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Tribological analysis of sliding motion on carbon-fiber based composite material enhanced by clay and CNT with texturing effect

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ABSTRACT – The aim of the study introduces tribological performance to the adding ratio of CNT and Clay in carbon fiber epoxy composite (CFEC) and texturing effect on grease lubrication for pure sliding motion. Increasing the adding ratio of nanoparticles can effectively increase their mechanical properties and heat conduction coefficient and improves their tribological performances. Smooth surface, plowing and the tooth textured surface was tested by a pin on disc pure sliding experiment with grease lubrication. Texturing pattern can significantly decrease the friction, especially in the tooth pattern situation owing to the leak can be avoided and keep more grease in the grooves.

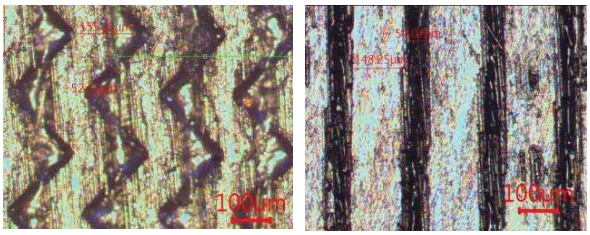
1. INTRODUCTION

The Surface pattern on steel is wildly used in the journal bearing, piston, cylinder ring …so on, and has excellent friction behavior. With the rapid development of technology, the material with single characteristic has been unable to meet the demand of diversified applications in practice. On the contrary, the variety of a composite's functions is highly required nowadays. Thus, Nanocomposites on particular properties has become one of the popular issues among material research and will be extensively applied in the near future. The friction behavior for a textured composite mechanical component has a high opportunity in decreasing friction and extending its using life.

The design factors for texturing pattern include geometry shape, depth and covering ratio of a surface. The proper design of geometry shape can highly increase the bearing ability on journal bearing [1]. If no, cavitation will be occurred between two relative motion components and decrease the load bearing ability. For the covering ratio of a surface, enough number of dimples can effectively reduce friction coefficient [2]. While the covering ratio of a surface for dimple increases to 11%, the film thickness is the thickest [3]. Different geometry design has different best covering ratio, the V groove shape is 6%, and plowing shape is higher is better. The pattern of step groove design has excellent friction behavior on journal bearing [1], but the fabrication method is hard to apply to each component. The depth of pattern is a key factor and has the higher effect than the other two factors. Because it affects the minimum film thickness. In 2013, Ramesh et al. [4] proved the optimal depth for dimple is 102 μm by theoretical model and confirmed by experiment.

2. EXPERIMENT DETAIL

This study, test specimens of nanocomposites were produced through the vacuum assisted resin transfer molding, VARTM. By using Epoxy and multiple layers of carbon fibers as a substrate, clay and muilti-wall carbon nanotube are enhanced material. The carbon fibers are featured in high strength and high thermal conductive. Also, the clay and the carbon nanotube have outstanding nature of strength and tribology ability. Therefore, the combination of these three materials can efficiently strengthen the mechanical property and reducing the friction on carbon fiber Epoxy based nanocomposites (CFEN). And then, laser engraving was used to process the pattern on the test specimens. The textured surface is shown in Figure 1. In order to simulate the wear of Nanocomposites under reciprocating motion, the test specimens were installed on a vertical abrasion tester and forced to conduct sliding motion with grease. Experiment conditions are shown in the Tab.1. Friction coefficient was measured by friction torque devices and wear volume was also obtained by surface morphology measuring.



(a) Tooth groove (a) Plowing groove

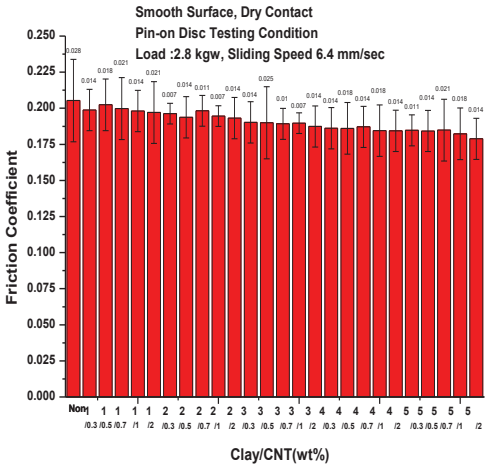
Figure 1 Surface pattern.

Table 1 Testing condition of pin on disc experiment.

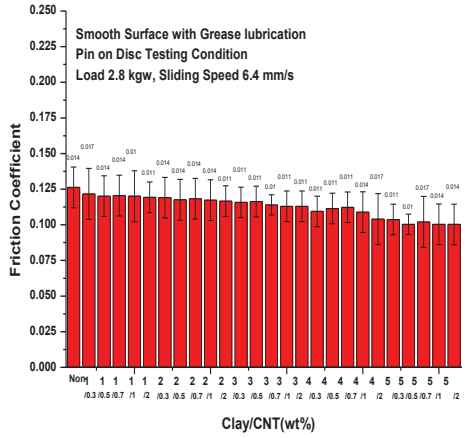
Upper specimen	SUJ2 ball	12.7mm	
Lower specimen	CFEN	17.1mm*17.1mm*2.6mm	
Temp.	25±2 (°C)		
Groove pattern	Smooth	Plowing	Tooth groove
Lubricant	Non	Grease (40 cst at 40 °C, base oil)	
Load	2.8 (kgw)		
Sliding speed	6.4 (mm/s)		
Testing time	60 (min)		

3. RESULTS AND DISCUSSION

Prepared specimens were tested by dry and grease lubricated conditions and shown in Figure 2. Grease lubricated test has lower friction coefficient. Both results show that the friction coefficient is reduced with the increase of content density of CNT and clay. One reason is owing to the surface hardness is enhanced by the CNT and clay as shown in Figure 3, the Vicker's hardness and tensile stress are rising with the increase of nano particles. The other reason is the tribological property of these two nano particles are excellent and can effectively reducing the friction coefficient. Figure 4 shows the lost volume is effectively reduced by the rising of the content ratio of nano particles. Textured specimen has lower friction comparing with non-textured under grease lubricating condition, especially on tooth groove specimen. The groove can keep liquid lubricant and increase the oil film thickness. The sliding direction is perpendicular to the pattern and tooth pattern has higher flowing resistance to the grease, so the lubricant is easier to stay at contact area than the plowing groove.



(a)



(b)

Figure 2 Pure sliding pin on disc testing on smooth surface. (a) Dry contact, (b) grease lubricated.

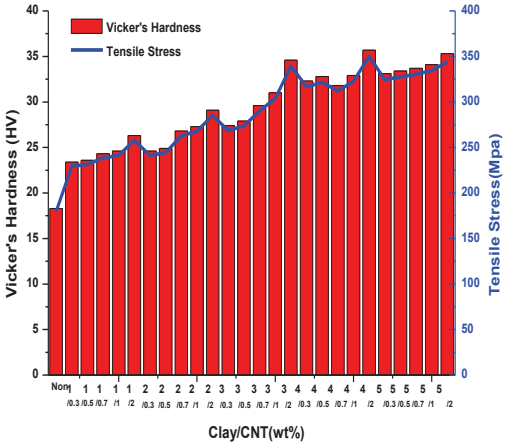


Figure 3 Mechanical properties.

4. SUMMARY

The experiments have indicated that the mechanical and tribology properties of CFEN can be elevated by combining clay and carbon nanotube with the substrate under certain weight ratio. With the optimized amount of additives, physical properties of the material, including hardness, tensile strength, and tribology property have increased by 48 %, 52 %, and 20.6 %, respectively. The pattern textured with tooth geometry on the surface has the lowest friction owing to can keep more lubricant at the contact area.

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