{V_{loss}}{FL} \quad (1)$$

Where, V_{loss} is the volume loss (mm^3), Ws is the specific wear rate (mm^3/Nm), F is the applied load (N), and L is the sliding distance (m).

3. RESULTS AND DISCUSSION

Figure 1 shows the wear rate of OPF/E composite changes with temperature. At certain temperature, the wear rate was sharply increased, which the transitions to severe wear is realized. To be confirmed, the surface morphology was observed at 50^0C and 130^0C and presented in Figure 2 and Figure 3.

Figure 2 shows the worn surfaces of 30 wt.% OPF/E composite at 50^0C and 130^0C. It was clearly show that the surface was not highly damaged, as shown in Figure 2(a). Furthermore, it can be seen that the surface is still adhered well and there is a patch of the resin (mark as "R") which is protecting the fiber from severe damage.

As temperature increases to 130^0C, debonding of fiber (mark as "De") occurred and micro cracks were observed (mark as "Cr"). According to El-Tayeb et.al

[8], surface heating in sliding contact would influence the extent of surface damage and thus increasing wear rate.

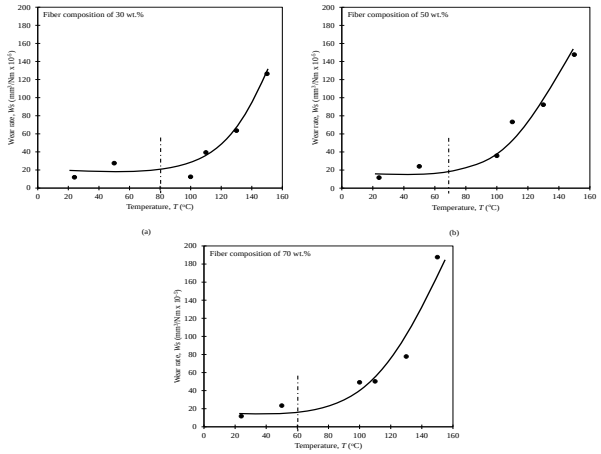
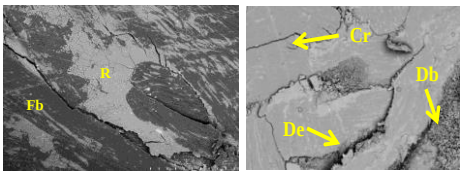


Figure 1 Effect of temperature on the wear rate of OPF/E composite (a) 30 wt.% (b) 50 wt.% (c) 70 wt.%.

Table 1 Mechanical properties of the OPF/E composite pin and disc materials.

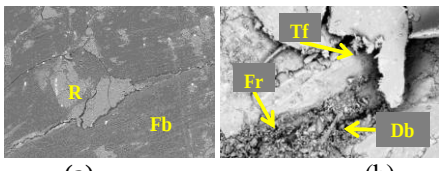
Oil Palm Fiber/Epoxy				
Properties	**[a]Pin 30wt.%**	**[a]Pin 50wt.%**	**[a]Pin 70wt.%**	**[b]Disc SKD11**
Hardness, *H* [GPa]	7.14	7.13	6.7	7.35
Density,ρ [g/cm3]	1.34	1.336	1.321	7.72

[a] Properties from laboratory measurements.
[b] Properties from manufacturer.



(a) (b)

Figure 2 SEM micrographs of worn surface of 30wt.% OPF/E composite at (a)50^{0}C and (b)130^{0}C [De: debonding, Db: Debris, Fr: Small fracture, Cr: Micro-Crack, R: Resin. Fb: Fiber].



(a) (b)

Figure 3 SEM micrographs of worn surface of 50wt.% OPF/E composite at (a)50^{0}C and (b)130^{0}C [Tf: Torn Fiber].

From Figure 3(a), the worn surface of 50 wt.% OPF/E composite is similar with 30 wt.% with less damages are observed. Meanwhile, at the severe region of 130^{0}C, it can be seen the fiber seem to be torn (mark as "Tf") and existed of fracture (mark as "Fr") associated with generated debris (mark as "Db") as shown in Figure 3(b). This could be the other reason for the higher specific wear rate at higher temperature.

The above observations, 30 wt.% OPF shows lower wear rate than 50 wt.% and 70 wt.%. Chand and Fahim [1] noted that low hardness lead to increase the real area of contact thus increases the wear rate. Hence, the reason is believed due to the high hardness at 30 wt.% as shown in Table 1.

4. CONCLUSION

In summary, the findings provide insights that the OPF/E composite with 30 wt.% fiber has the lowest wear rate. It can be concluded that higher fiber composition in composite is not suitable for application at high temperatures, especially in tribology applications due to the high wear rate.

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REFERENCES

[1] N. Chand and M. Fahim, Tribology of natural fiber polymer composites. Elsevier, 2008.

[2] A.N. Kasim, M.Z Selamat, N. Aznan, S.N. Sahadan, M.A.M. Daud, S. Salleh, and R. Jumaidin. "Effect of pineapple leaf fiber loading on the properties of pineapple leaf fiber–polypropylene composite," in *Proceedings of Mechanical Engineering Research Day 2015,* 2015, pp. 3-4.

[3] M.M Davoodi, S.M Sapuan, D. Ahmad, A. Aidy, A. Khalina and M. Janoobi, "Concept selection of car bumper beam with developed hybrid bio-composite material," *Materials & Design,* vol. 32, no.10, pp. 4857-4865, 2011.

[4] A. O'donnell, M.A. Dweib and R.P Wool, "Natural fiber composites with plant oil-based resin," *Composites Science and Technology*, vol.64, no.9, pp. 1135-1145, 2004.

[5] B.F Yousif, S.T. Lau and S. McWilliam, "Polyester composite based on betelnut fibre for tribological applications." *Tribology International*, vol. 43, no.1, pp. 503-511, 2010.

[6] A.K. Mohanty, M. Misra and L.T. Drzal, eds. *Natural fibers, biopolymers, and biocomposites*. CRC Press, 2005.

[7] F.E. Kennedy, "Frictional heating and contact temperatures," *Modern tribology handbook*, vol.1, 235-259, 2001.

[8] N.S.M. El-Tayeb, B.F. Yousif and P.V. Brevern, "On the effect of counterface materials on interface temperature and friction coefficient of GFRE composite under dry sliding contact." *American Journal of Applied Sciences 2*, vol. 11, pp. 1533-1540, 2005.