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The Influence of Tangential Relative Velocity on Interface Friction in Vibration State

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Abstract. There are a lot of vibration and friction phenomena in the operation of mechanical systems. Interaction between vibration and friction often occurs when a machine is running. The effects of friction on mechanical systems are sometimes beneficial but sometimes harmful, so it is of great significance to study the influence of vibration on friction. Based on the self-built experimental platform, this paper studies the effect of vibration on interface friction reduction when tangential relative sliding velocity changes. The results show that under the condition of fixed vibration frequency and amplitude, the slower the tangential relative velocity, the greater the effect of vibration on the friction reduction between the interfaces, the faster the tangential relative velocity, the smaller the effect of vibration on the friction reduction between the interfaces.

1. Introduction

Vibration and friction are widespread in mechanical systems. Vibration and friction often interact. Sometimes the effects of vibration on friction are harmful. For example, in the process of vehicle braking or emergency shutdown of mechanical system, mechanical vibration will reduce the friction of contact surface and delay the shutdown or braking time. In addition, the vibration of mechanical components will reduce the friction between screws or bolts and components, and the looseness of screws or bolts used for fixation will affect the reliability of the equipment. Sometimes the effect of vibration on friction is beneficial. For example, in the packaging process of granular products, vibration device should be installed on the funnel container or transmission pipeline of packaging machinery to reduce friction between particles through vibration, so as to increase fluidity of particles and improve packaging efficiency. All the above phenomena are the result of the vibration which significantly changes the contact friction. Therefore, it is necessary to study the internal mechanism of contact friction affected by vibration.

Existing research results have shown that vibration can reduce friction between interfaces. For the first time, Fridman and Levesque[1] carried out experimental research on reducing static friction force and found that the vibration caused by ultrasound can reduce static friction to almost zero. Robert W. Carpick[2] used the atomic force microscope to prove that vibration reduces friction at the nanometer scale. When the cantilever beam probe vibrates, the friction force on the sample surface is obviously less than that in a non-oscillating state.

Some scholars think that reducing friction caused by normal vibration perpendicular to the interface is more obvious. The research results suggest that normal vibration causes the change of normal contact state between interfaces, which leads to the reduction of friction coefficient [3-5]. Experimental results show that the amplitude and frequency of normal vibration can affect the magnitude of friction between interfaces[6]. However, the effect of tangential relative sliding velocity on interface friction is not clear.

In this paper, the effect of the normal vibration on the friction between interfaces is studied. More attentions are paid on the effect of normal vibration on friction between surfaces when tangential relative sliding velocity changes.

2. Experimental Facility

To achieve the research goal, relevant experimental devices are designed independently. The schematic diagram of experimental devices is shown in figure 1.

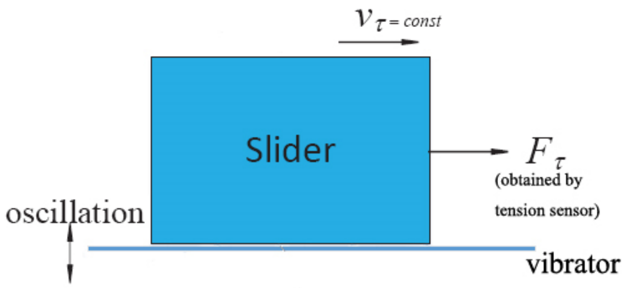

Figure 1. The schematic diagram of experimental devices

In figure 1, the signal generator is used to input normal sinusoidal vibration signals of different vibration frequencies and amplitudes to the vibrator. Under the excitation of this signal, the vibrator will produce normal vibration. The slider moves at a constant speed v_{τ} on the vibrator under the pull of the horizontal tension machine. Because the slider moves at a uniform rate on the vibrator, the force value collected by the sensor of the horizontal tension machine is the friction force between the sliding block and the vibrator. The experimental device is shown in figure 2.

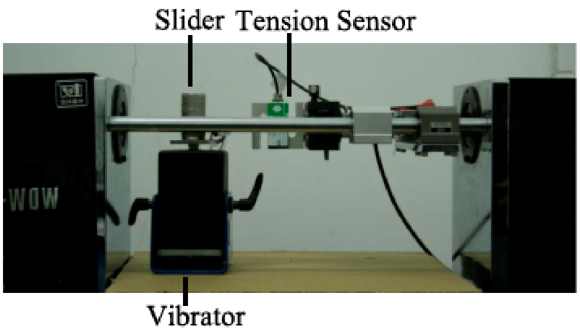

Figure 2. Physical diagram of the experimental device

The vibrator and slider are made of stainless steel. With the temperature and humidity of the experimental environment temperature and humidity meter records, all the experiment is about 40% in humidity, temperature at 26 °C or so.

During the experiment, the friction force with no vibration between the interfaces is measured at first. Then, the normal vibration signal is input, and the vibrator begins to produce vibration. At this time, the change of friction between interfaces is measured, and the influence of vibration on interface friction is observed. As the voltage value of the input normal vibration signal increases, the amplitude of the vibrator increases, and the influence of the amplitude change on interface friction can be observed. After fixing the amplitude, the vibration frequency was changed to observe the influence of the vibration frequency on interface friction. Under the condition of fixed amplitude and frequency, change the relative sliding velocity between the sliding block and the vibrator, and observe the effect of relative velocity change on the interface friction.

3. Result and Analysis

3.1. Influence of normal vibration on interface friction

Under the condition of 50Hz, the normal amplitude A_n of the vibrator was changed, and the influence of vibration on the friction between the interfaces was measured under different normal amplitude. The friction between the interfaces is represented by F_d, and the horizontal sliding speed of the slider is 1mm/s. The experimental results are shown in figure 3.

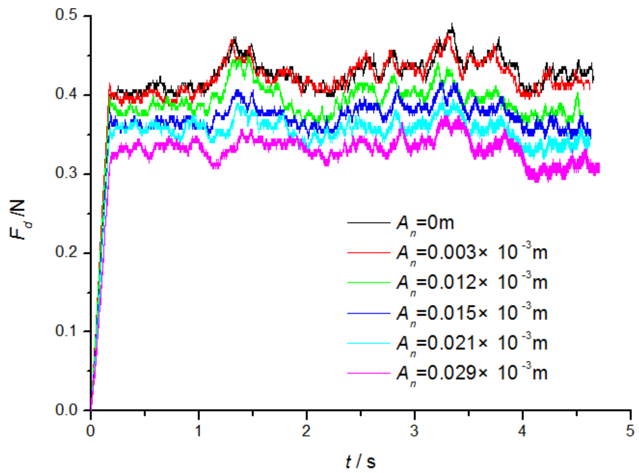

Figure 3. The relation between F_d and normal amplitude under 50Hz

According to figure 3, when A_n=0.003×10^{-3}m, the effect of friction reduction is not obvious. However, as the normal amplitude increases, the friction between the interfaces decreases, and the friction between the interfaces decreases more and more obviously. The above data suggest that vibration does reduce friction between interfaces.

3.2. Influence of tangential relative velocity on interface friction

On the basis of the above experiment, the pulling speed of the horizontal tension machine, that is, the tangential relative moving speed between the sliding block and the vibrator, is changed, and the vibration and friction data are measured at the same time.

Firstly, under the fixed condition that the vibration frequency f_r is 75Hz and the normal amplitude A_n=0.0148x10^{-3}m, the horizontal sliding velocity of the slider is changed to observe the decreasing effect of interface friction under vibration conditions. In order to better reflect the friction properties between the interfaces, the friction coefficient between the interface is calculated by using the friction force, and the relation between the friction coefficient and the sliding speed of the slider is drawn, as shown in figure 4.

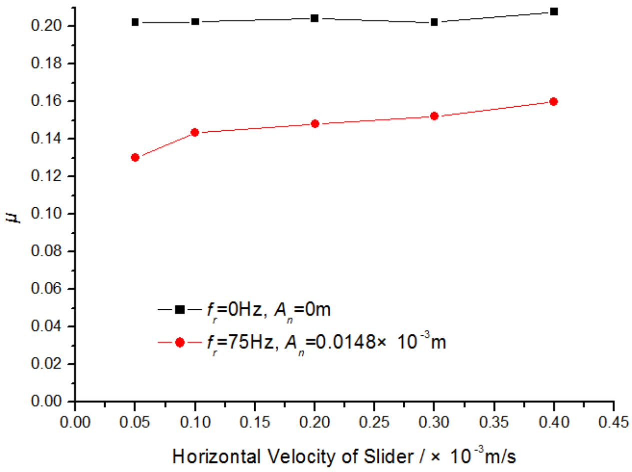

Figure 4. The relation between friction coefficient and the sliding speed of slider under 75Hz

The black line in figure 4 shows the sliding friction coefficient between the interfaces under the condition of no vibration. The red line is the relation between sliding velocity and friction coefficient under the fixed condition of vibration frequency f_r=75Hz and normal amplitude A_n=0.0148×10^{-3}m. Figure 4 shows that the friction coefficient between the interfaces decreases gradually as the sliding speed slows down. It shows that the sliding speed has influence on the effect of vibration friction reduction. The slower the sliding speed, the more obvious the effect of vibration friction reduction. To better clarify the relationship between sliding speed and friction reduction, more experimental data are shown in figure 5.

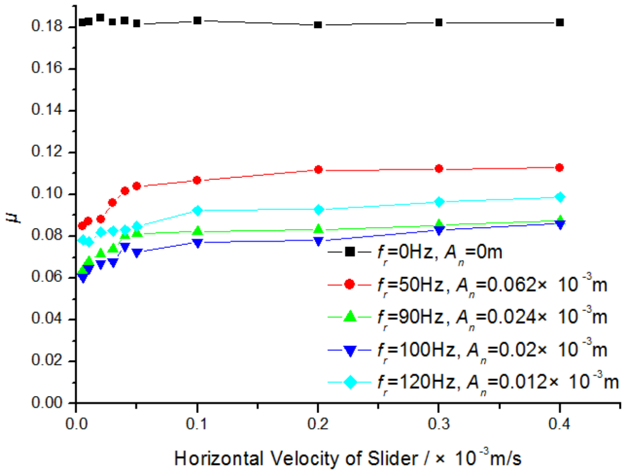

Figure 5. The relation between friction coefficient and slide velocity in the case of fixed vibration frequency and amplitude

In figure 5, the black line is the interface friction coefficient with no vibration. The other lines show the relation between the sliding velocity and the interface friction coefficient under different vibration frequency and amplitude. All the four curves under the vibration condition show that under the same vibration frequency and amplitude condition, the slower the sliding speed of the slider on the vibrator, the smaller the friction coefficient between the interfaces. The data in figure 5 shows that the sliding speed has a significant impact on the effect of vibration on friction reduction, and the effect of friction reduction under the same vibration parameters becomes more obvious as the tangential relative velocity decreases.

4. Conclusion

The experimental system which can reflect the relationship between vibration and interface friction is designed and constructed independently. Firstly, using this experimental system, it is proved that vibration can reduce the friction between interfaces. Secondly, when the amplitude and frequency of vibration remain unchanged, the horizontal sliding velocity of the slider, that is, the tangential relative moving speed, is changed. It is found that the slower the tangential relative moving speed, the greater friction reduction under the condition of vibration.

Acknowledgments
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