THE EFFECT ON FRICTION COEFFICIENT AND WEAR RATE OF PALM KERNEL ACTIVATED CARBON-EPOXY (PKAC-E) COMPOSITE AT DIFFERENT TEMPERATURES

Noor Ayuma Mat Tahir[1,a]**,** *Mohd Fadzli Bin Abdollah*[1,2,b], *Rafidah Hasan*[1,2,c], *Hilmi Amiruddin*[1,2,d]

[1]Faculty of Mechanical Engineering, Universiti Teknikal Malaysia Melaka,
Hang Tuah Jaya, 7610 Durian Tunggal, Melaka, Malaysia

[2]Centre for Advanced Research on Energy, Universiti Teknikal Malaysia Melaka,
Hang Tuah Jaya, 7610 Durian Tunggal, Melaka, Malaysia

[a]areyouum.mattahir@gmail.com, [b]mohdfadzli@utem.edu.my, [c]rafidahhasan@utem.edu.my,
[d]hilmi@utem.edu.my

ABSTRACT

The purpose of this study is to investigate the tribological effect on friction coefficient and wear rate of Palm Kernel Activated Carbon-Epoxy (PKAC-E) composite at different temperatures. All specimens were prepared by using compaction technique. The tribological test was carried out by using a pin-on-disc tribometer in dry sliding conditions by applying different temperatures at constant sliding speed and applied load. The worn surfaces were analyzed from the images displayed in Inverted Microscope. The results show that both COF and wear rate of the composites is increased with temperatures. Some adhesive and abrasive wear types were seen on the worn surfaces.

Keywords— Palm kernel activated carbon, temperature, friction coefficient, wear

1. INTRODUCTION

Self-lubricating components which contains softer second phase components are widely used in sliding applications nowadays. Currently, published information available on the mechanics of friction and wear of such materials is relatively little. The formation of self-lubricating materials may differ with the friction conditions, the process controlled, and also adhesive interactions at the interface (Alexeyev & Jahanmir, 1993). Abdollah et al., (2010) explained that hydrogen-free amorphous carbon (a-C), commonly known as diamond-like carbon (DLC) has its excellent properties such as high hardness and thermal stability, low friction coefficient and good chemical inertness. Liao et al., (2004) reported that the tribological properties decreases as the slicing cycles or load increasing due to the graphitization of DLC films within the wear track. Meanwhile Liu et al., (1996) presents proof that transfer layer contains a fine distribution of graphite nano-particles that arranged in distorted diamond-like structure. The graphitization process that took place probably due to thermal and strain effects from the repeated friction. A year later, Liu et al., (1997) explained that the transformation of graphite-like-carbon from DLC also could be triggered by shear stresses that occur at the surface. In 2005, Zhou stated that the formation of DLC coatings at the wear tracks was highly because of the formation of a compact wear debris layer rather than a frictional heating effect. A few researcher found out that porous carbon exhibited its potential to act as a self-lubricating material when reinforced in aluminium alloy can significantly improved wear resistance. Gomes et al., (2001) explained that carbon-carbon composites exhibits almost independent speed for COF but it is highly affected by test temperature. Therefore this study is proposed to investigate the effect on tribological behavior of Palm Kernel Activated Carbon-Epoxy (PKAC-E) at different temperatures.

2. METHODOLOGY

Fine powder of PKAC (±1000μm) were mixed with Epoxy at ratio of 70 wt.% PKAC and 30 wt.% Epoxy (1:4 - Hardener:Resin). The composition were then compacted into a die at 80ºC with 2.5MPa applied pressure as shown in Figure 1a and b. The schematic diagram of the experimental setup are shown in figure 2a and b. The specimen were left to be cured for 2 days. The density of the specimen were tested using densitometer. Prior to tribological testing, the disc were prepared with average surface roughness of ±0.13μm and cleaned in an ultrasonic bath. The pin were polished against 1000grit SiC paper until flat with average surface roughness up to ±0.40μm. The tribological test were carried out following the ASTM G99-05 standard at different temperature of 27ºC, 60ºC, 90ºC, 120ºC, and 150ºC. All tests were performed under constant speed of 1000rpm, applied load of 49.05N, and sliding distance of 2500m. The pin were weighted before and after running the test in order to determine the wear volume and specific wear rate both were determine using Equation 1 and 2. The worn track pattern and direction were observed under the inverted microscope.

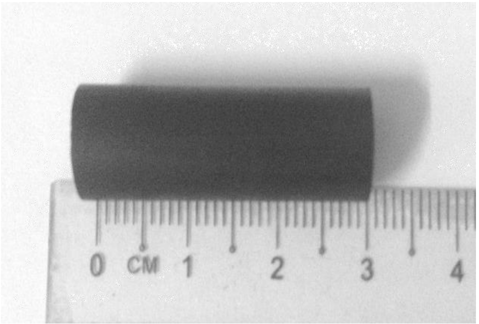

Figure 1a: The PKAC Composite Specimen

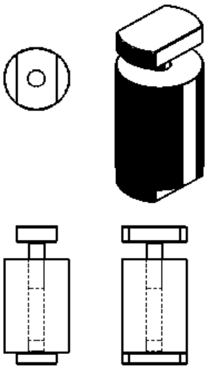

Figure 1b: The Mold Used for Compression

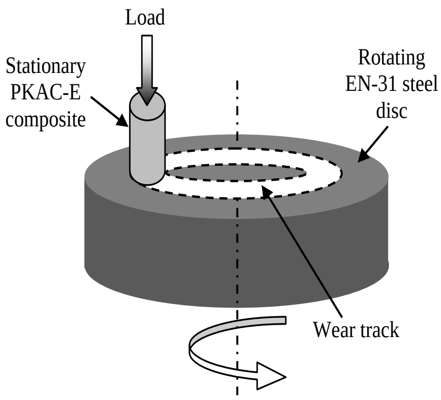

Figure 2a: The Schematic Diagram of Pin and Disc

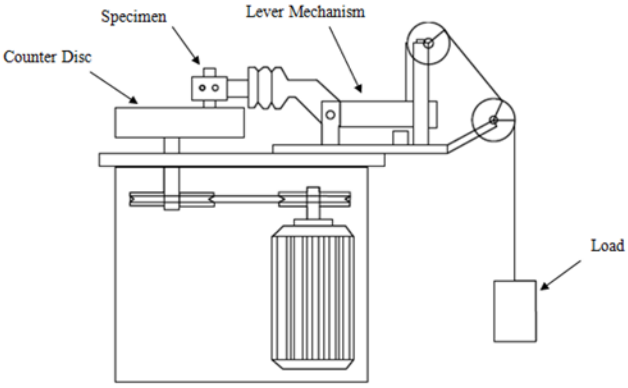

Figure 2b: Schematic Diagram of Pin-on-Disc test Tribometer

$$V_{loss} = \frac{m_{loss}}{\rho} \quad (1) \qquad k = \frac{V_{loss}}{WL} \quad (2)$$

Where V_{loss} is the volume loss (mm^3), m_{loss} is the mass loss (g), and ρ is the bulk density (g/mm^3). For Equation 5, k is the specific wear rate (mm^3/Nmm), W is the applied load (N), and L is the sliding distance (mm). The illustration and schematic diagram of the pin-on-disc test were shown in Figure 2.

3. RESULTS AND DISCUSSION

Based on the result collected beforehand, the average density of the specimen are 1.352 g/mm^3. Figure 3 shows the overall graph of COF versus the function of time. From the graph, it can be seen that the COF are ranging between 0.2 to 0.8. The graph start off with rapid increasing and starting to constant after a while for t27 and 60. However, the graph seem unstable for t90, 120, and 150. Over all, the graph indicates that the COF were highest at 150ºC and lowest at 27ºC. Rapid increase at the beginning of the graph indicates that there are frictional force occurs between the surfaces due to load applied. The graph slope become smaller after a while was believed that the tribofilm had been formed slowly and at the time the COF were constant, the tribofilm had been formed completely to protect the contacted surfaces. Chua et al., (2014) stated that the frictional heating is responsible for the decreasing of friction. This was supported by Luo (2013) that tribofilm can be generated by various process involves complex mechanical, chemical and thermal reaction. The tribofilm were generated from the wear of the soft carbon materials that adhering on the worn surface which breaks the adhesion between the asperities and hence it leads to low friction. However, at higher temperature were believed to be damaged due to the excessive heat generated.

Figure 4 shows the graph of COF against tested temperature. It can be seen from this graph that the pattern indicates that the COF of PKAC-E is highly affected with the temperature as the COF were low at 27ºC and highest at 150ºC. Figure 5 shows the graph of Specific Wear Rate against tested temperature. It can be seen that the wear rate increases as the temperature increases. This was believed that the tribofilm were damaged at high temperature. This was contrary with Rao & Das (2011) findings, as they found that the heat generates more at further distance had created more tribofilm than shorter distance.

Figure 6 shows the unworn and worn surface of composites at 27ºC and 150ºC. It was believed that there were some abrasive wear and adhesive wear occur alongside the contact surface of the specimen. However, higher temperature, it seems that the surface of the composite had become smoother. The wear track seems less deep and finer compare to the wear track from lower temperature. This was proved that there were a reduction in abrasion

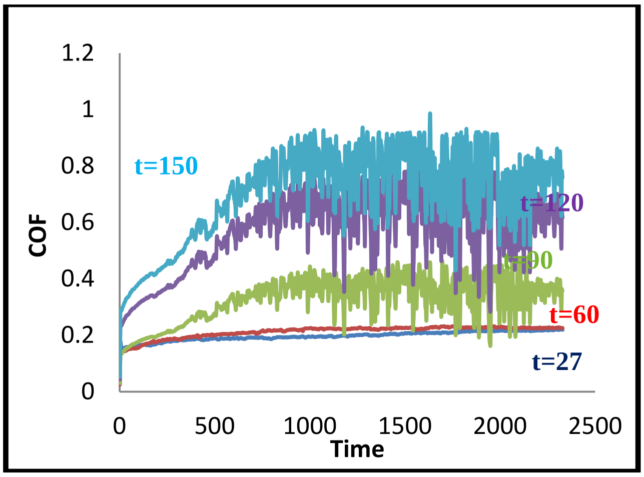

Figure 3: Graph of COF Against Function of Time

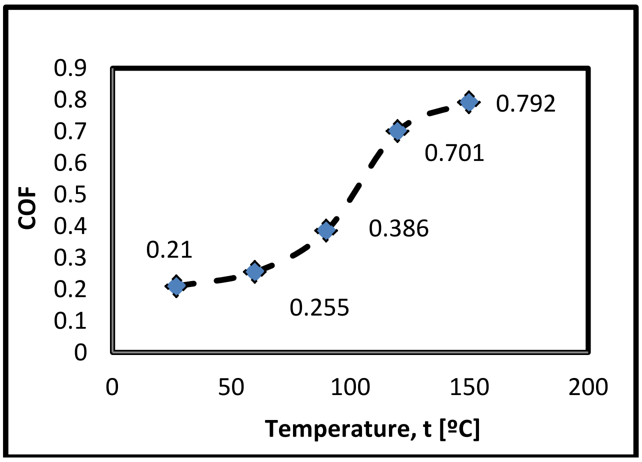

Figure 4: Graph of Coefficient of Fiction Against Temperature

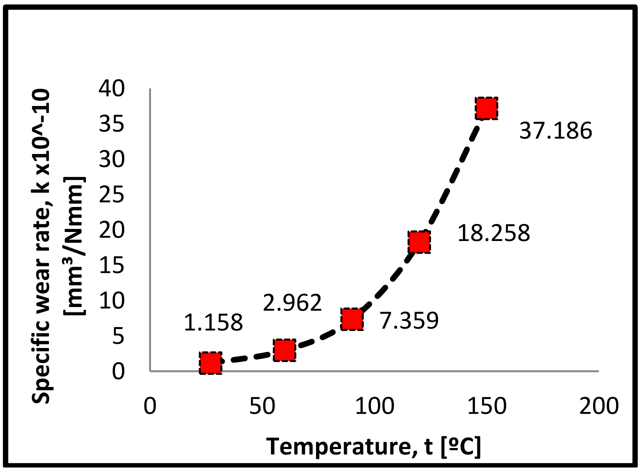

Figure 5: Graph of Specific Wear Rate Against Temperature

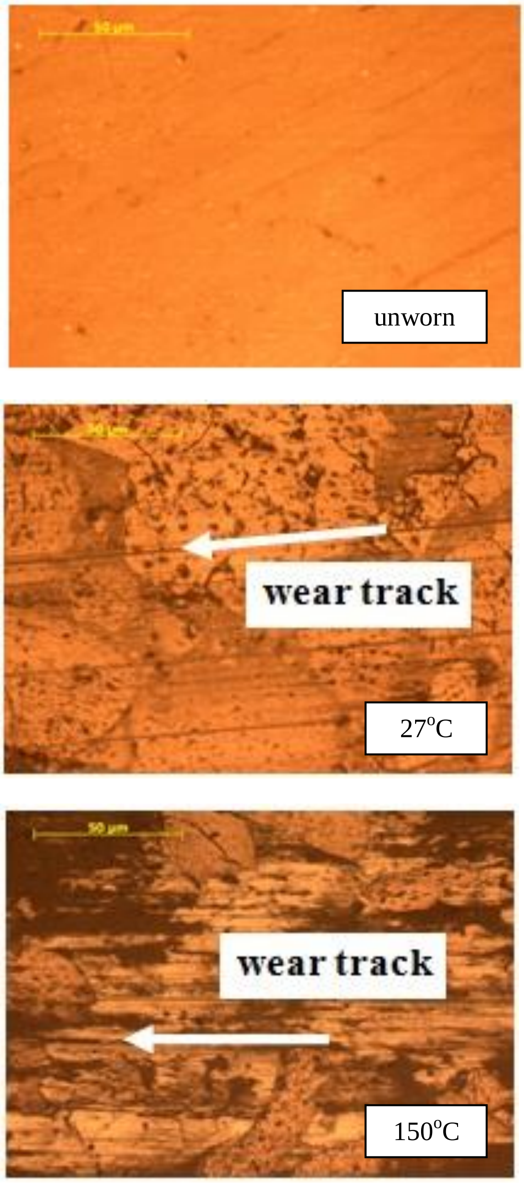

Figure 6: Image of Unworn and Worn Surface Under Inverted Microscope

4. CONCLUSION

In summary, there were significant effect on COF and specific wear rate of PKAC-E composites at different temperatures.

5. ACKNOWLEDGEMENT

The authors gratefully acknowledge contributions from the members of the Green Tribology and Engine Performance (G-TriboE) research group. This research was supported by the grant from the Ministry of Education Malaysia (Grant No.: ERGS/2013/FKM/TK01/UTEM /02/04/E00016).

REFERENCES

[1] Abdollah, M. F. B., Yamaguchi, Y., Akao, T., Inayoshi, N., Umehara, N., & Tokoroyama, T., "Phase Transformation Studies on the a-C Coating Under Repetitive Impacts", *Surface and Coatings Technology*, *205*, pp. 625–631, 2010.

[2] Alexeyev, N., & Jahanmir, S., "Mechanics of Friction in Self-Lubricating Composite Materials II: Deformation of The Interfacial Film", *Wear*, 166, pp. 49-54, 1993.

[3] Chua, K. W., Abdollah, M. F. B., Tahir, N. A. M., & Amiruddin, H., "Potential of Palm Kernel Activated Carbon Epoxy (PKAC-E) Composite As Solid Lubricant : Effect of Load On Friction And Wear Properties", *Jurnal Tribologi, In Press, 2014.*

[4] Gomes, J., Silva, O., Silva, C., Pardini, L., & Silva, R., "The Effect of Sliding Speed And Temperature on The Tribological Behaviour Of Carbon–Carbon Composites", *Wear*, *249*, pp. 240–245, 2001.

[5] Liao, J. X., Xia, L. F., Sun, M. R., Liu, W. M., Xu, T., & Xue, Q. J., "The Tribological Properties of a Gradient Layer Prepared By Plasma-Based Ion Implantation on 2024 Aluminum Alloy", *Surface and Coatings Technology*, *183*, pp. 157–164, 2004.

[6] Liu, Y., Erdemir, A., & Meletis, E. I., "A Study of The Wear Mechanism of Diamond-Like Carbon Films", *Surface and Coatings Technology*, *82*, pp.48–56, 1996.

[7] Liu, Y., Erdemirb, A., & Meletis, E. I., "Influence of Environmental Parameters on The Frictional Behavior of DLC Coatings", 94-95, pp.463-468, 1997.

[8] Luo, Q., "Tribofilms in Solid Lubricants", Ensiklopedia of Tribology, 2013

[9] Rao, R., & Das, S.,"Effect of Sliding Distance On The Wear And Friction Behavior of as Cast And Heat-Treated Al–SiCp Composites", *Materials & Design*, *32*, pp. 3051–3058, 2011.

[10] Zhou, Z. F., Li, K. Y., Bello, I., Lee, C. S., & Lee, S. T., "Study of Tribological Performance of ECR–CVD Diamond-Like Carbon Coatings on Steel Substrates", *Wear*, *258*, pp. 1589–1599, 2005.