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A Study on Reduction of Coefficient of Friction by Using Ultrasonic Vibration
超音波振動を利用した摩擦係数低減に関する研究

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1. Introduction

It is well known that a fictional force between two sliding surfaces can be reduced to excite the ultrasonic vibration on the one side of a solid surface. By applying the near-field acoustic levitation, it is possible to reduce a frictional force without using a special lubricant such as Teflon coating or polyurethane coating. Moreover, as the application example of the near-field acoustic levitation, the non-contact transportation methods using traveling wave generated by flexural vibration are used in various field such as powder technology, food industry etc..

The purpose of this study is to obtain the fundamental knowledge of the reduction of frictional force using the ultrasonic levitation. In this work, several experiments are performed; especially, the coefficients of static and kinetic friction are examined at the condition of the intermediate state leading to the complete levitation.

2. Experimental Methods

A step horn is combined with a bolt-clamped Langevin-type transducer connected with the ultrasonic oscillator. The main conditions are as follows: the material of the aluminum alloy A7075, the frequency of 38kHz, and the amplitude magnification factor of 1.0. The flange of the horn is attached by six screws to a steel board, and the steel board for fixation is equipped on the stock vice fixed to the base plate.

The weights for measuring the coefficient of friction are made of the copper block and the acrylic resin block whose bases are square 10mm on each side. The five kinds of height of weight are prepared in order to investigate the relationship between the normal force and the coefficient of friction. In the experiments using the acrylic resin, we pick the five kinds of copper weight up on the acrylic resin. Table 1 shows the mass of weight. For measuring the frictional force, the weight put on the horn is horizontally moved by the aluminum rod connected to the load-cell. Shown in Fig. 1 is the schematic diagram of force measuring system.

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Table 1 Mass of the copper and acrylic resin specimen

Number	Material	Mass[g]	Material	Mass[g]
No.1	Copper	3.5	Acrylic resin + copper	4.1
No.2		5.2		5.8
No.3		7.0		7.6
No.4		8.6		9.2
No.5		10.4		11.0

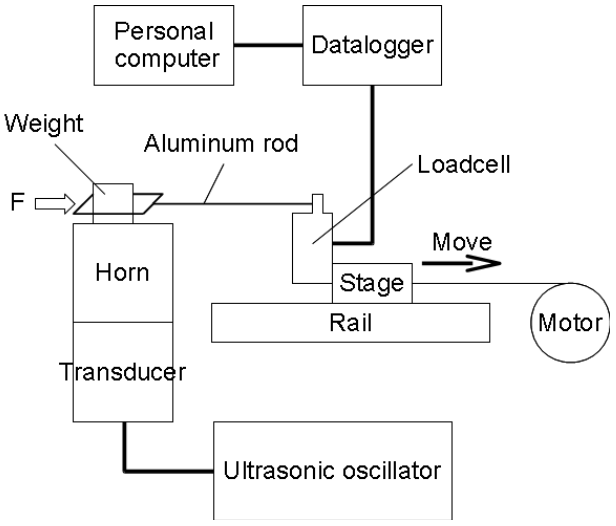

Fig.1 Schematic diagram of force measuring system

Deformation at tip of horn is measured by using laser Doppler vibrometer whose response frequency is 3MHz, and the amount of levitation at tip of weight is measured by using laser displacement meter whose repeatability is 0.05μm. The data of the deformation at tip of horn and the amount of levitation at tip of weight are simultaneously collected in personal computer via a data logger that can carry out sampling at intervals of 1μs, enabling the observation of rapid phenomena. Figure 2 show the schematic diagram of length measuring system.

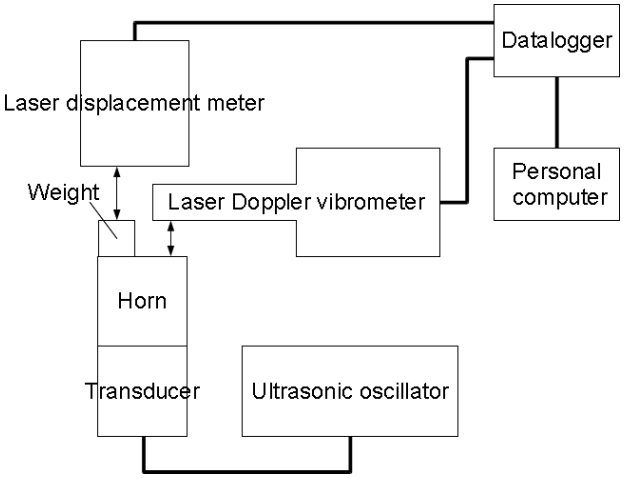

Fig2. Schematic diagram of length measuring system

3. Experimental results and discussion

Figure 3 shows the relationship between the coefficient of friction and the normal force when using copper and acrylic resin specimen without ultrasonic vibration. In the experiments, the number of test times is three in the case of copper specimen, two in the case of acrylic specimen; therefore the plotted data in Fig. 3 are the average value. The tendency of coefficient of friction is to not fluctuate with varying the normal force at two kinds of specimen. Table 2 show the average value of coefficient of friction without ultrasonic vibration. The coefficients of friction when using the specimens of acrylic resin are slightly larger than that of copper weight.

Figure 4 shows the relationship between the coefficient of kinetic friction and the amplitude of ultrasonic vibration when using the specimen of No.3 and No.5 at the copper weight, and the specimen of No.3 and No.5 at the acrylic resin weight. The coefficient of friction is drastically decreased with increasing the amplitude of vibration. At the amplitude of 1.6μm, all results are below the coefficient of friction of 0.05. Moreover, the coefficients of friction when using the specimens of acrylic resin are slightly larger than that of copper weight; these results are same results of Fig. 3.

4. Conclusion

In order to obtain the fundamental data of the reduction of coefficient of friction using the ultrasonic levitation, we construct the experimental equipment which can measure the frictional force and the high speed phenomena of ultrasonic vibration. It is clarified that over the amplitude of 1.6μm on ultrasonic vibration horn, the coefficients of friction are drastically decreased.

Acknowledgment

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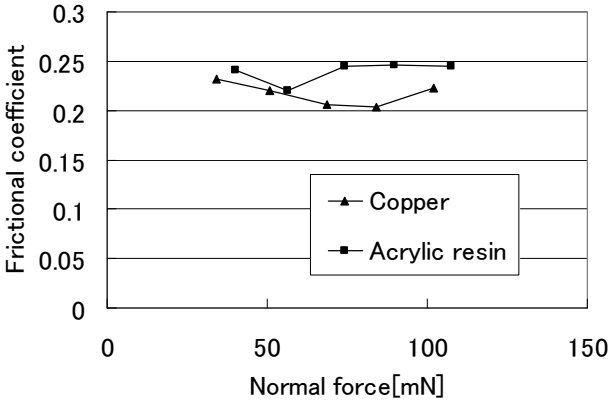

Fig.3 Relationship between the coefficient of friction and the normal force without ultrasonic

Table 2 Average of frictional coefficient

Copper	0.22
Acrylic resin	0.24

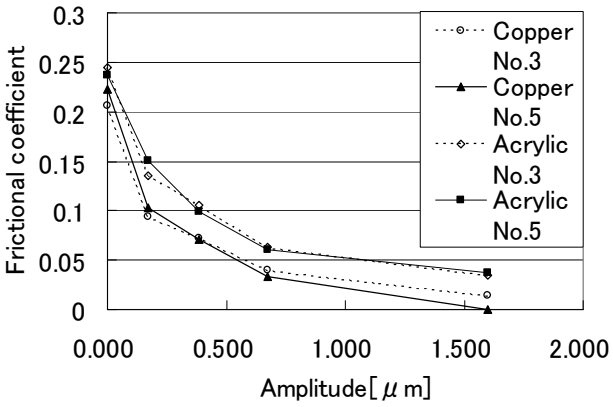

Fig.4 Relationship between the coefficient of kinetic friction and the amplitude of ultrasonic vibration