

PAPER • OPEN ACCESS

The Effect of Mechanical Vibration on Interfacial Friction

To cite this article: Jiandong Lu 2019 *IOP Conf. Ser.: Mater. Sci. Eng.* **490** 052020

View the [article online](#) for updates and enhancements.



IOP | ebooks™

Bringing you innovative digital publishing with leading voices
to create your essential collection of books in STEM research.

Start exploring the **collection** - download the first chapter of
every title for free.

The Effect of Mechanical Vibration on Interfacial Friction

Jiandong Lu^{1,*}

¹Department of Dynamics and Control, Beihang University, Beijing, China

*Corresponding author e-mail: lululu0831@sina.com

Abstracts. Vibration and friction, which often interact with each other, exists widely in mechanical system. The study on the influence of vibration on friction is helpful to explain some physical phenomena in mechanical system and remove faults. In this paper, from the perspective of experiment, the change of friction between the interfaces in the vibration state is measured by designing and building the experimental platform independently. The results show that the friction between the interfaces can be reduced by vibration, and the friction decreases more obviously with the increase of amplitude or vibration frequency.

1. Introduction

In the movement of mechanical system, the contact action between system components is often accompanied, and friction action is unavoidable. Because the component itself is not rigid, the friction between the components will arouse high frequency vibration of the component itself. The vibration of the component itself may in turn significantly affect the contact friction between the components. For example, machinery makes vibration noise when moving. The screws or bolts used for fixation will become loose. Deep well drilling assisted by high frequency vibration can reduce the friction resistance of the drill bit. The above examples show that vibration can obviously affect friction force.

It can be seen that the study of vibration affecting contact friction is of great significance in explaining some physical phenomena in mechanical systems, troubleshooting and guiding production. The study of the relationship between vibration and interface friction has become the goal of some scholars.

There have been studies on the relationship between vibration and friction, such as experimental study on the phenomenon of ultrasonic friction reduction. G.M. Cheng et al [1]. proposed that the ultrasonic vibration causes the rotor to vacate and the contact area decreasing to reduce the ultrasonic friction. M.J. Huang et al [2]. believe that ultrasonic vibration reduces the contact time between stator and rotor, and the friction coefficient thus reduces. Other scholars [3-5] pay attention to macroscopic vibration parameters that affect friction, such as the direction of wave, dynamic frequency, amplitude and pressure. In the microscopic field, an experimental study by A. Socoliuc found that the friction of



the contact end of the atomic force microscope is reduced by vibration [6]. However, the reason for the influence of vibration on friction, especially the relationship between normal vibration and friction, is not clear.

Since a large number of contacts in mechanical systems are contact between surfaces and are mostly normal vibrations, this paper focuses on the influence of normal vibrations on friction between interfaces. The effect of normal vibration on interface friction is analyzed experimentally. The experimental results show that the vibration can reduce the friction between the interfaces, and the vibration frequency and amplitude have a great influence on the friction between the interfaces.

2. Experimental Facility

The experimental devices are designed independently to measure vibration and friction. The design drawing of experimental equipment is shown in Fig. 1.

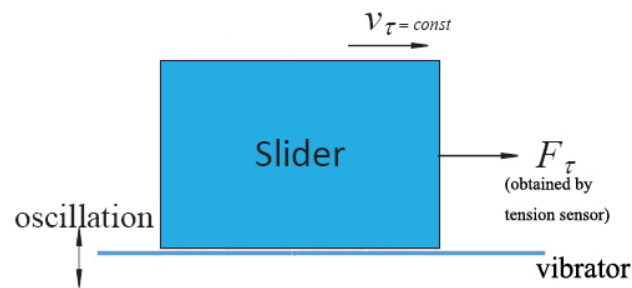


Figure 1. The design drawing of experimental equipment.

In Fig. 1, The exciter sends a normal sinusoidal signal to the vibrator. Due to the excitation of the exciter, the vibrator starts to vibrate in the normal direction. The slider on the vibrator is pulled at a constant speed v_{τ} by the horizontal tension machine. Since the average speed of the slider is uniform when pulled by the tension machine, the force value F_{τ} measured by tension sensor of the horizontal tension machine is equal to the average friction between the slider and the vibration plate. The physical drawing of the experimental device is shown in Fig. 2.

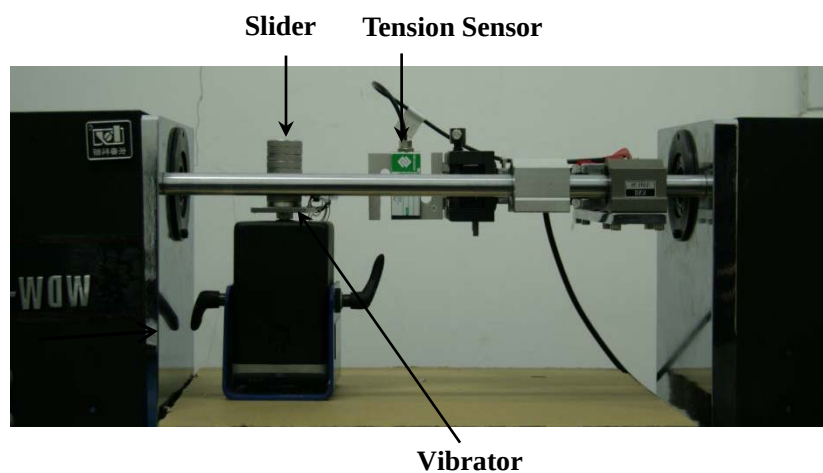


Figure 2. The physical drawing of the experimental device

Firstly, the vibration frequency remains constant. Different voltage values of the input normal vibration signal are sent to the vibrator. The larger the voltage value, the larger the normal amplitude of the vibrator. The friction force between the slider and the vibrator is measured at different normal

amplitudes. Under the condition of fixed frequency, the effect of normal amplitude on friction can be observed. Then, the normal amplitude remains constant. Under the condition of fixed normal amplitude, the effect of vibration frequency on friction is observed by changing vibration frequency. Both the vibrator and the slider are made of stainless steel. According to temperature and humidity meter records, all the experiments were finished at 40% humidity and 26°C temperature or so.

3. Result and Analysis

3.1 Relationship between Friction and Time

The normal amplitude A_n of the vibrator was changed under the condition of 50Hz. Under this condition, the friction force F_d between the slider and the vibrator under different normal amplitudes were measured respectively. The experimental data are shown in Fig. 3, and the horizontal sliding speed of the slider is 2mm/s.

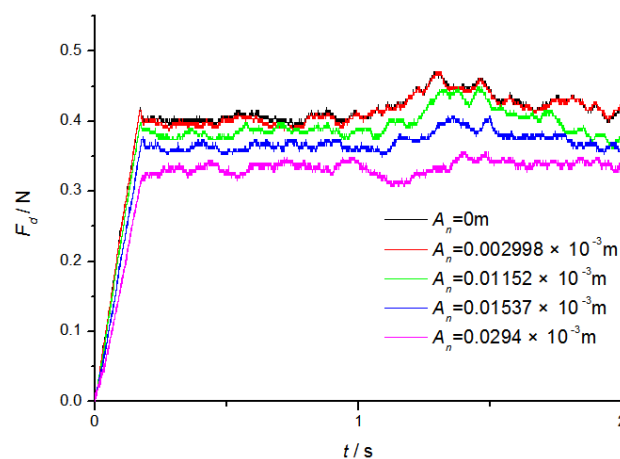


Figure 3. The relation between friction and time when amplitude changes.

As can be seen from Fig. 3, when $A_n = 0.002998 \times 10^{-3} \text{ m}$, the friction force between the vibrator and the slider does not decrease, but with the increase of normal amplitude, the friction force becomes smaller and smaller. This shows that the vibration does reduce the friction between the the vibrator and the slider.

In order to achieve the research goal, the variation of friction between interfaces under more vibration parameters was measured. In addition, friction coefficient is calculated by using friction force. As shown in Fig. 4 and Fig. 5, the relation between friction coefficient and amplitude or frequency is drawn.

3.2 Influence of Amplitude on Interfacial Friction Coefficient

Firstly, the vibrator frequency f_r is set to be 30Hz, and the horizontal sliding speed of the slider is $0.05 \times 10^{-3} \text{ m/s}$. Under the condition of a fixed frequency of 30Hz, the normal amplitude of the vibrator is changed, and the friction coefficient between the interfaces is measured at the same time. Secondly, the relation between vibration and friction coefficient is measured at 50Hz and 90Hz, respectively. The experimental results between normal amplitude and friction coefficient are shown in Fig. 4. According to Fig. 4, the influence of the change of amplitude on the friction coefficient is analyzed.

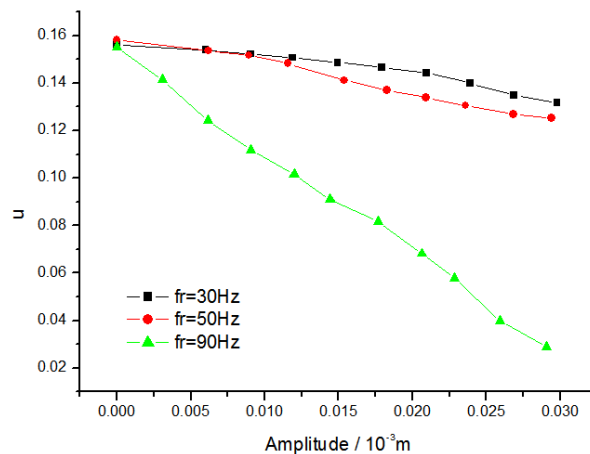


Figure 4. The relation between the friction coefficient and amplitude when the amplitude changes.

In Fig. 4, the three curves are the variation of interface friction coefficient with amplitude when the vibrator vibrates at a fixed frequency of 30Hz, 50Hz and 90Hz respectively. All three curves show that, when the vibration frequency remains constant, the friction coefficient between the interfaces becomes smaller and smaller with the increase of the normal amplitude of the vibrator, especially when $f_r=90\text{Hz}$. The above data show that the amplitude is one of the parameters that affect the friction coefficient between the interfaces.

3.3 Effect of Vibration Frequency on Interfacial Friction Coefficient

Firstly, the normal amplitude of the vibrating plate is set as $0.012 \times 10^{-3}m$, and the horizontal sliding speed of the slider is set as $0.05 \times 10^{-3}m/s$. Under the condition of fixed amplitude $0.012 \times 10^{-3}m$, the vibration frequency of the vibrator is changed, and the friction coefficient between the interfaces is measured. Secondly, the friction coefficient is measured when the normal amplitude is $0.018 \times 10^{-3}m$ and $0.027 \times 10^{-3}m$ respectively. The relation between interface friction coefficient and vibration frequency is shown in Fig. 5.

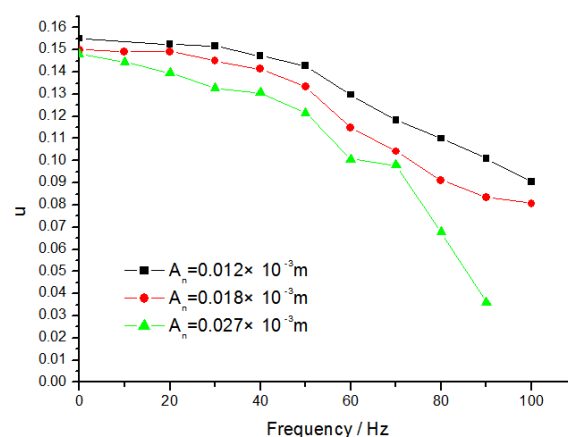


Figure 5. The relation between friction coefficient and frequency when frequency changes.

In Fig. 5, the three curves are the variation of interface friction coefficient with vibration frequency when the vibrator vibrates with fixed amplitude of $0.012 \times 10^{-3}m$, $0.018 \times 10^{-3}m$ and $0.027 \times 10^{-3}m$ respectively. All three curves show that the friction coefficient between the interfaces becomes smaller and smaller with the increase of normal vibration frequency of the vibrator when the amplitude

remains constant. The data in Fig. 5 shows that the frequency is one of the parameters that affect the friction coefficient between the interfaces.

Compared with Fig.4, the curves in Fig. 5 are not completely inversely proportional, while the curves in Fig.4 are close to inversely proportional. According to the experimental data in Fig. 3-Fig. 5, normal vibration can indeed reduce the friction between the interfaces. With the increase of normal amplitude or vibration frequency, the reduction of friction between the interfaces becomes more and more obvious.

4 Conclusion

The experimental system which can reflect the relationship between vibration and interface friction is designed and constructed independently. The experimental system is used to change the experimental parameters such as vibration frequency and amplitude to measure the change of interface friction under different vibration parameters. The results show that vibration can reduce the friction between the interfaces, and the vibration parameters of amplitude and frequency can effect the friction reduction. When amplitude or vibration frequency increases, the friction between the interfaces decreases more obviously.

Acknowledgments

This work was financially supported by NSFC (11572017) and Research Projects of Beijing Institute of Graphic Communication (Ed201804) fund.

References

- [1] G.M. Cheng, P.H. Zeng, X. Y. Qiu, et al, Study on Ultrasonic Vibration, Antifriction Phenomenon. 20 (5) (1998) 322-325.
- [2] M.J. Huang, T.Y. Zhou, Q.H. Wu, The Influence on Friction Force by Ultrasonic Vibration, Acta Acustica. 25 (2) (2000) 115-118.
- [3] T.Y. Zhou, Y.Liu, S.M. Yuan et al, The Effect of Acoustic Levitation on Ultrasonic Reducing Friction, Acta Acustica. 29 (2) (2004) 111-114.
- [4] J.J. Qu, X. Tian, F.Y. Sun, Study on Ultrasonic Vibration and Anti-friction Test Based on Travelling Wave Type Ultrasonic Motor, Tribology. 27 (1) (2007) 73-77.
- [5] B.D. Wu, et al, Experimental Study and Theoretical Analysis on Anti-friction Capability of Ultrasonic Vibration, China Mechanical Engineering, 15 (9) (2004) 813-815.
- [6] A. Socoliuc, et al. Atomic-scale Control of Friction by Actuation of Nanometer-sized Contacts, Science, 313 (2006) 207-210.