Jurnal Teknologi

Full paper

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

Salmiah Kasolang, Mohamad Ali Ahmad*, Mimi Azlina Abu Bakar , Ahmad Hussein Abdul Hamid [a]

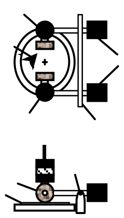
[a]Faculty *of Mechanical Engineering, Universiti Teknologi MARA, 40450 Shah Alam Selangor, Malaysia*

*Corresponding author : alie_76_02@yahoo.com

Article history

Received :15 June 2012
Received in revised form :12 August 2012
Accepted :28 August 2012

Graphical abstract



Abstract

This paper presents an experimental investigation carried out to compare specific wear rate and surface morphology between two types of natural fibres namely kenaf and oil palm empty fruit bunch (OPEFB). Kenaf fibres were received in long fiber size and OPEFB in different sizes (100, 125, 180 and 250 µm). Both materials were mixed with the epoxy resin to produce epoxy composites. Wear tests were carried out using Abrasion Resistance Tester in dry sliding condition. These tests were performed at room temperature for different loads and at a constant sliding velocity of 1.4m/s. Based on the results, the specific wear rate of Kenaf Fibre composite starts to converge to one similar value beyond 6km distance. In the case of OPEFB epoxy composite, it was found the fiber size of 100 um has produced the highest specific wear rate.

Keywords: Abrasive wear, surface morphology, roughness, surface temperature

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), betelnut (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). On Oil Palm Empty Fruit Bunch (OPEFB) fibres, many of previous work on morphology, chemical constituents and properties of OPEFB have been reviewed (Shinoj *et al*. 2011). However, it was noticed that many of the researchers have focused more on the physical properties, mechanical properties, water absorption characteristics and degradation/weathering effects (Rozman et.al. 2001; Rozman *et al*. 2004; Kalam et.al 2005). Literatures on the dynamic mechanical analysis, abrasion test, thermal conductivity and electrical properties were limited.

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 occurs 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, Ws, can be generally determined

$$W_s = (\Delta m) / (L \times \rho \times F) \quad (1)$$

W_s in (mm3/Nm); Δm is weight loss (g); F is applied load (N), ρ is density (g/mm3); and L is sliding distance (m).

3.0 APPARATUS AND EXPERIMENTAL PROCEDURE

3.1 Material

In a current study, raw kenaf fibers 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 fibers 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.

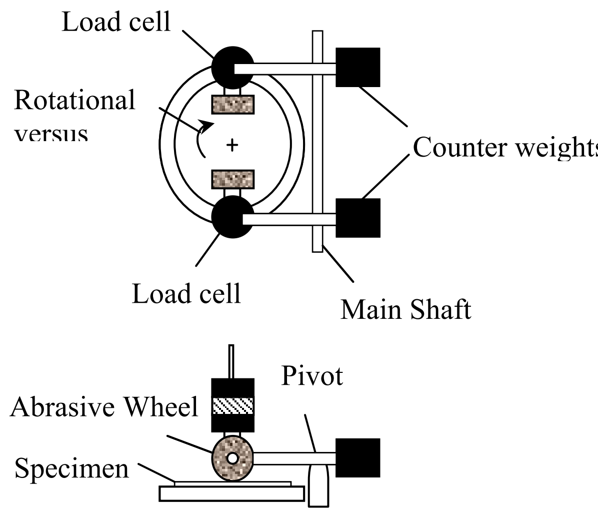
3.2 Wear Test

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.

(a)



(b)

Figure 1 (a) Abrasion Resistance Tester (b) Schematic diagram of the abrasion test apparatus

Table 1 Operating parameters in abrasion test

Parameters	Experimental conditions
Type of motion	Unidirectional sliding
Contact geometry	Cylinder on flat
Applied load (N)	5, 20 and 30 (Kenaf)
	10 and 30 (OPEFB)
Sliding speed (m/s)	1.4
Temperature (°C)	24.8 ± 1.0
Humidity (%)	65 ± 2
Sliding distance (m)	1000 to 10 000 at interval of 1000

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.

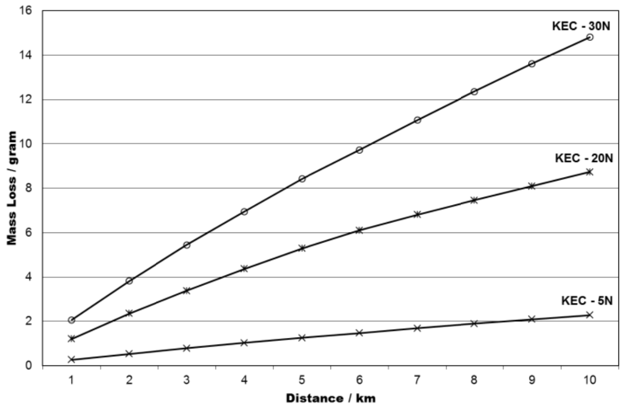


Figure 2 Mass loss of Kenaf epoxy composite over distance

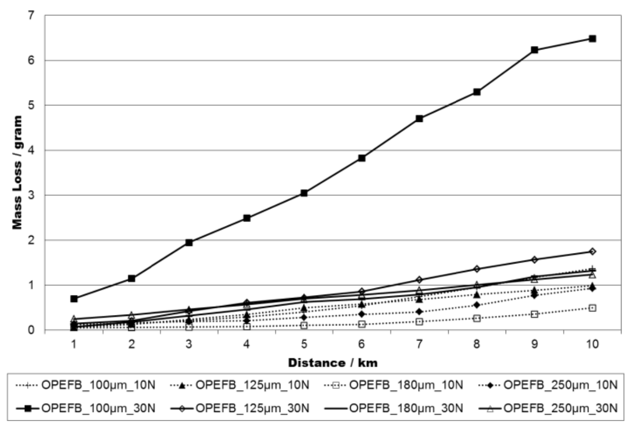


Figure 3 Mass loss of OPEFB epoxy composite over distance

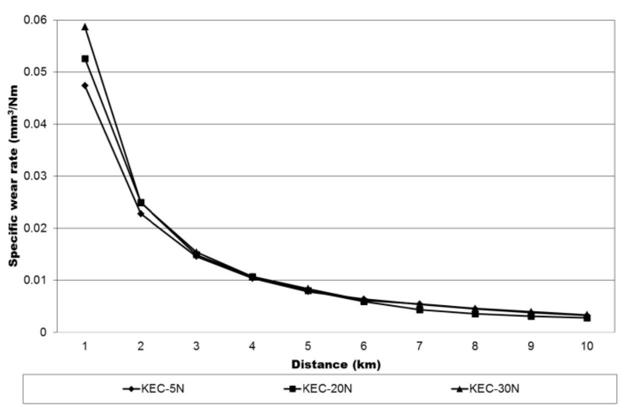


Figure 4 Specific wear rate profiles for kenaf epoxy composites over distance

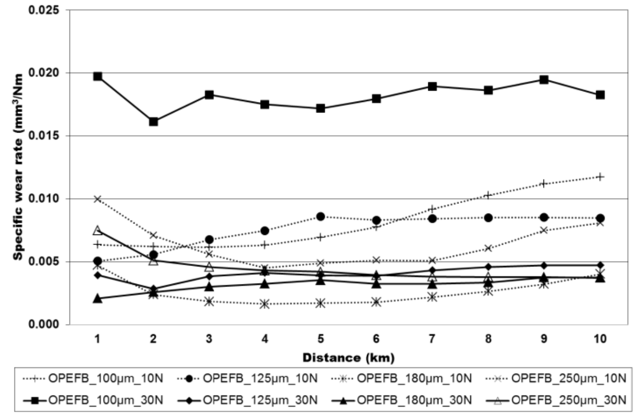


Figure 5 Specific wear rate profiles for OPEFB epoxy composites over distance

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 homogenity of the mixing of fibers and epoxy.

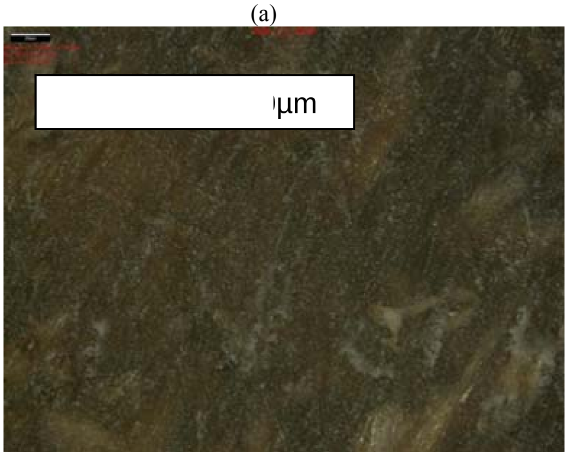
From the results obtained, in the case of OPEFB epoxy composite, it can be safely said that at a higher load, a smaller fiber size (i.e. 100 um) tends to get worn out faster. For the rest of the sizes examined, the specific wear rate is not distinctively different. In the observation of surface morphology, 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

	Load 10 N			
	100µm	**125µm**	**180µm**	**250µm**
Before (µm)	5.502	1.003	2.482	2.073
After 10km (µm)	0.734	0.951	0.759	0.888

	Load 30 N			
	100µm	**125µm**	**180µm**	**250µm**
Before (µm)	2.894	1.822	1.289	1.172
After 10km (µm)	1.020	1.192	1.032	1.069

(a)



(b)

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.

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.

(2) In the case of OPEFB epoxy composite, at 30N load, the smallest fiber size examined (i.e. 100 um) produces the highest specific wear rate.

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

Acknowledgement

The authors would like to thank the Ministry of Higher Education of Malaysia (MOHE) for the financial support extended to this study through the E-science and FRGS Grant award. The authors are also in debt with the Research Management Institute of UiTM for facilitating this project.

References

[1] Archard, J. F. 1953. *Journal of Applied Physic*. 24: 981.

[2] Chin C. W. and Yousif B. F. 2009. Potential 0f Kenaf Fibres as Reinforcement for Tribological Applications. *Wear*. 267: 1550–1557.

[3] Crivelli Visconti I., Langella A. and Durante M. 2001. The Wear Behaviour of Composite Materials with Epoxy Filled with Hard Powder. *Applied Composite Materials*. 8: 179–189.

[4] El-Tayeb N. S. and Gadelrab R. M. 1996. Friction and Wear Properties of E-Glass Fiber Reinforced Epoxy Composites Under Different Sliding Contact Conditions. *Wear*. 192: 112–117.

[5] Hanafi Ismail, Edyham M. R. and Wirjosentono B. 2002. Bamboo Fibre Filled Natural Rubber Composites:The Effects of Filler Loading and Bonding Agent. *Polymer Testing.* 21:139–144.

[6] Kalam, A., Sahari, B. B., Khalid, Y. A., Wong, S. V., 2005. Fatigue Behaviour of Oil Palm Fruit Bunch Fibre/Epoxy and Carbon Fibre/Epoxy Composites. *Composite Structures*. 71: 34–44.

[7] Kasolang, S., Ahmad, M. A., Ghazali, F. A. and Azmi, A. M., 2011. Preliminary Study of Dry Sliding Wear in Kenaf Epoxy and Carbon Epoxy composites. *Applied Mechanics and Materials.* 52(54): 464–469

[8] Li, J. and Xia, Y. C. 2010. Evaluation of Tribological Properties of Carbon Fiber-Reinforced PA6 Composites. *Polymer Composites*. 31(3):536–542.

[9] Maleque, M. A. and Belal, F. Y 2007. Mechanical Properties Study of Pseudo-Stem Banana Fiber Reinforced Epoxy Composite. *The Arabian Journal for Science and Engineering.* 32(2B).

[10] Rozman, H. D., Ahmadhilmi, K. R. and Abubakar, A. 2004. Polyurethane (PU)-oil Palm Empty Fruit Bunch (EFB) Composites: The Effect of EFBG Reinforcement in Mat Form and Isocyanate Treatement On The Mechanical Properties. *Polymer Testing*. 23: 559–565.

[11] Rozman, H. D., Tay, G. S., Abubakar, A. and Kumar, R. N. 2001. Tensile Properties Of Oil Palm Empty Fruit Bunch-Polyurethane Composites. *European Polymer Journal*. 37: 1759–1765.

[12] Sastra, H. Y, Siregar, J. P., Sapuan, S. M., Leman, Z. and Hamdan, M. M. 2005. Flexural Properties of Arenga pinnata Fibre Reinforced Epoxy Composites. *American Journal of Applied Sciences*. (Special Issue): 21–24.

[13] Shinoj, A., Visvanathan, R. Panigrahi, S. and Kochubabu, M. 2011. Oil Palm Fiber (OPF) and Its Composites: A Review. Industrial Crops and Products. 33: 7–22.

[14] Umar. Nirmal, Yousif, B. F. Dirk Rilling and Bevern, P. V. 2010. Effect of Betelnut Treatment and Contact Conditions on Adhesive Wear and Frictional Performance of Polyester Composites. Wear. 268: 1354–1370.

[15] Yousif, B. F., Umar Nirmal and Wong, K. J. 2010. Three-body Abrasion On Wear And Frictional Performance of Treated Betelnut Fibre Reinforced Epoxy (T-BFRE) Composite. *Materials and Design*. 31: 4514–4521.