Proceedings of Malaysian International Tribology Conference 2015, pp. 32-33, November 2015

Evaluation of transformed layer of DLC coating after friction test using Atomic Force Microscopy (AFM)

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Keywords: DLC; transformed layer; AFM

ABSTRACT – Diamond-like carbons (DLC) with hardness of 47.1 GPa were coated on SUJ2 rollers, and their tribological properties were investigated after friction test under boundary lubrication conditions in an additive-free mineral-based oil at different testing oil temperatures of 24, 80 and 160 °C. From the results of the Raman analyses and Spectroscopy ellipsometry, we found that the structure changed of DLC at the topmost of sliding surface and their thickness will measured using AFM. It is found that the transformed layer increased with increases of testing oil temperature.

1. INTRODUCTION

Diamond-like carbon (DLC) provides very excellence performance in term of friction coefficient and wears resistance under boundary lubrication in mineral-based oil with or without additives [1]. DLC became more interesting as a coating material in tribological applications especially in the automotive industry in order to reduce the fuel consumption [2], because of their significant tribological properties such as low friction, high hardness, and high wear resistance. Improvements in coating technology have made the DLC coating suitable for various machine components that operate under severe conditions i.e under boundary lubrication. The low friction mechanism in the DLC coating under friction tests in either dry or boundary-lubricated conditions is due to the formation of a graphite-like layer in the non-lubricated [3] or transformed layer [4] which provides low shear strength at the contact interface. The transition phase of the as-deposited DLC to graphite-like structure at the topmost sliding interface is due to graphitization by conversion of sp^3 to sp^2. This transition phase has been reported in other studies as a friction-induced transformation of the topmost sliding interface of the DLC coating [5]. However, the nano characteristic of the transformed layer has not been studied in-terms of its thickness which is believed to have a significant effect in the tribological performance, such as a low friction coefficient under boundary lubrication conditions. The most important finding in this study is the scratch hardness of the transformed layer at the topmost of the sliding interface of the DLC from the AFM scratch test under different oil temperatures.

2. METHODOLOGY

2.1 Friction Test

Figure 1 is the experimental setup for friction test. The friction tests were conducted using a pin-on-disk apparatus, where the DLC-coated cylindrical pin specimen with hardness of 47.1 GPa was in a sliding line contact on the disk specimen. The constant normal load of 10 N was applied to the pin. The disk specimen was rotated with a constant velocity of 65 mms^{-1}, and the pin was kept stationary. Friction tests were conducted for 100 m sliding distance at different oil temperatures of 25, 80 and 160°C.

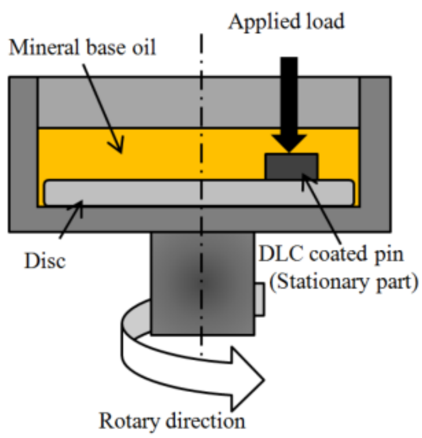

Figure 1 Schematic diagram of pin-on-disk friction test apparatus.

2.2 Scratch Test

The scratch test was carried out using a commercial AFM (SII, SPA-400) in ambient temperature and humidity of 25°C and 40%, respectively. The poly-crystal diamond (PCD) tip cantilever has a tip radius of 150 nm and a spring constant of 42 Nm^{-1}, was used to perform the scratch test. Figure 2 shows the scanning and the scratch area when the scanning process was done before and after the scratch hardness test in order to obtain different surface profiles of the worn area.

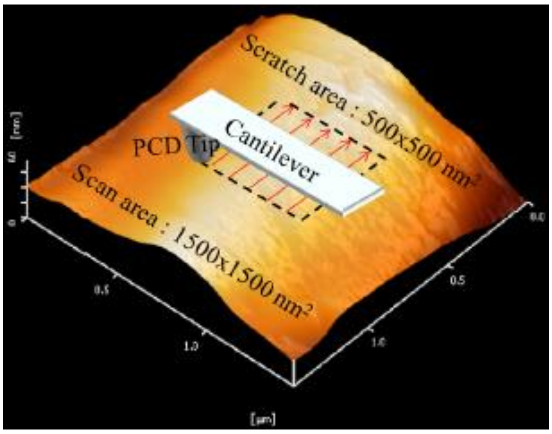

Figure 2 Schematic diagram of scan and nano-scratch test area at worn surface of DLC coating after friction test.

3 RESULTS AND DISCUSSION

Figure 3 shows the surface topography after the scratch hardness test on DLC with different oil temperatures of the friction test. These AFM images showed that an apparent worn area was created after the scratch test. Figure 4 shows the cross-sectional profile of the worn area.

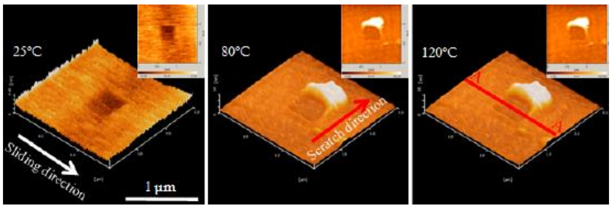

Figure 3 Surface topography after scratch hardness at different oil test temperatures.

The increasing in the scratch depth by increasing the oil temperature showed that the DLC coating became softer during the friction test and was influenced by the oil temperature [4].

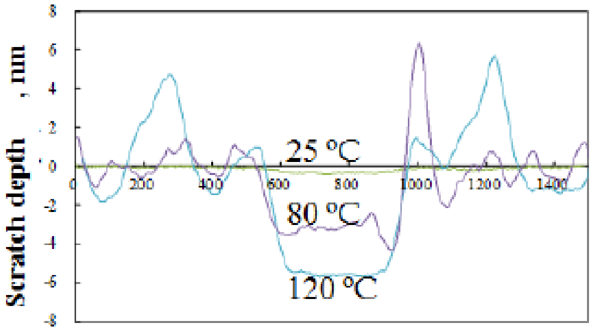

Figure 4 Cross-section profile of A-A and wear depth at different oil test temperatures.

The structure of the coating at the sliding contact interfaces has transformed the DLC into a graphite-like layer due to the friction-induced graphitization process [5]. The graphite-like transformed layer has a more sp^2 structure compared to the as-deposited DLC. The friction-induced graphitization process softened the contact interface during sliding which contribute to low friction [4].

4 CONCLUSION

It is found that the hardness of the transformed layer depends on the test oil temperature.

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