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# Effect of Ultrasonic Vibration on Friction and Wear Properties of GCr15/45# Steel Frictional Pairs under Oil Lubrication

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**Key words:** Ultrasonic vibration, Oil lubrication, Friction and wear properties.

**Abstract.** Ultrasonic vibration friction and wear experiments were carried out by MFT-R4000 reciprocating friction and wear tester bonded with ultrasonic device. The surface morphologies of wear scars were examined by scanning electron microscope (SEM). The influences of ultrasonic vibration on friction reduction and anti-wear properties of GCr15/45# steel frictional pairs under different loads were discussed. The experimental results showed that, the friction of GCr15/45# steel frictional pairs could be reduced by ultrasonic vibration, and the reduction of friction coefficient became more obvious as the loads increasing. The friction coefficient measured under ultrasonic vibration is 12% lower than it measured without ultrasonic vibration when the load was 50N. However, the wear of frictional pairs increased under ultrasonic vibration, and the amplitude of wear volume enlarged with the loads increase, which is 63% at the load of 50N.

## Introduction

It has been found that ultrasonic vibration could influence the friction between the objects, for example, the objects on the table would optional move under vibration, and the nut became loosening due to the vibration of bolts. The cause of these phenomena is that the vibration changed the friction state of friction pairs, which lead to the decrease of friction coefficients. As is known, ultrasonic vibration is a special case of the vibration, the problem about how the ultrasonic vibration influence on friction-factor have attracted the attention of many scholars at home and abroad. Japanese scholars Maeno [1] have found that the conclusions to be consistent with test results, only when the friction coefficients of theory formula lower than the actual measured, which indicated that the friction coefficients between the rotor and stator of the ultrasonic motor (USM) has been decreased. It has been recognized that the frictional resistance could be decreased to 1/10~1/30 due to the effect of ultrasonic levitation force [2]. Ultrasonic vibration could lead the friction coefficients of metal material and non-metallic decrease rapidly, and the friction coefficient of metallic materials decreased more significantly than non-metallic materials [3].

Recently, as the studies on the effects of ultrasonic vibration on friction and wear behavior of several frictional pairs mainly focus on dry sliding condition, there were few studies on the friction and wear in Condition of ultrasonic vibration and oil lubrication. In this paper, the effects of ultrasonic vibration on friction and wear properties of GCr15/45# steel pairs in condition of oil-lubricated and different loads were investigated, and the mechanism were discussed.

## Experimental

**Experimental materials.** The upper samples used for this investigation was GCr15 steel ball with a diameter of 6mm, hardness of 770HV, and the lower samples were 45# round block steel with Φ25.4×6mm, hardness of 770HV 48~50HRC. The liquid lubricant is paraffin.

**Experiment equipments and principles.** Fig.1 gives the principles of the experiments. The ultrasonic transducer was bonded to the oil groove and the ultrasonic power lead it to generate ultrasonic vibration, so the friction experiments under the conditions of ultrasonic vibration and oil lubrication. In the test, the upper sample was fixed, the lower disc was reciprocating, and the tracks on the disks are the same diameter of 10mm. The friction and wear test were performed at the frequency of 5Hz with loads of 20N, 30N, 40N and 50N, and the ultrasonic vibration frequency was 0KHz and 40KHz. All the experiment results were the average of three times. After ultrasonic cleaning in acetone solution, the wear scars were used for wear-resistance mechanism analysis.

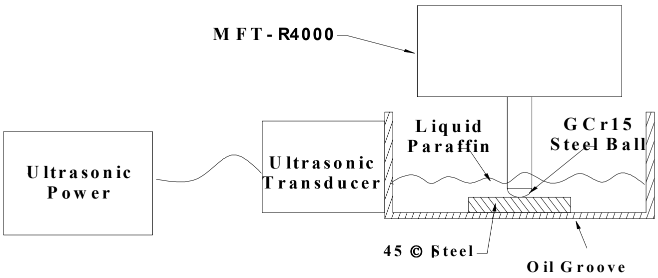



Fig. 1 The principles of friction and wear experiment under ultrasonic vibration

## Results and discussion

**Friction and wear properties.** Fig. 2 gives the friction coefficient variation with different loads in the condition of ultrasonic vibration. It is found that the friction coefficient with ultrasonic vibration was generally 2% lower than that without ultrasonic vibration at the loads of 20N. When the loads were 30N/40N/50N, the average friction coefficient with ultrasonic vibration was 9%/8%/12% lower than that without ultrasonic vibration, respectively. The ratio revealed that ultrasonic vibration has a greater effect on the friction coefficient as the load increased, due to the ultrasonic vibration could make the lower samples generate ultrasonic levitation force. And the levitation force, decreased with the distance far from the surface of lower samples [4], would reduce the pressure of upper samples. In the test, the distance between the friction pairs was far at the low load and close at high load, leading to the ultrasonic vibration under high load would have more obvious effect on friction coefficient compared with it under low load. So the ultrasonic vibration could have advantage effects on the friction coefficient, especially at high load.

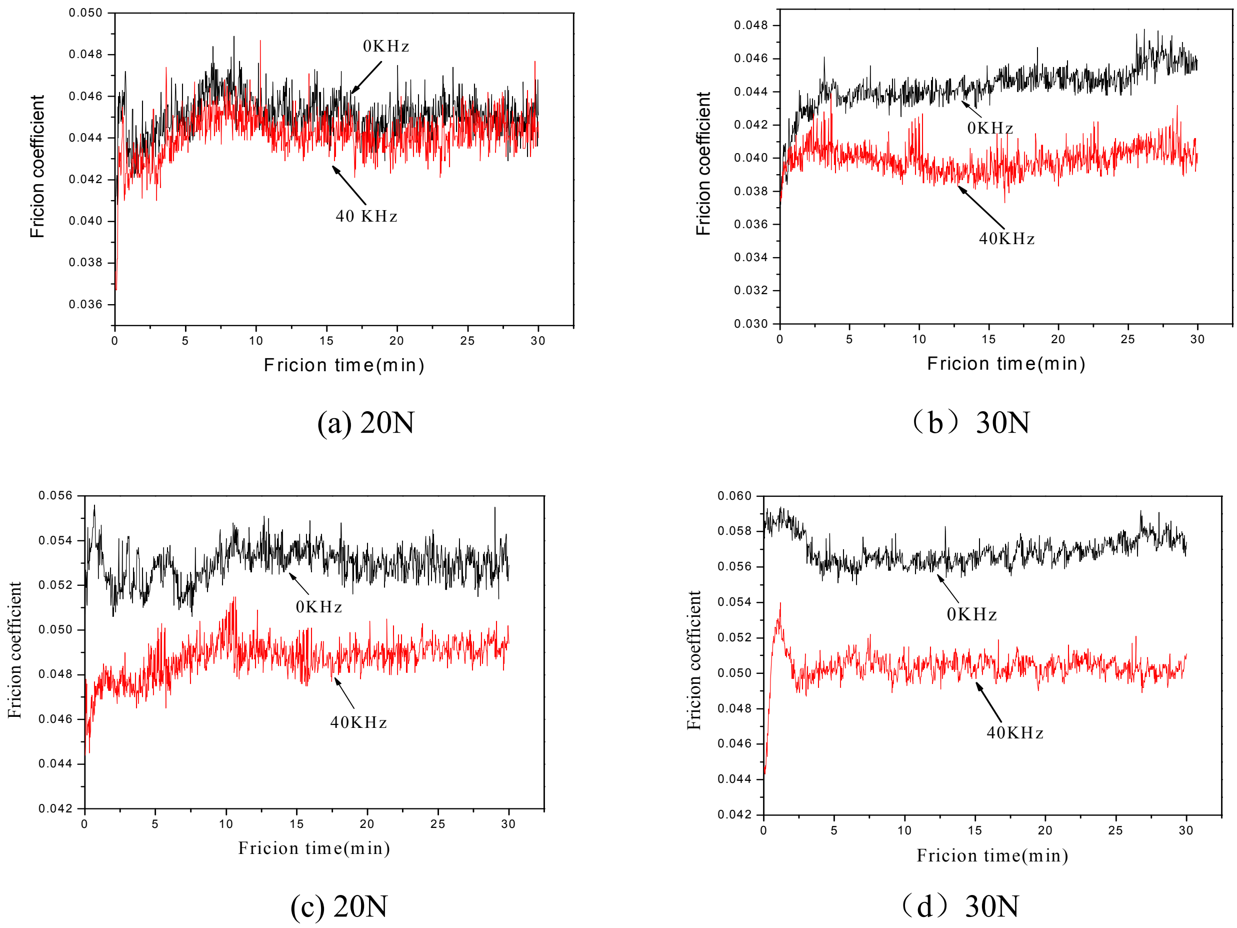



Fig. 2 Variation of the friction coefficient with different loads under the ultrasonic vibration

Fig. 3 is the variation of wear-loss with load and ultrasonic vibration, showing that the ultrasonic vibration could accelerate the wear of the frictional pairs, and the wear would be more serious with the load increased. For example, the wear volume under ultrasonic vibration was 5% and 63% higher than that without ultrasonic vibration, when the load was 20N and 50N, respectively. During the test, the particles on the surface of frictional pairs would move under ultrasonic vibration, which result in the surface strength of samples decrease significantly and the surface is sensitive to cracking. At the same time, the friction would generate some microcracks, and its expansion could be accelerated by ultrasonic vibration. Moreover, ultrasonic vibration would make the surface of the samples difficult to form a layer of oil film or the oil film easily damaged. These would make the materials peel off the surface of the samples.

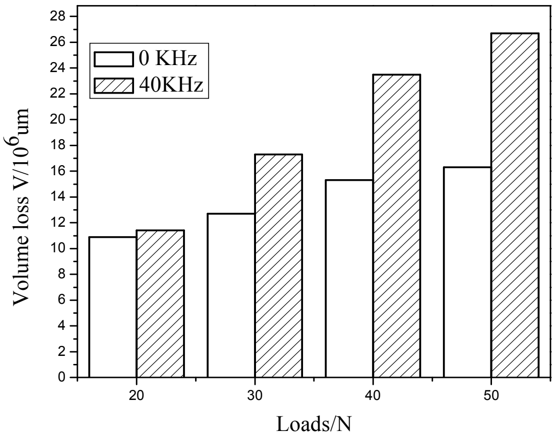
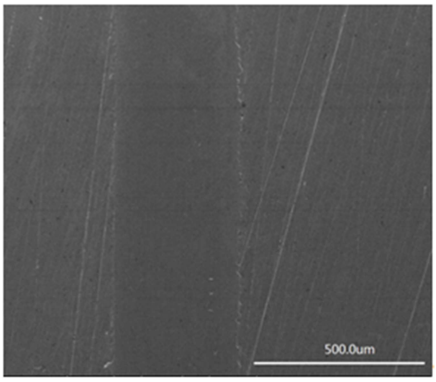


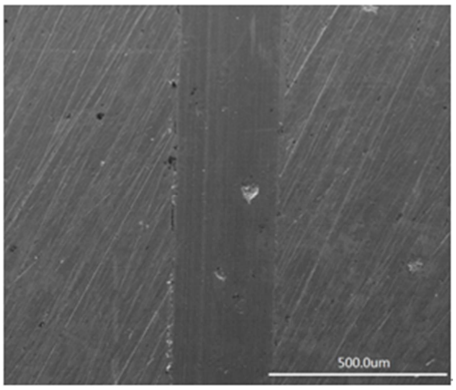

Fig. 3 Variation of the wear-loss with different loads under ultrasonic vibration

## Morphologies of worn scars

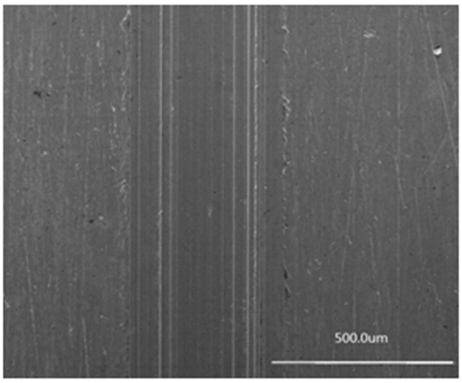
Fig. 4 gives the morphologies of wear scars at different experimental conditions. Fig. 4(a) shows that the wear scar was shallow and narrow, and its surface was smooth, there is no spalling on the worn surface, when the load was 20N and the ultrasonic vibration frequency was 0KHz. However, when the load was still 20N and the ultrasonic vibration frequency increased to 40KHz, there was a slight spalling and ploughing occurred on the worn surface of the sample (As is shown in Fig. 4(b)). Fig. 4(c) shows some spalling and ploughing occurred on the worn surface of the sample, when the load is 50N and the ultrasonic vibration frequency is 0KHz. Fig. 4(d) shows the wear scare significantly broadened and the quantity of ploughing remarkably increased compared with Fig.4(c), and a lot of spalling occurred on the worn surface due to ultrasonic vibration. The results also indicate that the ultrasonic vibration would produce an adverse effect on wear resistance of friction pairs.



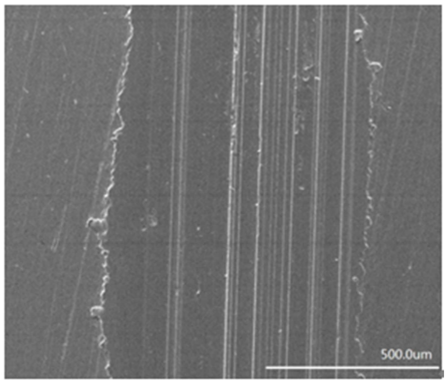

(a) 20N, 0KHz




(b) 20N, 40KHz




(c) 50N, 0KHz




(d) 50N, 40KHz

Fig. 4 Morphologies of worn scares under different experimental conditions

**Conclusions**

40KHz ultrasonic vibration frequency could reduce the friction coefficient of GCr15/45$^{\#}$ steel frictional pairs, and the reduction of friction coefficient became more obvious as the loads increasing, due to that ultrasonic vibration would make the lower samples generate ultrasonic levitation force, which lead to the pressure decrease of the sample surface, especially at high load. However, the ultrasonic vibration could aggravate the wear of friction pairs, and the wearing degree became more serious as the load increase, because that the particles on the surface of frictional pairs would vibrate under ultrasonic vibration, leading to the strength of samples surface decrease significantly and the surface sensitive to crack.

**Acknowledgments**

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