BEARING LOAD CAPACITY OF A PALM KERNEL ACTIVATED CARBON-EPOXY COMPOSITE

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1. INTRODUCTION

From previous studies, many researchers established that different types of solid lubricants can be applied in tribological applications such as material coating or reinforcement [1]. Hence, the development and formation of this tribolayer on sliding surfaces can affect the material tribological behaviour characteristics such as thickness, hardness, fracture, and materials composition [2]. The potential usage of local waste products as reinforcement substitute in the manufacturing of lightweight materials such as metal and polymer matrix composites has gained attention due to its self-lubricating properties and zero waste approach at an affordable cost [3]. Some research cases found that porous carbon, such as Palm Shell Activated Carbon (PSAC) have displayed capability to turn into a self-lubricating material when reinforced with aluminium alloy which can considerably improve wear resistance by increasing PSAC content up to 10 wt.% [4]. In the recent decade, studies regarding on Palm Kernel Activated Carbon (PKAC) have been widely conducted by numerous researchers due to its remarkable properties in the tribology field. Developed from waste materials of palm oil extraction process, it contains carbon properties and residual oils (natural lubricant) which can change into a new self-lubricating material with a low friction coefficient and high wear resistance. Thus, potential for zero waste strategy and improving tribological properties at an affordable cost can be attained by applying carbon materials formulated from agriculture wastes as a new reinforcement substitutes in the fabrication of polymer matrix composites [5]. Since there are a limited number of studies conducted regarding on the effects of applied load on PKAC materials as solid lubricants in polymer matrix composites, the aim of this project is to determine the load bearing capacity of PKAC-E composite under a dry sliding condition.

2. METHODOLOGY

In this research, PKAC were used as a self-lubricating material with high-density epoxy [West system 105 epoxy resin (105-B) and West system 206 slow hardener (206-B)]. The fine powder of PKAC was prepared using a crusher machine and sieved into particle sizes of 250 µm using a sieves shaker. The 60 wt% PKAC powder was then mixed with 40 wt% epoxy of resin to hardener ratio 4:1. The mixture of PKAC and epoxy was then placed into a mould with a layer of wax before compressing it using a hot-press machine. The equipment was used at a working temperature and pressure of 80°C and 2.5MPa respectively
The sample was compressed in 10 minutes and then cooled down to room temperature for another 15 minutes before extracting it out from the mould. The completed disc specimens of 74mm in diameter and 5mm thickness were left to be cured at room temperature for one week. This can be seen in Fig. 1. The densitometer and shore hardness tester (Type D), were used to measure density and hardness respectively. Mechanical properties of the disc specimens and steel ball are shown in Table 1. The dry sliding test was conducted at a constant 60 wt% of PKAC using a ball-on-disc machine with according to standard ASTM G99-05 (2010). All tests were performed at speed 500 rpm and 3000m sliding distance with applied load between 20-100N. The morphology of the particles and worn surfaces were observed and analysed using a scanning electron microscope (SEM). Fig. 2 shows the schematic diagram of ball-on-disc tribometer.

Table 1: Mechanical properties of the ball and disc materials before testing

Properties	Disc (60 wt% PKAC + 40wt% epoxy)	Ball (carbon chromium steel)
Hardness (H), HRC	8.36	61
Density, ρ [g/cm3]	1.4	7.79
Surface roughness (Ra), µm	0.4	0.022

Fig. 1 Sample of PKAC-E composite disc.

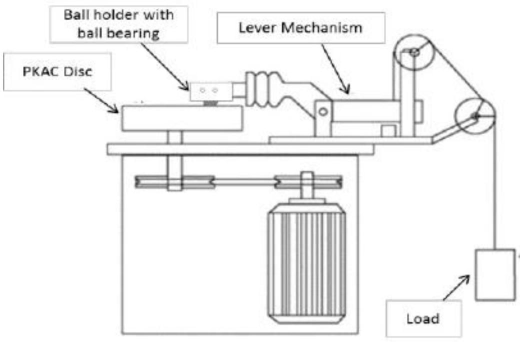

Fig. 2 Schematic diagram of ball on disc tribometer

3. RESULTS AND DISCUSSION

Fig. 3 shows the coefficient of friction, COF results of PKAC-E composite sliding against carbon chromium ball steel from the ball on disc test with increasing operating load. The tests were divided into three stages for a better understanding of tribological behaviour relating to contact mechanisms during the experiment process. As illustrated in Fig. 4, the first stage (Stage I) shows the COF value decreased dramatically. This could imply that when applied load is increased, the real surface contact area increases as well which in return causing more plastic deformation or damaging of asperities. As a result, surface roughness will diminish and would lead to decrease value of COF. Second stage test (Stage II) shown to have similar results which suggest that there are no significant differences statistically where the value of COF remains steady about 0.11. The result mentioned could be explained by the fact that the tribolayer generated from the preferential wear of the soft carbon material is caused by a carbon-based tribofilm adhering onto the counter surface which breaks the adhesive joints between the asperities [6]. Fig. 4(a) shows that the transfer layer of the PKAC-E material is formed on the counter surface thus helps to stabilise COF due to the surface contact change from PKAC-steel to PKAC-PKAC. This correlates with the results established by Mat Tahir et al. [5] in 2016. In the final stage (Stage III), the COF value significantly, where more friction is generated and abrasive wear occurred. Because of that, the transfer layer deteriorates making the ball bearing no longer have a protective layer to act as self-lubricant. This also means that the contact surface experienced high abrasion due to the ploughing of harshness between contacting surfaces which might influence on the increment of friction force [7]. Fig. 4(b) visualise a higher magnification micrograph of damaged regions and the formation of debris. From the above discussion, the overall results show that when the applied load exceeds 80N, the value of COF will increase again due to the breaking of the protective transfer layer. Therefore, the load bearing capacity for PKAC-E composite is proposed to be 80N.

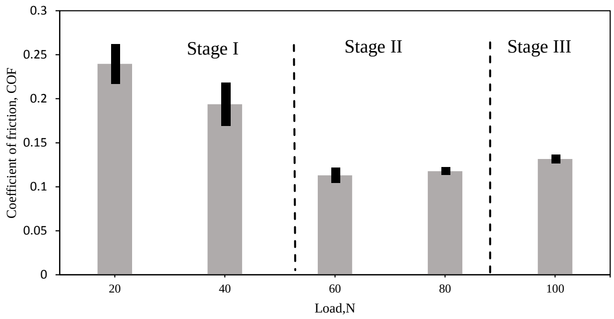

Fig. 3 Average steady state COF of the PKAC-E composite at different load. The error bar is for standard deviation.

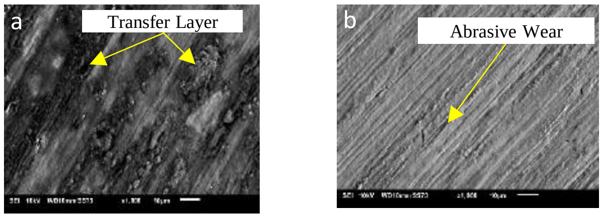

Fig. 4 SEM micrograph at (a) 60 N (b) 100 N of the PKAC-E composite.

4. CONCLUSION

In a nut shell, high load ball-on-disc experiment has been successfully carried out to stimulate tribological behaviour of PKAC-E composite. Overall, it can be said that the COF value from Stage I to Stage III decreases and increases from a low to high bearing load respectively with Stage II being considered as the optimum load range for the specimen. Hence, this study suggests that the load bearing capacity for PKAC-E composite is 80N.

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