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Tribological properties of solid lubricant contained soft metal coating

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ABSTRACT – A novel coating process based on semi-solid state casting of zinc-tin alloy was developed to form solid lubricant thin film on an aluminum cast alloy. Resulting surface morphology was consisted of the dispersed molybdenum disulfide and sliver fine particles fixed with the tin-zinc alloy. Tribological properties were evaluated with a ring on disc type testing apparatus using a cast iron ring as the counter specimen in lubricated condition. Results showed that the friction coefficient of the coating surface was low and stable. Furthermore, the addition of silver into the film seemed to be effective means to shorten the running-in distance.

1. INTRODUCTION

It is well recognized that soft metal such as lead, tin and silver acts as self-lubricating film on a hard substrate because of their low shear strength and melting temperature [1-3]. From above mentioned, lead has been widely applied as an overlay for journal bearings of internal combustion engines. As well as lead, tin has been used as the self-lubricant overlay and was previously coated on the piston skirt surface. However, polymer film containing solid lubricants such as molybdenum disulfide (MoS_2), graphite and PTFE performs lower friction properties and has been applied as the overlay substituting the soft metals.

Because of the poor solubility and the wet ability between the interfaces, various process such as sintering [4], sputtering [5] and cold spraying [6] were applied to compose solid lubricates with metals. The solid lubricant is generally damaged by heating and the processing temperature is restricted depending on the material. During the sintering process, the existence of the liquid phase results in semi-solid state and plays role of densification below the melting temperature of the metal. Therefore, it is expected that the application of the semi-solid state for the composing process is possible to coat the solid lubricant containing soft metal film at low temperature.

The present study describes tribological properties of solid lubricant dispersed soft metal coating on an aluminum cast alloy. Tin (Sn) –zinc (Zn) alloy and molybdenum disulfide (MoS_2) was used for the matrix and the solid lubricant for coating elements. An applicability of the developed coating process as the surface modification for internal combustion engine components was evaluated.

2. MATERIAL

An aluminum cast alloy disc (the outer/inner diameter of 44/20 mm and the thickness of 7 mm) was used for the substrate materials. Sn-Zn alloy system was used as brazing material for an aluminum alloy because of the higher oxidation reduction properties of Zn, the eutectic alloy with small solubility and lower solidification temperature of 200 degree Celsius. Sn (80 wt. %)-Zn alloy was melt on the aluminum alloy disc surface at 250 degree Celsius. The melting and solidification temperature of the Sn-Zn alloy system was approximately 270 and 200 degree Celsius. Therefore, the alloy system was semi-solid state at the settled temperature.

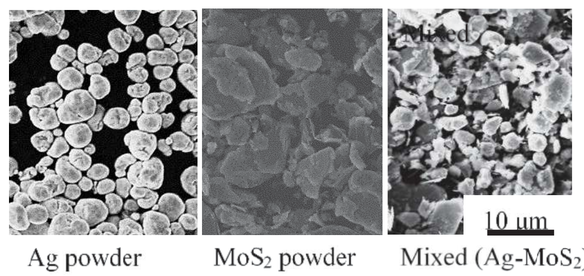

Figure 1 SEM image of Ag (left), MoS_2 (middle) and mixed (right) powder.

A SEM image of silver (Ag), molybdenum disulfide (MoS_2) and mixed powder was shown in Figure 1. Ag and MoS_2 was mechanically mixed with a pestle and a mortar. The size of Ag and MoS_2 powder was 5-10 μm and became slightly smaller after the mixing. The objective of Ag addition is to raise the solidification temperature and to enhance lubricity of the matrix alloy. The semi-solid alloy system was spread on the aluminum alloy surface using mechanical means and the mixed Ag-MoS_2 powder was injected into the alloy system then was mixed. After cooling, the coating thickness was adjusted at a range of 5-10 μm by polishing. The coating film without Ag and MoS_2 was also prepared. A SEM/EDX image of the coating surface was shown in Figure 2. Sn and Zn were dispersed almost uniformly on the surface. Ag, Mo and S dispersion was scattered: This suggested that Ag and MoS_2 was distributed without alloying or decomposition. The hardness of the coating surface was 20 Hv for Sn-Zn alloy and 30-40 Hv for Ag- MoS_2 contained Sn-Zn alloy.

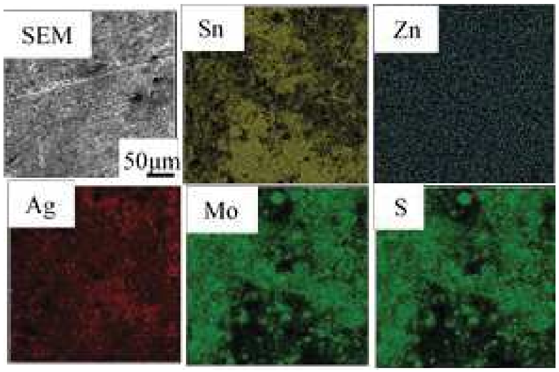

Figure 2 SEM/EDX image of Ag-MoS_2 containing coating film.

3. RESULTS AND DISCUSSION

Tribological properties were evaluated with a ring on disc type testing apparatus mated with a gray cast iron ring (ϕ40× ϕ30×h15mm). The testing surface was mirror finished less than 0.01µm Ra. The testing condition was 300 N of an applied load (=1.04 MPa of contact stress), a sliding speed of 0.5m/s. An engine oil (0W-8) without friction modifiers were used as the lubricant.

Friction coefficients as a function of the sliding distance were shown in Figure 3. The friction coefficient of the Sn-Zn coating was 0.03-0.04 at initial stage and decreased to 0.02 with the increase in the sliding distance. The friction coefficient further decreased with the addition of Ag–MoS_2 and was approximately 0.01 after 100 m of the sliding distance. In addition, the running-in distance became smaller.

An optical micro scope image of the surface after the friction experiment was shown in Figure 4. There was no significant difference of the coating surface and only small amount of the wear loss was found.

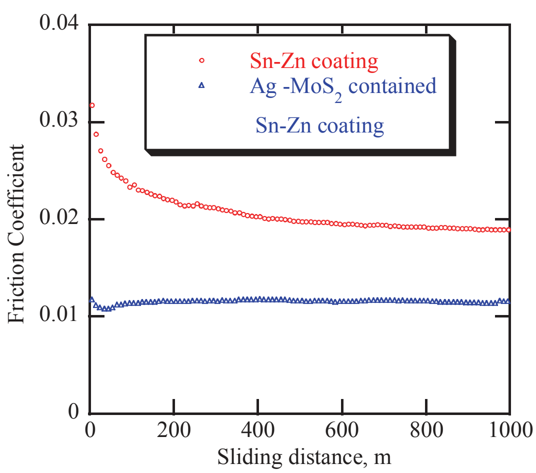

Figure 3 Friction coefficient of coating surface as a function of sliding distance.

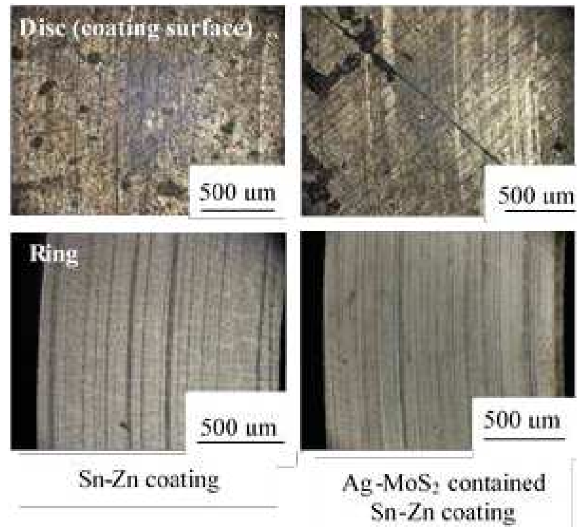

Figure 4 Optical micro scope image of wear surface.

4. SUMMARY

Tribological properties of Sn-Zn coating process using semi-solid state on an aluminum cast alloy was evaluated. Results showed that the friction coefficient of the coating surface was low and stable. Further reduction of the friction coefficient and the sliding distance for running-in was obtained with addition of silver and molybdenum disulfide powder.

ACKNOWLEDGMENT

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