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Study on low friction under low sliding velocity condition using PTFE material with copper particle as filler

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ABSTRACT – Lower friction of a slide guide-way under low sliding velocity condition is essential to improve the accuracy of machine tools. To fulfill this requirement, PTFE based composite material is used in combination with special lubricant for a slide guide-way. However, why lower friction is developed in this combination is poorly-understood. In this study, friction mechanism under low pressure sliding contact using the PTFE based composite material is experimentally investigated by changing materials and performing sliding friction test. As a result, it was found that contacting condition of copper particle make influences on maintaining velocity dependency under boundary lubrication condition.

1. INTRODUCTION

Many machine tools with a slide guide-way as a feeding mechanism. Low friction property of the slide guide-way has an important role to move precisely along a commanded displacement of a cutting tool. When lubricant containing oleylacid phosphate (hereinafter called OLAP) is used, thicker viscous boundary film is formed on the sliding surface and friction coefficient significantly reduces under the low sliding velocity condition. In addition, friction coefficient has a strongly positive velocity dependence necessary to slide in a dynamically stable manner [1]. Furthermore, friction can be reduced by using PTFE based composite material with copper particle as filler (hereinafter called PBCCu). Under low pressure sliding contact generated in the machine tool' slide guide-way, this combination makes friction property better than using them alone. Elucidating why this synergy effect occurs will makes friction property much better. So, Objective of this study is investigation into mechanism of low friction developing in combination of the PBCCu and the special lubricant with OLAP.

2. METHODOLOGY

2.1 Evaluation method of friction

It has been reported that the positive velocity dependence of friction coefficient (positive μ–V dependence) is caused by viscous substance derived from OLAP. On boundary friction, this friction property can be approximated by following equation.

$$\log \mu = \alpha \log V + \beta \quad (1)$$

In this equation, α denotes a velocity dependence index and β denotes a factor of friction magnitude at reference sliding velocity.

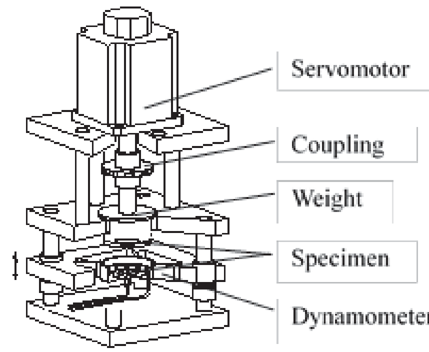

Figure 1 Schematic of experimental apparatus.

In this experiment, friction coefficient was evaluated and discussed by these indices. In addition, further consideration was done by observing specimen surface.

2.2 Experimental condition

Experimental apparatus with the type of thrust collar is shown in Fig.1. Six pin-type specimens with flat top were uniformly assigned on the upper rotating collar. Friction force can be measured with dynamometer on which the lower collar is fixed. Surface roughness of all specimens was 3.0–3.5 μm R_{zJIS} except for copper pins with a roughness of about 10 μm R_{zJIS}. Sliding velocity ranged from 10^{-5} – 10^{2} mm/s and average contact pressure was set to 0.31 MPa. A running-in velocity was set to 9.2 mm/s. As an experimental parameter, the material of the upper specimens and the running-in time were changed as shown in Table 1. In contrast, the material of the lower specimen was fixed to cast-iron. As a lubricant, mineral oil (ISO VG68) that contains OLAP additive (concentration: 1.0 wt%) was used.

Table 1 Experimental condition.

Exp. No.	Upper Specimens	Run-in duration
1	PBCCu	16 hours
2	Cast iron	16 hours
3	Copper	2 hours
4	Copper	16 hours

3. RESULTS AND DISCUSSION

Figure 2 shows the results of test and shows properties of friction in the boundary lubrication area. Figure 3 shows the relationship between the velocity dependency index α and the factor of friction magnitude β. Comparing PBCCu and cast iron, magnitudes of α are almost the same but a magnitude of β of the PBCCu is about one-third of that of the cast iron. The roughness of the PBCCu after running-in with long duration was markedly reduced. That means that the specimen surface uniformly worn over all regardless of material property, such as hardness. This result always indicates that copper particles in the PBCCu have a role not only to prevent the surface from wearing but also to support the normal load substantially. In this case, the mating surface was well-truncated although its hardness is larger than those of PTFE and copper. It is considered, in this case, that the contact occurred between a flat and smooth surface and a well-truncated surface as shown in Fig.4. Therefore, even after running-in, the copper particles substantially supported the normal load. Namely, if if a normal load sharing ratio simply determines an average friction coefficient, a friction coefficient of the PBCCu / iron combination might be close to the same value of Cu / iron combination. However, the friction coefficient of the PBCCu / iron combination was much smaller than that of Cu / iron combination. In the Cu / iron combination, the smaller the roughness became due to running-in, the higher the coefficient of friction became. Conversely, the friction coefficient in large roughness is smaller than that of small roughness. Namely, it is considered that copper particle in PBCCu has the same effect as large roughness and that friction became smaller.

Although, it is hard to think that copper particle in PBCCu has only effect on reduction of friction. The main material of PBCCu is PTFE. PTFE has a low energy surface and an effect to reduce friction. Therefore, it is considered that there is synergy effect between effect of copper particle as large roughness and effect of PTFE as low energy surface.

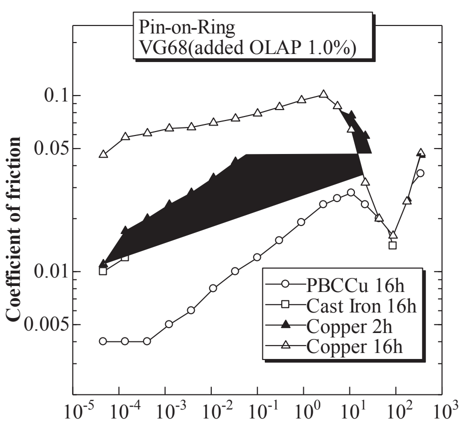

Figure 2 Boundary friction properties of these experimental results.

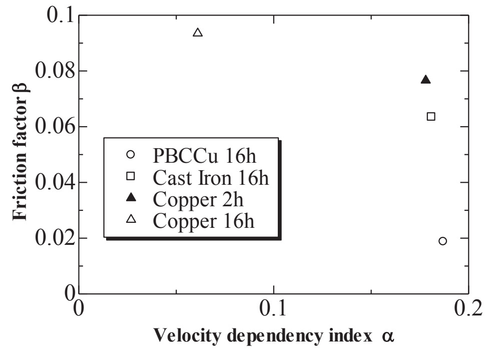

Figure 3 The relationship between velocity dependence and friction factor.

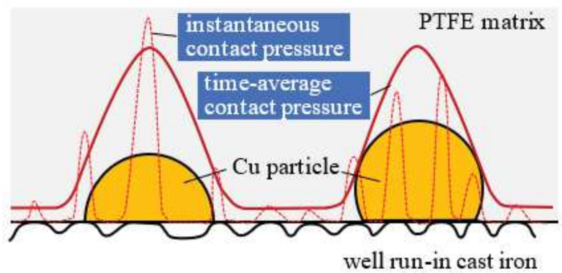

Figure 4 Possible contacting pressure distribution after running-in.

4. CONCLUSIONS

In this study, mechanism of low friction developing in combination of the PBCCu and the special lubricant with OLAP was researched. Obtained results are summarized as follow:

(a) The roughness of PBCCu after running-in with long duration was reduced. So, copper particle in the PBCCu always supported the normal load substantially.

(b) Comparing with copper experiments, it is considered copper particle in the PBCCu has same effect as large roughness.

(c) It is considered that there was synergy effect between effect of PTFE as low energy surface and effect of copper particle as large roughness.

REFERENCE

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