Friction Characteristics between Two Bodies under the Vibration Working Condition and Their Applications

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Abstract. This paper mainly focuses on vibration friction and discusses the dynamic characteristics of the friction under the vibration working condition. It is rather valuable to study such a special kind of friction vibration in engineering. Many practical projects have already proved that under the vibration working condition, the friction force between workpieces can be reduced obviously. Wear and damage of the machine parts can be obviously decreased. The work efficiency can be improved greatly. The Characteristic of friction under the vibration working condition is described in the paper firstly. Two fundamental experiments illustrate the basic features of vibration friction. With the nonlinear dynamics and tribology of vibration friction, some key machinery is introduced in the paper briefly. The study of vibration tribology is attracting more and more interest of investigators.

Introduction

Tribology is a science investigating the interactive action mechanism of the contact surfaces between two relative motion objects. Friction and wear generally exist between two bodies or materials which have relative sliding [1, 2, and 3]. In industries, the wear and damage phenomena are so remarkable that steels and electric powers are consumed annularly.

Mostly, one object of tribology is to study the underlying friction principles. In addition, the other goal based on the first is to study and propose suitable technologies and measurements to lighten the friction and wear, so as to save energy and material consumptions. Then the economic and social benefits of the enterprise can be improved.

Many researches have proved that the dynamic characteristics of mechanical system will change obviously if vibration is applied in a friction process [4]. In this paper, friction characteristics and their applications are studied for some cases utilizing vibration. It is an essential important to study characteristics of friction with vibration.

Main Contents in the Study of Friction Vibration

Many researches have been performed and good measurements have been proposed to reduce frictions and wears. It is known that vibration is an effective way to decrease friction and increase output in some cases. Some practical demands are listed in our work as follows.

(1) Vibratory pile driver-extractor. The friction surrounding piles can be reduced by applying vibration when the piles are driven and uplifted. For example, a 1200 tonnage static pressure piler can be replaced by a 500 tonnage one with vibration.

(2) Vibratory road roller. A vibratory roller utilizes vibration to compact soil and rocks efficiently and can make the compactness degree of road surface over 95%.

(3) Vibration forming. The needed is about 10 times of that a vibration forming machine.

(4) Vibration tamping. The vibration tamping technology is widely applied in civil engineering.

(5) Vibration plastic working. It is proved experimentally that vibration can reduce the resistance of plastic working greatly.

Thus, vibration can be used effectively to reduce friction, wear and damage, and to save energy. All these are attractive to many engineers. In our research of friction vibration, the characteristic between the machine and processed material under the vibration working condition are studied and
suitable measurements are developed in order to reduce friction and wear of machines. There are three categories as follows:

1. The friction between solid materials or the inner of them under the working condition of vibration;
2. The friction in dry materials under the working condition of vibration;
3. The friction between wet solid materials and liquid under the working condition of vibration.

The friction vibration can be studied from the following aspects:

1. The interactive mechanism between the machine and workpiece utilizing of vibration;
2. The mechanism between the particles of incompact materials under vibration, which is associate with dynamics of porous materials;
3. The elastic-plastic deformation characteristics of materials under vibration, which is associate with nonlinear dynamics of system with a hysteretic force;
4. New materials with good property of higher anti-wear, which is fit for the vibration working;
5. Effective measurements that can reduce friction forces, wear and damage, and save energy;
6. New machines that can reduce friction forces between working materials and increase the flow of porous materials.

Fundamental Experiments of Vibration Friction

**Experiment 1: Sliding friction on a vibrating slope plate.** The test rig, as shown in Fig.1, consists of sliding block 1, slide plate 2, vibration experiment tester 3, front bracket 4, back bracket 5. For the mechanical model showing of Fig. 2, the classical mechanics friction work can be expressed as follows:

\[
W_c = f_s = \mu m g \cos \delta \times \frac{L}{\cos \delta} = \mu m g L. \tag{1}
\]

The friction work of the vibrating body with sliding material can be given as follows:

\[
f_m = \frac{a \cos \delta}{v a}. \tag{2}
\]

\[
W_v = f_m \times s = \frac{a \cos \delta}{v a} \times \frac{L}{\cos \delta} = \frac{a L}{v a}. \tag{3}
\]

An example is used to prove the correction of the theory. The body excitation frequency \( n = 330 \) r/min; vibration amplitudes \( \lambda = 14.5 \text{mm} \); angle of vibration \( \delta = 22^\circ \); the angle of vibration body \( \alpha_0 = 0 \); friction coefficient between the material and body \( f_0 = f = 0.95 \); the slope angle \( \mu = 43^\circ \text{40'} \). According to equations (1) and (3)

\[
W_c = \mu m g L = 0.95 m g L = 9.31 m g L. \tag{4}
\]

\[
W_v = f_m \times s = \frac{a \cos \delta}{v a} \times \frac{L}{\cos \delta} = 0.252 m v \times \frac{L}{\cos 22^\circ} = 0.271 m v L. \tag{5}
\]
Comparing equation (5) with (4), it is can be concluded that the $W_v$ is reverse proportion to the frequency $v$, and is much less than the classic friction work $W_c$. The above experiment of friction vibration shows the influence of friction under the vibration working condition.

**Experiment 2: Vibration drawing of metal specimens.** The one way to change stress and strain of low carbon steel is to draw this metal by applying vibration. On contrast to the metals drawing ordinarily with ultrasonically oscillation, the drawing of middle and low frequency vibrations (below 100Hz) is applied on metals at different vibration amplitudes and frequencies.

The diameter of standard test pieces is $\Phi=5$ mm. The gauge length is $L=60$ mm. The frequency of the experiment is kept constant of $27.70$ Hz. The amplitude is increased gradually from zero. The load-shape $P-\Delta L$ curve can be obtained. Then the stress-strain curve can be obtained from the load-shape curve. The load-shape curve and the stress-strain curve show that the yield limit $\sigma_y$ and the ultimate strength $\sigma_b$ decrease gradually with the increase of the amplitude.

The transient load, shape, stress and strain signals of the vibrating draw were registered when the deformation rate was kept constant and the frequency was 1Hz. The experiment result of intermittent vibrating draw could be obtained in different vibrating draw conditions. All the results showed that the average stress was decreased when the vibration is increased [5, 6].

**Some Successful Engineering Applications of the Characteristic of Friction Vibration**

Several kinds of construction machines and processing equipment utilizing vibration are introduced. In the working process of these machines, friction between the workpiece and material are generally present, including frictions between porous materials. Vibration roller is taken as an example firstly to illustrate the application of friction vibration.

Vibration roller is important equipment for the construction of roads, airports and dams, especially highways. The compactness degree of road utilizing the vibration roller can reach more than 95%, which cannot be achieved by a static pressure roller. Only the compactness degree of highway in more than 95%, road quality and service life can be guaranteed. The process of vibration compacting is a typical nonlinear one with elastic and plastic characteristics. The vibration compacting system is regarded as one with hysteresis.

There are many types of vibration rollers, such as single drum roller, double-drum roller, vibration roller and oscillation roller, etc. Figure 3 shows a single drum roller, which is made up of vibration wheel frame 1, vibration wheel 2, operation platform and cab 3, rear wheel 4 with rubber type, rear wheel frame 5, etc. Figure 4 shows the structure of a vibration wheel. The inertia excitors in the vibration wheel are driven by hydraulic motors and produce exciting forces acting on soils through the steel wheel. Generally the course of soil vibration compacting is typical nonlinear dynamic hysteretic course, and the hysteretic loop changes during vibration compacting process.

![Fig.3 A vibration road roller](image1)

![Fig.4 Structure of a vibration wheel](image2)

The similar application with the above vibration roller is the paver for asphalt surfaces of highway construction. The compound materials are dispersed and pressed during the paver working and moving. The pressure bars and plates work efficiently if with vibration, and can save many
compacting steps needed. In addition, there are kinds of machines including vibratory piler, vibrating compactor, vibratory cutter, vibratory stamp rig, vibrating feeder and shift, and so on.

**Conclusions and Discussion**

Up to billions of tons of ore, stone and sand are required to process annually. The requirement of energy and metal materials is enormous. We shall consider how to reduce energy consumption, wear, damage and depreciation rate. The significance cannot be underestimated.

Nowadays, many of machines using vibration theory have been developed, such as vibratory roller, vibratory piling, and vibratory crushing, and so on. These vibration machines possess higher efficiency than traditional machines. At the same time the depletion of energy and metal materials is much lower than that of conventional mechanical engineering. Therefore, it is of great significance to emphases the research of vibration equipment and friction vibration.

As vibration utilization engineering being a new rising discipline, it has inextricably link in the production of human activities and life. It has showed boundless vitality and broad prospects for development in various fields of science and technology and industrial application. Thus, it is essential to research and manufacture vibration machine in china.

Since such a kind of machine has special advantages and brings significant economic and social benefits, it has important theoretical and practical significance to do such work. Therefore, it is proposed that the friction vibration shall become one branch of tribology, and shall be list into the national basic and application research planning of this field.

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