EFFECTS OF MICROSCOPIC SPHERICAL PARTICLES MIXED IN LUBRICATING OIL ON FRICTIONAL CHARACTERISTICS OF LINEAR SLIDE GUIDE

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ABSTRACT

In order to develop a superior linear slide guide having friction coefficient independent of sliding velocity, the authors have proposed a method to supply microscopic spherical particles to hardened sliding surfaces finely finished by lapping. The frictional characteristics of a slide guide to which the method was applied were investigated using a model of machine tool's slide guide. Experiments were carried out at the sliding velocity ranging from 1 to 6000 mm/min. Adding spherical particles with a 5 μm diameter to a vegetable lubricating oil having a viscosity of 215 mm²/s leaded to a constant friction coefficient excluding ultra-low sliding velocity range.

INTRODUCTION

Because the rigidity and the damping performance of a slide guide are superior to those of a rolling guide, the slide guide is suitable for the machining of difficult-to-cut materials. It is desirable for the friction coefficient of a linear guide to be both lower and invariable in a wide sliding velocity range. Though the rigidity and damping performance of the slide guide made of cast iron and finished by scraping are better than those of the rolling guide, the friction coefficient of the slide guide depends on sliding velocity[1]. In the boundary lubrication region, the friction coefficient of a slide guide is generally higher than that in any other lubrication regions, and a decrease in sliding velocity induces a sudden increase in friction coefficient, which causes a decrease in positioning accuracy of the slide guide. For the accurate and efficient machining using a machine tool equipped with slide guides, it is indispensable to develop a slide guide whose friction coefficient is lower and independent of sliding velocity.

To realize the slide guide with above-mentioned frictional characteristics, we have recently proposed a slide guide which uses a vegetable lubricating oil with microscopic spherical particles on the finely finished hardened sliding surfaces. In this report, friction tests were carried out using the proposed slide guide model. The effects were examined of the model surface roughness, the particle diameter, and the particle hardness on the sliding frictional characteristics of the slide guide model.

EXPERIMENTAL CONDITIONS OF SLIDING FRICTION TESTS

Figure 1 shows the outline of a sliding friction tester used in experiments. The tester can measure friction force, which is detected by a load cell through a fulcrum, when a plate moves at a sliding velocity \( V_s \) under a slider being pressed on the plate with a constant vertical load. The load is applied by a weight put on the slider. The specimens used in experiments were made of a alloy steel of SKD11 for cold working molds. After the specimens were quenched and tempered, they were finished in a maximum surface roughness of about 0.5 μm by lapping. The hardness of the slider and that of the plate were about 60 HRC and 59 HRC respectively. The contact surface size was 20 x 20 mm. Table 1 shows the experimental conditions of the tests. Experiments were carried out at room temperature. Though the slider can move back and forth, as shown in Fig.1, the experiments were done under the condition of unidirectional sliding to get rid of the influence of the sliding
direction. The sliding velocity range was between 1 mm/min and 6000 mm/min.

Figure 2 shows SEM images of the microscopic spherical particles mixed in the lubricating oil. The 2 and 5 µm diameter particles were used in experiments to examine the effects of the particle on friction coefficients. The 400 HV and 800 HV hardness particles with the 5 µm diameter were also used in experiments to investigate the effects of the particle hardness on friction coefficients. The weight percent of the particle added to the lubricating oil was about 4 %. Approximately 2 - 5 ml lubricating oil was spread on the plate before the start of test.

Table 1  Experimental conditions in sliding friction tests

| Test load N | 39.2 |
| Sliding distance mm | 100 |
| Sliding velocity mm/min | 1 ~ 6000 |
| Sliding direction | unidirectional |
| Atmospheric temperature K | 294 - 295 |
| Kinematic viscosity of vegetable lubricating oil at 293 K mm²/s | 215 |

EFFECTS OF PARTICLE HARDNESS ON FRICTION COEFFICIENT

Figure 5 shows the effects of the 5 µm diameter particle hardness on friction coefficients. Independent of the hardness, the friction coefficient was approximately constant against sliding velocity. The friction coefficient in the experiments with the 800 HV particle was smaller than that with the 400 HV particle.

CONCLUSION

The essential requirement to realize a slide guide independent of sliding velocity is that the contact surface should be hardened not less than 60 HRC and finely finished approximately 0.5 µm in maximum surface roughness. Adding spherical particles with a 5 µm diameter was effective to obtain a constant friction coefficient excluding the ultra-low sliding velocity range.

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REFERENCES