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Friction and wear characteristics of recycled aerocomposite carbon fibre reinforced polypropylene composites

A.A. Latiff[1], N. Mohamad[1,*], A.R. Jeefferie[1], M.H.M. Nasir[1], S. Siti Rahmah[1], M.A. Mahamood[1], M.I.H.C. Abdullah[2], M.F.B. Abdollah[2,3]

[1)] Carbon Research Technology, Faculty of Manufacturing Engineering, Universiti Teknikal Malaysia Melaka, Hang Tuah Jaya, 76100 Durian Tunggal, Melaka, Malaysia.
[2)] Faculty of Mechanical Engineering, Universiti Teknikal Malaysia Melaka, Hang Tuah Jaya, 76100 Durian Tunggal, Melaka, Malaysia.
[3)] Centre for Advanced Research on Energy, Universiti Teknikal Malaysia Melaka, Hang Tuah Jaya, 76100 Durian Tunggal, Melaka, Malaysia.

[*]Corresponding e-mail: noraiham@utem.edu.my

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ABSTRACT – Incineration or disposal of carbon fiber waste from the aircraft industry lead to serious energy consumption and environmental pollution. The use of this waste as reinforcement is a wise approach to appreciate the high performance of the carbon fiber. In this study, the sliding wear and frictional behavior of recycled aerocomposites grade carbon fiber prepreg (rCFP) reinforced polypropylene prepared via melt compounding method using an internal mixer were studied. The samples were categorized into polypropylene reinforced by carbon fiber with resin (A) and carbon fiber without resin (B). Pin on disc method was utilized to evaluate the effect of rCFP content and fiber state on tribological performance of the composites. The results were supported by morphological analyses using Scanning Electron Microscopy (SEM). It was found that polymer composites B for rCFP without resin exhibited better tribological performance than composites category-A. The addition of rCFP into polypropylene was observed to increase its wear resistance with minimum coefficient of friction was achieved at 3 wt. % of rCFP content for both polymer composites.

1. INTRODUCTION

Current scenario pertaining to the depletion and high cost of the metal supply had spurred scientist globally to seek and search for another green and innovative substitute over the non-conventional raw materials [1]. Polymeric matrices reinforced with glass and carbon fibers were being increasingly developed for numerous mechanical and tribological purposes, such as seals, gears, bearings and cams [2-4]. Whereas, carbon fiber reinforcement dominates high performance applications due to its outstanding mechanical properties combined with lightweight characteristic. Besides, the reinforcement plays a major role in maintaining strength, stiffness, thermal stability and frictional properties of a composite material [5, 6]. However, most of the present studies were only focused [5, 6] on mechanical or tribological properties of virgin fiber reinforced polymer composites yet very few deals with recycled carbon fiber reinforced polymeric matrix. Thus, the performance of recycled carbon fiber reinforced thermoplastic based composites in tribology needs further study.

2. METHODOLOGY

2.1 *Materials*

The polypropylene (PP) used in this research is polypropylene homopolymer (TITANPRO 6531, isotactic type) with a specified melt flow index of 6g/min. Recycled carbon fiber prepreg (rCFP) was supplied by local aerocomposites company (Figure 1a). The rCFP were cut into 5-10 mm in sizes using scissor. For category A, the rCFP was crushed using pulverizer to produce fine particle and sieved using sieve shaker without pre-cleaning. However, for category B samples, the rCFP was immersed in acetone for 1 hour to remove any residual, purities and resin entrapped in the fiber prepregs (Figure 1b). Then, the rCFP was washed with distilled water and dried in an oven at the temperature of 60°C for 24 hours to remove moisture before undergoing the crushing process to produce fine particle.

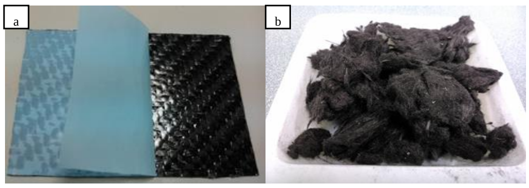

Figure 1 (a) Waste of carbon fiber prepreg (rCFP) and (b) crushed rCFP after cleaning with acetone for category-B composites.

2.2 *Preparation Process*

The preparation of PP reinforced with rCFP composites was performed using an internal mixer (Thermo Electron, Haake Rheomix OS) at 180ºC and rotor speed of 50 rpm for 10 minutes. The mixture was left to cool down to room temperature before crushed into pellets using a crusher. Subsequently, the mixture was compression molded using the hot compression machine at 200 ºC for 15 minutes to produce cylindrical shape for tribological testing in accordance with ASTM

G99. Five different compositions of category A and B composites were produced i.e., 3 wt.%, 5 wt.%,10 wt.%, 13 wt.% and 15 wt.% of rCFP including of neat PP as a control sample.

2.3 Test Procedure

Wear test was performed by the pin-on-disc tester (TR-20LE, Bangalore) machine. The wear test was conducted based on ASTM G99 to study the dry sliding wear of the fabricated composite. The geometry of sample dimension for the wear test is 6mm x 28 mm. Prior to the testing, the sample was polished with 2000-grade SiC emery paper to ensure smooth surface, Ra < 0.6 for a close contact with the counter surface. The test was carried out with the application of sliding velocity of 200 rpm, at constant load of 16 N and constant sliding distance of 2.261 km**.** Wear behavior as the function of wear rates, *Ws* and coefficient of friction (COF) for each sample was determined. Eq. (1) was used to compute the wear rates of the specimen.

$$Ws = \frac{\Delta m}{F_{N}.L}\left[\frac{g}{N.m}\right] \quad (1)$$

After the test, the counterface and the worn surface were observed under SEM EVO 50 (Carl Zeiss SMT, UK) at four magnifications which are 200x, 500x, 1000x, and 2500x to view the microstructure but only 500x are included in this abstract.

3. RESULTS AND DISCUSSION

In Figure 2a, both polypropylene composites exhibit similar pattern where COF increases with rCFP content except for loading at 3 wt%. Besides, the sliding resistance for category-A were lower than category-B once compared with virgin PP. This indicates the rCFP with resin showed increase tendency to improve lubricating performance of polypropylene. This behavior was resulted from interaction between uncured thermoset resins on rCFP surfaces with PP matrices and assisted with lubrication characteristics of carbon material. The lubrication effect decreases as the rCFP content increases due to the reduction in matrix fraction which essential to significant polymer-reinforcement interaction in the composites.

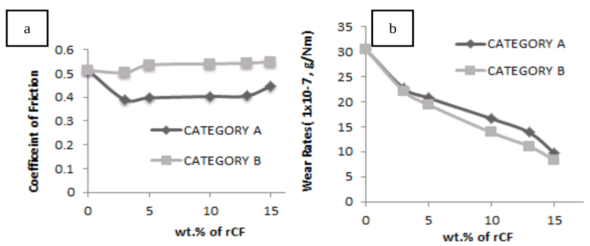

Figure 2 (a) Coefficient of friction and (b) wear rates of category-A and category-B composites.

Figure 2b shows wear resistance of the PP composites increases with the increase of rCFP content. In the range of 5 to 15 wt%, a slight difference was observed where category-B showed lower wear rates than category-A. It is in agreement with hardness value where category-A composites showed lower hardness than category-B composites. The detail results are not incorporated in this extended abstract. Softer surfaces of category-A composites increase the tendency of embedded fibers to be ploughed-out during the action of wear and tear. Furthermore, softer polymer surface provides greater adhesion with sliding member. These observations are in-line with morphological characteristics of the worn surfaces for both composites (Figure 3).

4. CONCLUSION

As the conclusion, the rCFP reinforced polypropylene was successfully produced via melt compounding method. It was found that different state rCFP (with/without resins) lead to polymer composites with unique tribological behaviors. Both category has potential to increase wear resistance with increment in lubrication effect for category-A (with resins) and better wear resistant exhibited by category-B (without resins). Furthermore, the rCFP content played major role in tribological properties for both categories. The wear resistance increases with the increase of rCFP loading in the composites with lower sliding resistance were observed at 3 wt% for both categories.

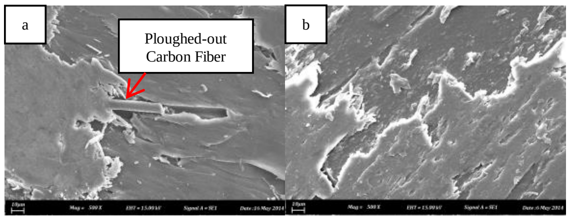

Figure 3 SEM micrographs of a (a) category-A composites for rCFP with resin and (b) category-B composites for rCFP without resin (x500).

5. REFERENCES

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