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Effect of surface groove and graphite penetration on friction properties of sulfide containing copper alloy journal bearing in dry condition

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Abstract

The present study describes friction properties of sintered copper alloy journal bearing. Sulfide contained copper alloy material studied as the material of the journal bearing. The micro structure of the copper alloy was consisted from micro sized pores and sulfide phase mainly dispersed at the boundary region. For the purpose of friction study, the sliding surface of the journal bearing was in the form of machined texture. A spiral groove was applied to the inner surface of the journal and graphite was occasionally penetrated into the groove. The experiment was carried out using a developed testing apparatus that consists of a spindle driven with an air cooled DC motor and a disc shape bearing holder in air atmosphere without lubricants. The hardened steel shaft having fine ground surface was used as the mating specimen. The results found that the application of spiral groove with graphite penetration was effective to increase the sliding distance up to the occurrence of seizure. In particular, the graphite penetration resulted in significant increase in the sliding distance despite that the decrease in friction coefficient. It was estimated that the application of the groove with graphite penetration restricted the transfer of the journal elements on the mating steel surface.

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Keywords: Sulfide contained copper alloy; Graphite penetration; Spiral groove texture; seizure, transfer

1. Introduction

Cupper (Cu) based alloy is used for bearing materials since the thermal conductivity and workability is excellent. Solid lubricants have been introduced into the Cu alloy to modify the tribiological properties including seizure occurrence. Graphite is frequently used as the solid lubricant and is dispersed into the Cu alloy. Recently, sulphide dispersed alloy was developed and showed that the friction resistance was lower and more stable than that of the lead contained alloy [1].

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It is well recognized that surface texturing, applying dimples and/or grooves with controlled geometry, is effective means for reduction and stabilize of the friction resistance not only in lubricated but also dry condition, because the grooves and dimples acts as oil reservoir and entrapment of wear debris. Mechanical means, such as turning and grinding are frequently used for surface finishing but also possible to fabricate the surface texture consisted from grooves. On the other hand, the graphite penetration into the dimpled Cu alloy resulted in the decrease of the friction resistance was confirmed [2]. Therefore, it is expected that the graphite penetration into the groove fabricated to the journal surface results in the improvement of the friction properties of the Cu alloy.

The present study describes friction properties of sintered Cu alloy journal with modified surface in dry condition. The surface texture consisted from spiral groove is fabricated to the surface of the journal. The surface penetrated graphite into the groove was also prepared. Effects of the groove and the graphite penetration on the friction properties were discussed.

2. Experimental procedures

2.1. Material

Materials used for the present study was cupper (Cu) based alloy prepared with sintering. A SEM/EDX image was shown in Fig. 1. The micro structure of the Cu alloy consisted from Cu rich grains, micro-sized sulphide phase and pores. The apparent density and Vickers hardness of the alloy was 92 % and 200 Hv. The sulphide phase and the pore is concentrated at the grain boundary. The sintered body was machined to a cylindrical shape of 12 mm of outer diameter and 12 mm of length. The inner surface corresponded to the testing one and was finished to 6.01 mm of diameter with a reamer.

Optical micro images and the surface profiles along to the axial direction were shown in Fig. 2. A spiral groove having triangle cross section was applied. The groove geometry was 350 μm of depth, 300 μm of width and 1100 μm of pitch, and the area fraction of the groove was approximately 20 %. Graphite was occasionally penetrated into the groove. It was Mechanical means with pushed in groove while rotating. As results, three kinds of the surface with different surface structure, nominal, grooved, graphite penetrated surface were prepared, however the surface finishing process was same and the difference of the surface profile of the top region was small. It was also found that the groove did not flatten after the graphite penetration.

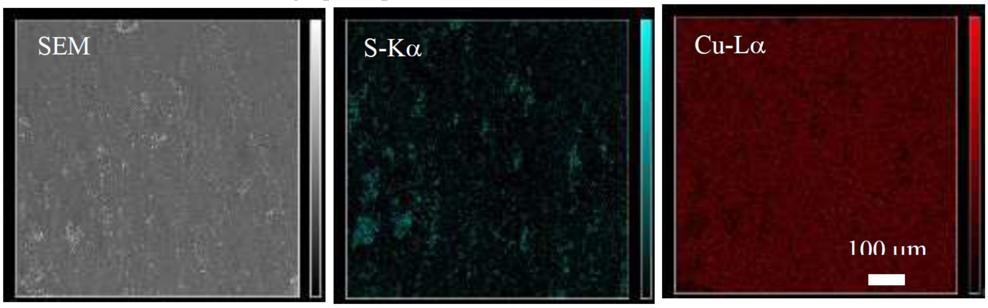

Fig. 1. SEM/EDX images of sulfide containing Cu alloy

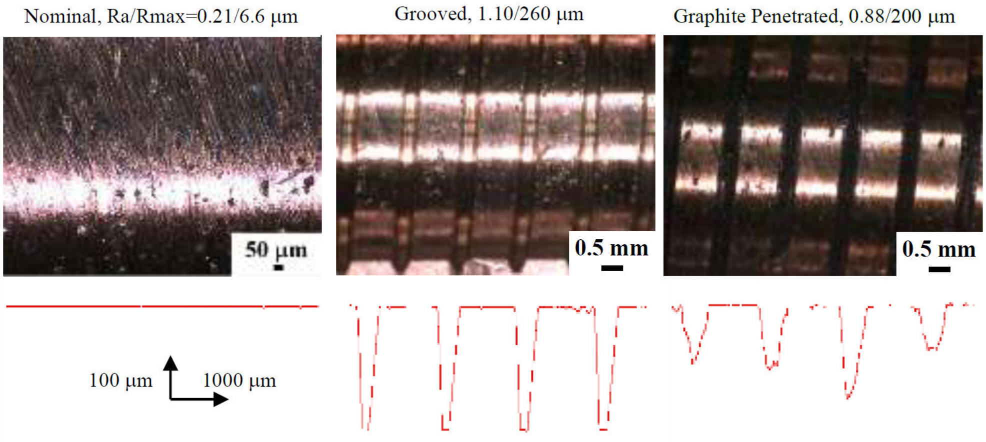

Fig. 2. Optical micro image and profile of inner surface of journal

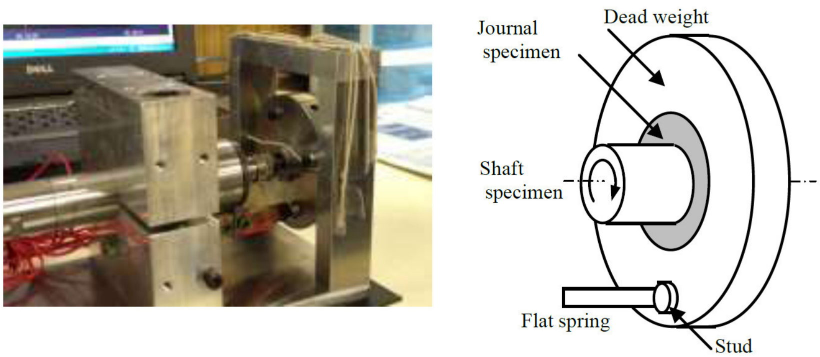

Fig. 3. Overview (left) and schematic (right) of testing apparatus

2.2. Testing apparatus

A developed journal type testing apparatus was used for the experiment. An overview and a schematic of the testing apparatus were shown in Fig. 3. A hardened carbon steel shaft (700 Hv, 5.99-6.00 mm of diameter and 40 mm of length) was used as the mating specimen and was fixed to an air cooled spindle through a collet chuck. The shaft specimen was driven with a DC motor. The journal specimen was installed in the centre of the disc shape dead weight including aligned studs. The friction resistance was measured with a flat spring with strain gages contacted to the stud.

The shaft specimen was inserted into the journal specimen then the experiment was started. The experiment was carried out 10 times at a sliding speed of 1.57 m/s, an applied load of 3.7 N in laboratory air without lubrication. The maximum sliding distance was settled to approximately 5600 m and the experiment was interrupted when the seizure determined from the rapid increase of the friction resistance accompanied with noise from the interface was detected.

3. Results and Discussion

3.1. Friction coefficient

Examples of the friction coefficient of the nominal surface were shown in Fig. 4 as a function of the sliding distance. The seizure occurrence was found in the all result. The friction coefficient varied from 0.01 to 0.02 at initial stage then increased gradually with the increase in the sliding distance up to seizure. The mean sliding distance up to the seizure occurrence was 50 m. Results of the grooved surface was shown in Fig. 5. The friction coefficient was 0.01 to 0.03. Although the seizure occurred in the all specimen and the effect of the groove on the decrease of the friction coefficient was small, the mean sliding distance up to seizure was 100 m, larger than that of the nominal surface.

Results of the penetrated graphite surface were shown in Fig. 6. The friction coefficient was similar to those of the nominal and the grooves surfaces and increased with the increase in the sliding distance. The significant increase of the sliding distance up to the seizure was found: The sliding distance of three results reached to the settled sliding distance without seizure occurrence and the minimum sliding distance was 100 m. Therefore, it is concluded that the groove and the graphite penetration is effective means for the increase on sliding distance.

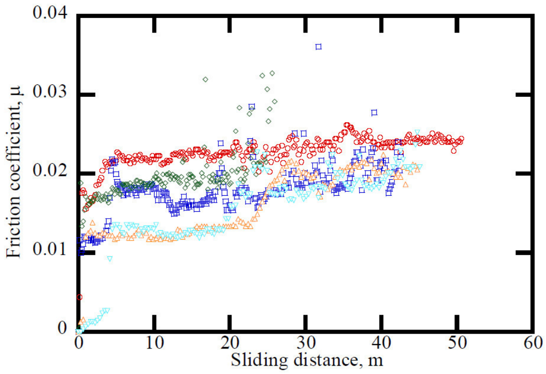

Fig. 4 Friction coefficient of nominal surface (Result of 5 times under the same condition)

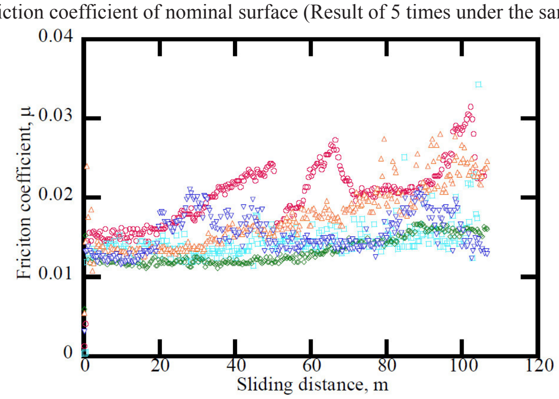

Fig. 5 Friction coefficient of grooved surface (Result of 5 times under the same condition)

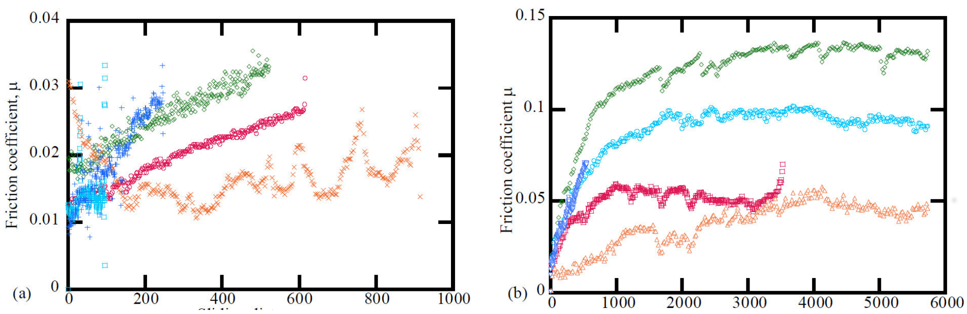

Fig. 6 Friction coefficient of graphite penetrated surface (Result of 10 times under the same condition) (a) seizure occurrence (b) non seizure occurrence

3.2. Wear surface

The shaft specimen after the experiment was observed with SEM/EDX, as shown in Fig. 7. The wear loss of the shaft was small and the transfer consisted from Cu and sulfur (S) was found. The morphology of the transfer was different depending on the journal surface properties. The transfer found on the surface mated with the nominal specimen was thick. On the other hand, the transfer formed on the surface mated with the grooved and the graphite penetrated specimen was thin.

It was also found that the wear debris entrapped into the groove and that the graphite was detected on the top region of the journal surface. Consequently, it is estimated that the groove and the graphite penetration resulting in the restriction of thick transfer formation is effective means to increase of the sliding distance up to seizure occurrence.

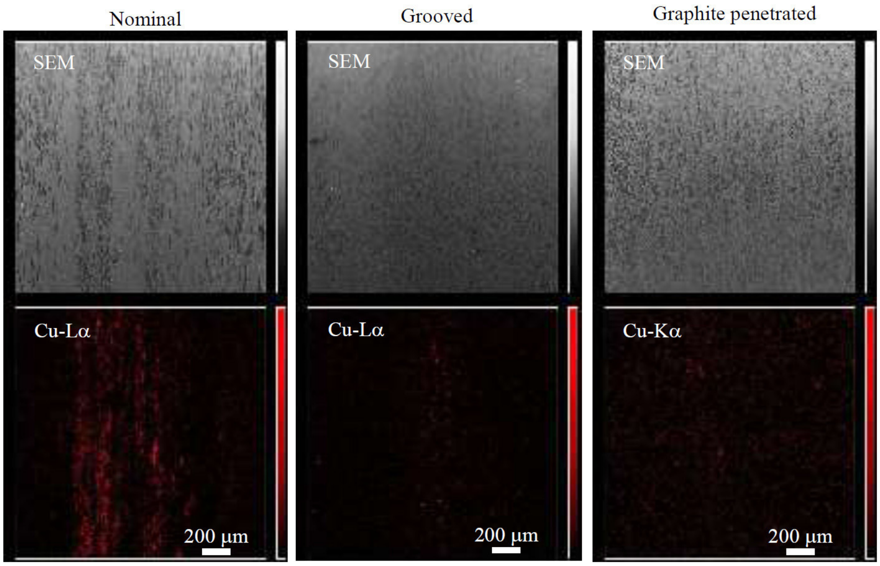

Fig. 7 SEM/EDX images of shaft surface after experiment

4. Conclusions

Effects of a spiral groove and graphite penetration on the friction properties of the copper based sintered alloy was evaluated using a journal type testing apparatus mated with hardened carbon steel in dry condition. Results found that the groove application was effective for improving the sliding distance up to the seizure occurrence. In addition, significant increased of the sliding distance was found in the graphite penetrated specimen. Furthermore, it was estimated that the groove and the graphite penetration resulted in the restriction of thick transfer formation which was effective to increase the sliding distance up to seizure occurrence.

Acknowledgements

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