Low Friction System with Laser-Irradiated Aluminum Alloy in Engine Oil

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Aluminum alloys, representative materials for sliding parts in engine, cause high friction under severe lubrication due to aluminum adhesion. Laser irradiation to aluminum alloy can suppress the adhesion and form tribofilm from additives, and reduction of irradiation pitch results in low friction with short running-in. Here, laser irradiation to entire aluminum surface is conducted in order to study influence of energy distribution on friction property of steel and aluminum alloy in engine oil. The experiments reveal that the system shows three friction modes determined by average energy density and uniform and high energy irradiation is required for further low friction.

Keywords: aluminum alloys, laser irradiation, engine oil, average energy density

1. Introduction

Aluminum alloys, which are used as representative materials of sliding parts in automobiles' engine, cause high friction in severe lubrication condition due to aluminum adhesion. Laser irradiation can suppress the adhesion and form tribofilm from additives, and reduction of irradiation pitch results in low friction with short running-in. In this study, we introduce laser irradiation to entire surface of aluminum alloy to study influence of energy distribution on friction property of steel and laser-irradiated aluminum alloy in engine oil.

2. Methods

Pico-second pulse laser with 6.3 μm of spot diameter d was irradiated to Al-Sn-Si alloy surface circumferentially with 20 μm and 100 μm of pitch p under 2.02×10^2 ~ 2.83×10^4 J/cm^2 of energy density E. Figure 1 shows SEM image of the laser-irradiated surface with 100 μm pitch. Ball-on-disk type friction tests with bearing steel (AISI 52100) ball and the laser-irradiated aluminum disk were conducted in fully-formulated engine oil including calcium salicylate, molybdenum dithiocarbamate (MoDTC) and zinc dialkyldithiophosphate (ZnDTP). All the experiments are performed under 0.1 m/s of sliding speed, 15 N of load and 80 °C of oil temperature representatively.

3. Results and Discussion

Figure 2 shows effect of laser pitch and energy density on friction property of bearing steel and Al-Sn-Si alloy in engine oil. High friction without running-in (mode I) is obtained in each pitch under low energy density condition. Under high energy condition, although low friction with friction drop and rebound (mode II) is obtained in 100 μm pitch, further low friction with friction drop and slight decrease (mode III) is obtained in 20 μm pitch. Figure 3 shows effect of average energy density E' $(= (d/p) \times E)$ on friction coefficient and friction mode of the system. Transition among three friction modes are determined by average energy density E' and higher average energy density more than 3.18×10^3 J/cm^2 (E'_{c2}) is required for mode III. This result indicates that uniform as well as high energy irradiation is required for running-in and further low friction.

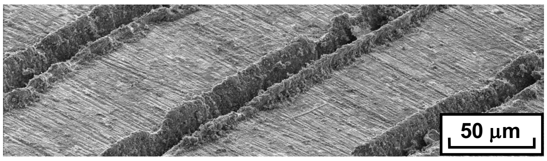

Fig. 1 SEM image of laser-irradiated Al-Sn-Si alloy with 100 mm pitch.

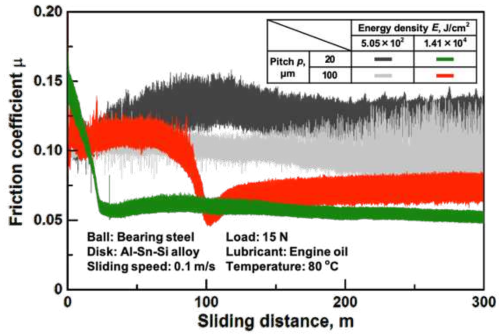

Fig. 2 Effect of laser pitch and energy density on friction property of bearing steel and Al-Sn-Si alloy in engine oil.

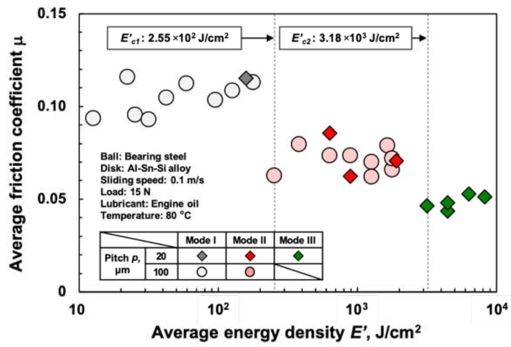

Fig. 3 Effect of average energy density on friction coefficient and friction mode of bearing steel and Al-Sn-Si alloy in engine oil.

4. Conclusion

Laser-irradiated Al-Sn-Si alloy rubbed against bearing steel in engine oil shows three friction modes: without running-in (mode I), friction drop and rebound (mode II), and friction drop and slight decrease (mode III). Transition of the modes are determined by average energy density E' and higher average energy density more than 3.18×10^3 J/cm^2 is required for mode III.