Proceedings of Asia International Conference on Tribology 2018, pp. 471-472, September 2018

Wear properties of nanoclay-filled basalt fiber reinforced polymer (BFRP) composites at different wear conditions

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Keywords: Basalt; nanoclay; specific wear rate

ABSTRACT – This paper is aimed to evaluate the effect of nanoclay incorporation on wear properties of basalt fiber reinforced polymer (BFRP) composites at different wear conditions; such as adhesive, abrasive and erosive. The materials used were epoxy polymer, unidirectional basalt fiber, and nanoclay filler with three different content, i.e. 1.0, 3.0 and 5.0 wt%. The composites underwent pin-on-disc, abrasion resistance and slurry erosion tests at 30N load, 300rpm velocity and 10000m distance. The results showed that nanoclay inclusion has improved wear properties of BFRP composite when tested in adhesive and erosive conditions. However, in abrasive condition the wear properties were reduced.

1. INTRODUCTION

Fiber reinforced polymer (FRP) composites are the most fast growing class of materials that are being utilized in various engineering applications due to their combination of high specific strength and specific modulus. They have replaced metals owing to their high strength-to-weight ratio, corrosion resistance, ease of manufacturing, and better wear resistance [1,2]. Besides fiber reinforcement, incorporation of nano-sized filler into polymer matrix has also proven to improve mechanical and tribological properties with only small amount (<5.0 wt%), without affecting other properties, such as toughness and strength, compared to traditional micro-sized filler [2]. Nanoclay incorporation has improved 85% wear resistance and 35% friction coefficient of polyester matrix when subjected to adhesive sliding [3]. The inclusion of nanofiller in FRP composite, developing an advanced polymer composite, has shown synergistic effect making them favourable to work in harsh environments, as found in research conducted in [1,4,5]. However, the wear properties of natural mineral fiber such as basalt are yet to be discovered especially when performed with incorporation of nanofiller. Therefore, in this study, the effect of nanoclay on wear properties BFRP composite was evaluated at three different wear conditions, i.e. adhesive, abrasive and erosive wear.

2. METHODOLOGY

The polymer used in this study was epoxy resin (Miracast 1517), which was supplied by Miracon (M) Sdn. Bhd., while the filler used was nanoclay I.28, which was supplied by Sigma-Aldrich (M) Sdn. Bhd. Basalt fiber used was in the form of unidirectional roving which was supplied by Haining Anjie Composite Material Co. Ltd. The nanoclay was dispersed uniformly in epoxy resin using three roll mill technique at 60°C and 12.7m/s roller speed. The nanoclay filled epoxy was then mixed with hardener at 100:30 ratio, degassed and poured onto filament wound basalt fiber, before it was left to cure at room temperature for 24 hours. The nanoclay content was varied at 1wt%, 3wt% and 5wt%, while basalt fiber was fixed at 15 vol%.

Density and Rockwell hardness measurement were conducted in accordance to ASTM D792 and D785-08, respectively, for physical characterization. The results are summarized in Table 1. The samples were then tested under adhesive, abrasive and slurry erosive wear conditions using Pin-on-Disc tester (TR-20LE), Abrasion Resistance tester (TR-600) and Slurry Erosion tester (TR-40), respectively. In adhesive wear test, the disc sample was run against smooth pin (GCr15, HRC62±2, R_a:0.1μm) at 30N load and 300rpm velocity for 10000m distance. In abrasive wear, the disc sample was run against vitrified bonded silicon carbide wheel (grade 46) at similar operating parameters. In slurry erosive wear, the rectangular flat sample was placed in vessel filled with slurry mixture of sand (medium coarse) and water, and run at 300rpm velocity for 10000m distance. The mass loss of composites was taken using precision balance for every 2000m distance interval. Based on mass loss, the specific wear rate was calculated.

Table 1 Physical characterization.

BFRP composite	Density (g/cm^3)	Hardness (HRR)
Pure	1.324 ± 0.009	119.50 ± 0.41
1.0 wt% NC	1.240 ± 0.008	121.58 ± 0.70
3.0 wt% NC	1.242 ± 0.014	122.15 ± 0.44
5.0 wt% NC	1.247 ± 0.006	121.63 ± 0.34

3. RESULTS AND DISCUSSION

The specific wear rate, Ks for adhesive, abrasive and erosive conditions is shown in Figure 1, Figure 2 and Figure 3, respectively. The Ks for all composites was decreased with decreasing rate as travel distance increased. In Figure 1, nanoclay-filled BFRP composite showed lower Ks compared to Pure BFRP composite indicating improved wear resistance. The highest wear resistance exhibited by 5.0 wt% NC BFRP with 31.74% improvement. Nanoclay enhanced the bonding between transfer film and counterface [5] and acted as effective barrier that prevent large scale fragmentation of epoxy during sliding [2,3].

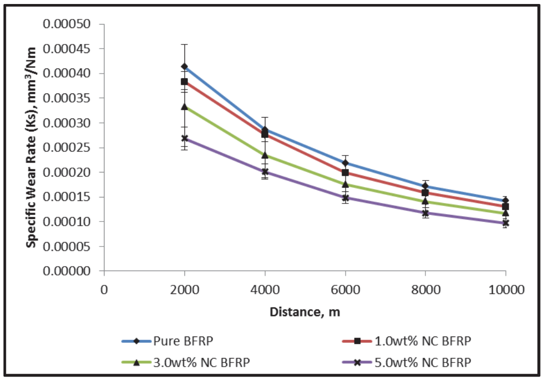

Figure 1 Specific wear rate vs distance for BFRP composites which were tested in adhesive condition.

In Figure 2, Pure BFRP composite showed the lowest Ks, while 5.0 wt% NC BFRP indicated the highest Ks. This shows that the incorporation of nanoclay reduced wear properties of BFRP composite when it was tested in abrasive condition. There is possibility that filler addition might reduce the toughness of epoxy polymer therefore reducing abrasive wear resistance of the composites [4]. The ploughed out nanoclay might also become three body abrasives that lead to further matrix and fiber damage.

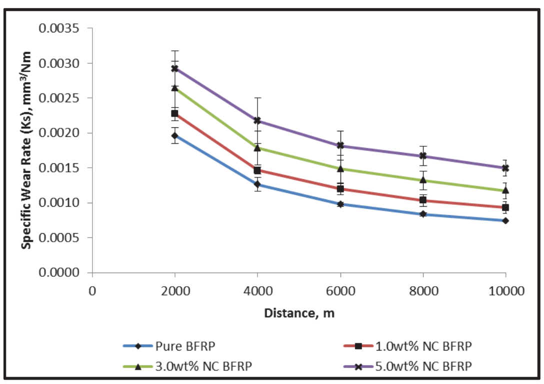

Figure 2 Specific wear rate vs distance for BFRP composites which were tested in abrasive condition.

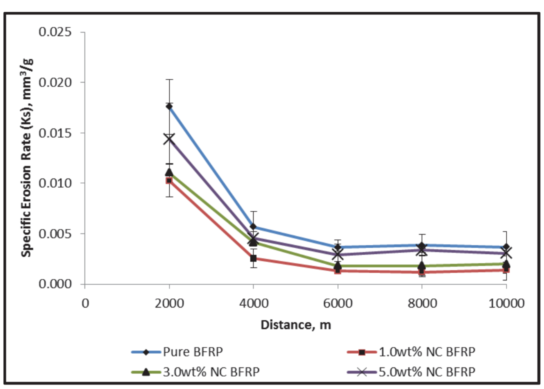

Figure 3 Specific wear rate vs distance for BFRP composites which were tested in erosive condition.

In Figure 3, nanoclay-filled BFRP composites exhibited lower Ks when compared to its pure state. Nanoclay acted as an energy barrier that prevents impact energy of sand mixture from penetrating into the surface [1]. However, as nanoclay content increased from 1.0 wt% to 5.0 wt%, the Ks value also increased. The reduced adhesion with epoxy matrix at high nanoclay content might reduce its erosive wear resistance. The lowest Ks was shown by 1.0 wt% NC BFRP composite with 51.12% improvement.

4. CONCLUSION

The specific wear rate of Pure BFRP and nanoclay-filled BFRP composites was successfully determined at three different types of wear conditions, i.e; adhesive, abrasive and erosive, in order to study the effect of nanoclay incorporation. In each test, nanoclay acted differently and caused several different types of wear failure mechanisms during testing. It is concluded that nanoclay improved the adhesion and erosion wear properties of BFRP composite, in which the improvements were up to 31.74% and 51.12% respectively. In abrasive wear, nanoclay did not aid in improving wear properties as it might act as third body abrasive.

ACKNOWLEDGEMENT

The authors would like to thank Institute of Research Management and Innovation (IRMI), Ministry of Education Malaysia and Institute of Graduate Studies (IPSIS) UiTM for the financial supports. This research works is performed at the Faculty of Mechanical Engineering, UiTM Malaysia under the support of Grant BESTARI 600-IRMI/MYRA 5/3/BESTARI (019/2017).

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