Proceedings of Malaysian International Tribology Conference 2015, pp. 294-295, November 2015

Tribological properties of polymer overlay coated on the micro-textured metal substrate

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Keywords: Polymer overlay; subsurface texture; friction

ABSTRACT – The present study describes fundamental tribological properties of polymer overlay coated on the micro-textured metal surface. The tribological properties were evaluated with a 3-ball-on-disc type testing apparatus in poor lubricated condition. Effects of substrate texture fabricated with a micro shot peening and a roller burnishing on friction behavior were discussed. Moreover, in the case of dispersing solid lubricant into overlay layer, effect on the durability of overlay layer was also evaluated. As results, the substrate texture resulted in the increase of the adhesion strength and the stabilization of the friction coefficient of the overlay. Although the adhesion strength decreased by dispersing solid lubricant, the subsurface micro texture restricted the peeling of the overlay and further decrease of the friction coefficient was achieved.

1. INTRODUCTION

Improvement of fuel consumption in transportation equipment is imperative problem towards the transition to the establishment of sustainable society. In particular, improvement of fuel consumption and reduction of friction loss in the internal combustion engine has been strongly demanded. In order to reduce the friction loss on sliding interfaces, surface modification methodology has attracted attention, and surface texturing is one of the most promising techniques [1]. In recent researches, it was reported that the creation of micro-sized texture on the sliding surface and the squeeze of solid lubricants into the texture are effective means for reduction of friction coefficient and improvement of seizure resistance [2].

On the other hand, forming a soft thin film such as solid lubricants or resins on the sliding surface can reduce the rigidity of the contact surface at the early stage of the friction, and is effective for moderate initial running-in. However, for the short lifetime of the resin or the solid lubricant as an overlay, improvement in durability is one of the problems to be solved.

In the present study, fundamental tribological properties of polymer overlay coated on the micro-textured surface were evaluated. First, the effect of the subsurface texture on friction behavior was discussed. Then, by dispersing solid lubricant into overlay layer, the effect of solid lubricant on friction behavior was also evaluated.

2. EXPERIMENTAL

2.1 *Materials*

A chromium alloy steel disc (850 Hv) was employed as metal substrate. The micro-sized texture consisting from micro sized truncated dimples on the disc was fabricated with a combined process of a micro shot peening and a roller burnishing or a polishing. The surface morphology of the non-treated (NT) and the micro-textured (SP) surfaces are shown in Fig. 1. In the textured surface, micro dimples were uniformly formed at random and convex tips of the asperities were truncated. The depth and the diameter of dimples were possible to control with adjusting the process condition.

Polyamide-imide (PAI) was employed as overlay material. PAI overlay and composite overlay dispersed solid lubricant such as molybdenum disulfide (MoS_2) were coated on the micro-textured surface by using a spin coating technique, and specimens were baked with an electric furnace. It was possible to control the thickness of the overlay layer by the revolution speed of the spin coating. It was found that the subsurface texture was affected to the coated surface profile as shown in Fig. 2.

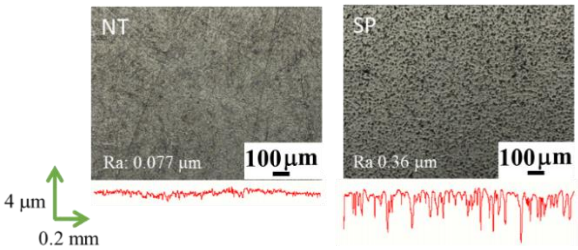

Figure 1 Surface morphologies of the metal substrates.

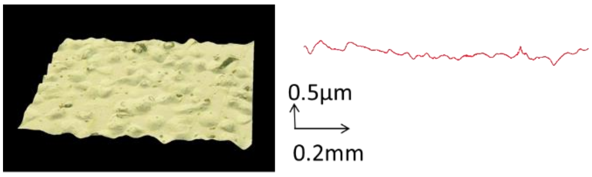

Figure 2 3D image and surface profile of the PAI single overlay coated on the subsurface texture.

2.2 *Testing Method*

Tribological properties were evaluated with a 3-ball-on-disc type testing apparatus. The mated 3-ball were the same material as the substrate. The testing surfaces were flat having 1.5 mm of the diameter and mirror finished and were installed at equal interval (=120 degree) on the same circumference. The testing condition was 1 m/s of sliding speed, 50 N of the applied load was 50 N (9.4 MPa of the apparent contact pressure), 2000 m of the sliding distance. 40 μl of PAO (5 cst at 313 K) was employed as lubricant.

3. RESULTS AND DISCUSSION

3.1 PAI Overlay on the Micro-Textured Surface

Figure 3 shows the friction behaviors of the PAI overlay coated on non-treated (NT) and micro-textured (SP) surfaces. The PAI overlay on the SP surface shows a low and stable coefficient of friction in comparison with the PAI on the NT surface. Optical micrographs of the surface after the friction tests are shown in Fig.4. In the case of the PAI on NT surface, PAI layer completely peeled off, since the adhesion strength between the substrate and PAI overlay is insufficient, and the metal substrate was appeared. However, in case of the PAI on the SP surface, PAI layer was survived after the friction test. This is because the adhesion strength between substrate and overlay layer was improved by the application of subsurface micro texture. Consequently, the durability of the overlay layer was also improved.

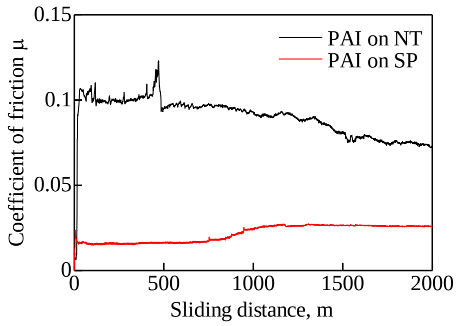

Figure 3 Friction behaviors of PAI overlay coated on the micro-textured surface.

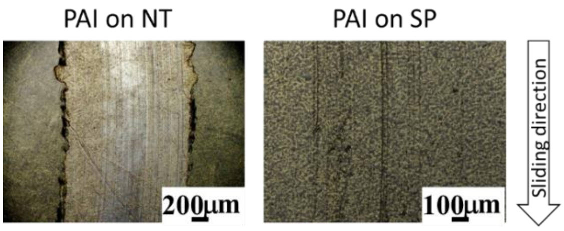

Figure 4 PAI overlay surface after friction test.

3.2 Composite Overlay on the Micro-Textured Surface

In the case of dispersing solid lubricant into the PAI layer, the effects of solid lubricant on the coefficient of friction and the durability of the overlay layer were discussed. Figure 5 shows the friction behaviors of PAI/MoS_2 overlay coated on micro-textured surface, and Figure 6 shows the optical micrographs of the surface of the composite overlay after friction tests. When the PAI/MoS_2 was coated on the NT surface, the coefficient of friction suddenly increased at the early stage, and the overlay layer was also peeled off such as in the case of PAI on the NT surface. On the other hand, when the PAI/MoS_2 was coated on the SP surface, the coefficient of friction was extremely low during the test, and the wear of the overlay layer was hardly observed.

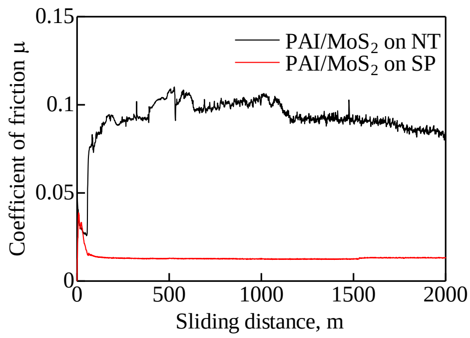

Figure 5 Friction behaviors of PAI/MoS_2 overlay coated on the micro-textured surface.

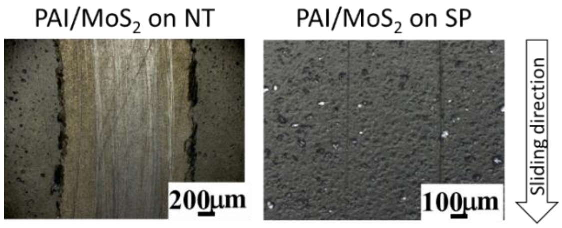

Figure 6 Composite overlay surface after friction test.

4. SUMMARY

Fundamental tribological properties of polymeric overlay coated on the micro-textured surface were evaluated, and effects of the subsurface texture on friction behavior was discussed. As results, the adhesion strength between substrate and overlay layer was improved by the application of subsurface micro texture, consequently, the durability of the overlay layer was also improved.

When the PAI/MoS_2 was coated on the textured surface, the coefficient of friction was extremely low and stable, and further reduction of the friction was achieved.

5. ACKNOWLEDGEMENT

This work was supported by Cross-ministerial Strategic Innovation Promotion Program "Innovative combustion technology".

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