Vibration Analysis of Rotor System Under the Action of Magnetorheological Damper

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Abstract

In order to solve the vibration problem of the rotor system crossing the critical speed, the vibration problem of the rotor system is analyzed based on the extruded magnetorheological fluid damper. Firstly, analyzed the influence of different volume ratio and excitation current on the performance of MR fluid by experiment and concluded that the stiffness and damping of damper can be changed by changing the volume fraction and excitation current. Secondly, based on the principle of vibration damping, testing the value of acceleration under different current and reached the vibration of the rotor can be reduced by changing the acceleration value under different current. It provided the basis for the vibration control of the following rotor system.

Keywords

Magnetorheological damper; Rotor system; Critical speed; Vibration.

1. Introduction

With the development of the times, the rotational speed of the rotor system is getting higher and higher in the rotating machinery. However, the high speed of work will make it vibrate over When crossing critical speed, resulting fault and reducing the working life of the equipment[1]. Therefore, taking corresponding measures to control the vibration of the rotor system is still an important problem to be solved at present. In this paper, magnetorheological fluid (MRF) is used to provide variable stiffness and damping characteristics under external magnetic field [2] is applied to rotor system with squeeze magnetorheological fluid damper and analyzing vibration of rotor system by experimental method.

2. Performance Analysis of MRF

As a new type of intelligent material, MRF has been widely used in various fields of [3] and it is mainly composed of three parts: ferromagnetic particles, carrier liquid and stabilizer[4]. Hongyun Wang[5]、Tao[6] reached MRF tensile stress is about 4 times of the shear yield though experiment. So the tensile and compression properties of MRF are indirectly obtained by direct testing of the shear properties of MRF.

2.1 Effect of Volume Fraction on Properties of MRF

In order to investigate the performance of MRF under different volume fraction, made the volume fraction of MRF is 20%, 30%, and 40%, The external excitation current is 2A and used the Anton Rheometer Physica MCR 301 rheometer test platform to testing, reached the changing rules between the shear stress and the shear rate as shown in Figure 1.

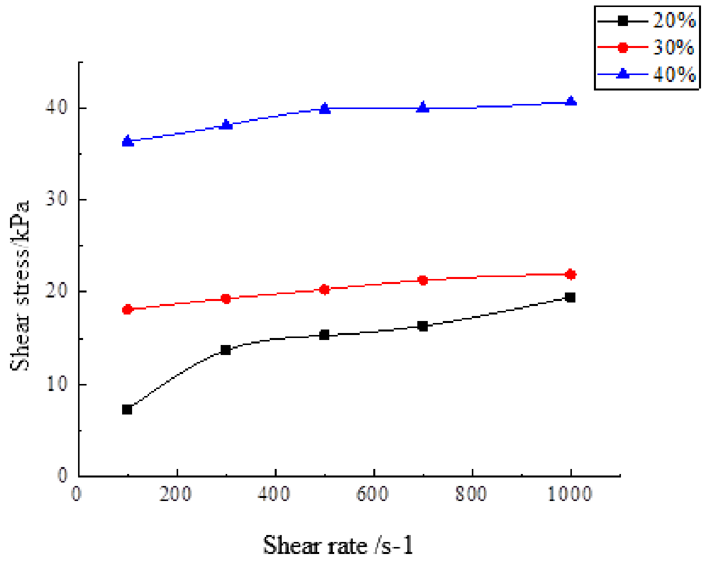


Fig1. the curve between shear stress and shear rate

From the above figure, the shear stress increases with the increase of the shear rate at the same volume fraction. When the same shear rate is set (the transverse coordinate is fixed), the shear stress increases with the increase of volume fraction. When the volume fraction is 40%, the shear stress is about 3 times that of 20%. At last, it is concluded that the shear rate has little effect on the performance of MRF, and the volume fraction has a great influence on the performance of MRF.

2.2 Effect of Excitation Current on the Performance of MRF

To explore the relationship between the external current and the performance of MRF, the volume fraction of MRF was 30%, and the set shear rate was $500s^{-1}$ in the experiment. The relationship between shear stress and exciting current is shown in Figure 2.

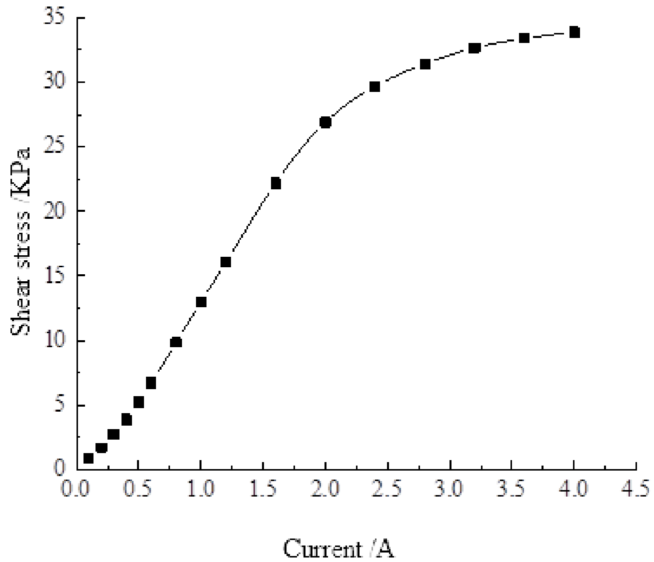


Fig 2. The variation curve of shear stress and electric current

It is known from the above diagram that when the external current is less than 2A, the shear stress of the MRF is approximately linear with the applied current. When the current is at 2A~3A, the increase of shear stress is relatively slow, and it is no longer linear. When the current is more than 3A, the increase of current has little effect on the shear stress and the shear stress tends to be stable.

3. Vibration Damping Principle Under the Action of MRF Damper

In order to explore the effect of the damper on the vibration of the rotor system, the rotor system model selected in this paper is shown in Figure 3 and structural parameters as shown in Table 1.

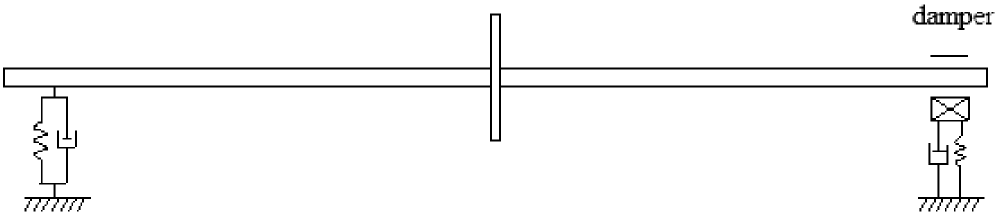


Fig 3. Simplified model of rotor system

Table 1. Related parameters of rotor system

Name	parameter
material	NO.45 steel
diameter	25mm
length	1300mm
disc diameter	170mm
disc length	10mm

Through the above analysis of the performance of MRF, it is concluded that MRF can get different stiffness and damping value under the action of external magnetic field and the vibration attenuation principle as shown in Figure 4.

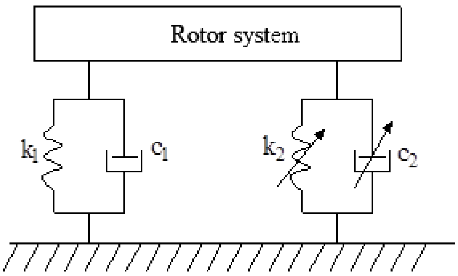


Fig 4. Single vibration principle of rotor system

In the system, the stiffness of the supporting rotor system is provided by the stiffness of the elastic rod and the stiffness of the MRF damper, that $k = k_1 + k_2$ .The damping of the supporting rotor system is also provided by the damping of the elastic rod and the damping of the MRF damper, that $c = c_1 + c_2$. The dynamic equation of the rotor system [7] is

$$m\ddot{x} + c\dot{x} + kx = me\omega^2 \cos \omega t \tag{1}$$

In which, m- the quality of the rotor and the support sleeve of the damper, kg;

c- the total damping of the rotor system, N/(m/s);

k- the total support stiffness of the rotor system, N/m.

The steady state response of a rotor system is

$$x(t) = X \cos(\omega t - \theta) \tag{2}$$

Finally, obtained the expression of the steady state response is

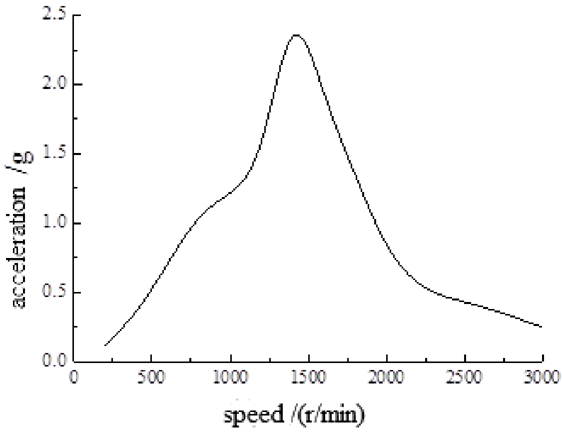
$$x(t) = \frac{me\omega^2 \cos(\omega t - \theta)}{\sqrt{(k - m\omega^2)^2 + (c\omega)^2}} \tag{3}$$

It is known from the above expression that the vibration of the rotor is influenced by the stiffness and damping of the applied support. The vibration of the rotor can be reduced by providing a reasonable stiffness and damping value to make it smooth across the resonance region.

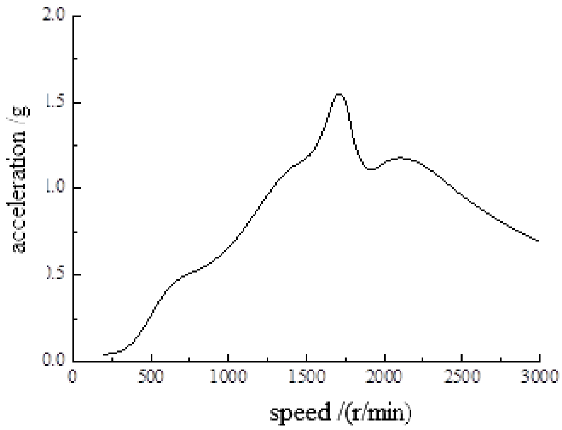
4. Experimental Test Analysis

The main purpose of the experimental test is to test the vibration of the rotor system under different parameters, thus proposed a reasonable vibration control scheme.

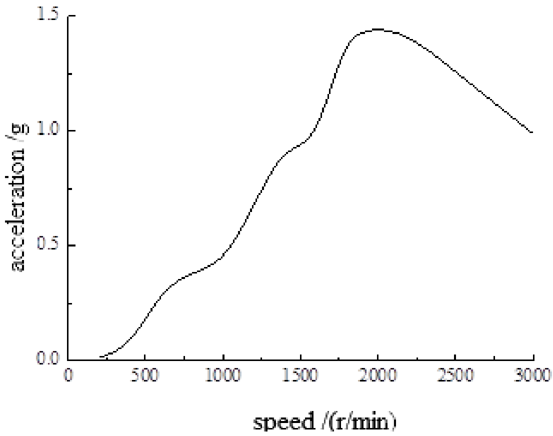
In order to control, the experiment selected MRF with volume fraction of 40%, exert the current with 0A, 2A, 4A respectively. The acceleration signal measured by the acceleration sensor is used to express the vibration of the rotor system indirectly. The curve of the acceleration is shown as shown in Figure 5.



（a）0A



（b）2A



（c）4A

Fig 5. Acceleration curve at different current

From the above diagram, we can see that under the same volume fraction, different acceleration can be obtained by introducing different current values, but the trend of acceleration increases first and then decreases (existence the maximum value). Compared with the above figure, we can see that with the increase of applied current, the maximum acceleration of the rotor system decreases correspondingly, and the corresponding working speed increases when the maximum acceleration occurs. The experimental results show that the vibration of the rotor system can be reduced by the MRF damper.

5. Conclusion

(1) The results show that the performance of MRF is influenced by the volume fraction, the external current and the shear rate. The shear stress of MRF increases with the increase of volume fraction and with the increase of the external current, it first linearly increases, then changes slowly, and finally tends to stability. The shear rate has little effect on the performance of MRF.

(2) At the same volume fraction and different current, the acceleration of the rotor system tends to increase first and then decrease (existence the strongest vibration). In addition, with the increase of applied current, the maximum acceleration of the rotor system decreases correspondingly, and the corresponding working speed increases when the maximum acceleration occurs.

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