The study of properties of metal rubber damper used in thruster

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Abstract. Developed a new type of metal rubber damper to reduce the vibration of a certain type of thruster, researched the mechanical properties of this new damper and rubber damper with experiment. The results show that: the area of protection, the static load capacity and the energy consumption of metal rubber damper are better than rubber damper, it is useful to adjust the performance of the metal rubber damper by adjusting the density, height, pre-compression and other parameters. The study provides some reference for reducing vibration of thruster with metal rubber damper.

1. Introduction

The thruster in the project application will withstand the rigors of space environment and mechanical environment, the material physical properties of the rubber damper (narrow temperature range, high and low temperature resistance) limit, has been unable to meet the long life and high bearing capacity requirements [1]. To this end, a new type of metal rubber damper is used to replace the rubber damper. According to the application requirements of the damping effect of the thruster, this paper studied the metal rubber damper and rubber damper static and dynamic characteristics and the comparison of the theoretical which approved the theoretical basis for the development of the use of the metal rubber damper.

2. Metal rubber damper installation

The metal rubber damper is composed of pressed metal rubber block with a circular cavity in the center which is arranged in the thrust ring on both sides. The screw makes some pre-compression of the metal rubber damper through the screw tightening. The installation of metal rubber damper is shown in figure 1.

From figure 1 we can see that when the thruster is subjected by axial vibration and shock, at least one damper play vibration damping function; when the thruster under radial vibration, part of the region of the two shock absorbers play a damping effect. By adjusting the bolt to control the pre-compression of the metal rubber damper and change its density and height to regulate the damping effect [2].
3. Experimental research and comparison

3.1. Static experiment contrast

In order to analyse and compare the static characteristics of the metal rubber damper and rubber damper, the two kinds of damper are tested by axial and radial static loading. The experimental results show that the hysteresis loop of metal rubber damper is obviously better than that of rubber damper. In order to strengthen the static experiment effect, by selecting the wire material, wire diameter, density, height of metal rubber to make the limit points of metal rubber damper working range and the rubber damper working range limit point as close as possible [3, 4]. According to the practical engineering experience, the effective damping range of metal rubber damper is generally within 0.7 times of the maximum deformation. That is \( A = A_{\text{max}} \) (\( A \)-metal rubber damper vibration range; \( A_{\text{max}} \)-metal rubber damper maximum deformation) [5]. The vibration amplitude of the thruster vibration damper is about 1.1mm, determine the structure parameters of metal rubber damper closest to the rubber damper hysteresis loop according to the vibration amplitude: metal rubber damper density-\( \rho = 1.679\text{g/cm}^3 \); wire diameter-\( D = 0.13\text{mm} \); pre compression-\( Y = 0.18\text{mm} \). The hysteresis loops of two types of dampers are shown in figure 2 and figure 3.

Figure 2. Axial static load hysteresis loop.
According to figure 2 and figure 3: metal rubber damper static and dynamic hysteresis loops showed obvious nonlinear characteristics; and the static and dynamic hysteresis loop of rubber damper was approximately linear, and the surrounding area was less than that of metal rubber damper hysteresis loop area surrounded. In order to characterize the damper performance, the energy dissipation coefficient was introduced [1].

\[ \Psi = \frac{\Delta S}{W} \]  
(1)

\[ W = \frac{F_{\text{max}} A_{\text{max}}}{2} \]  
(2)

Type: \( \Delta S \) - hysteresis loop area (mm\(^2\)); \( W \) - the maximum deformation energy of the metal rubber damper; \( F_{\text{max}} \) - maximum recovery force (N); \( A_{\text{max}} \) - the maximum deformation of the metal rubber damper (mm).

The experimental results show that under the same static load conditions, the energy dissipation performance of the metal rubber damper is better than that of rubber damper. At the same time, the difference of damping of the metal rubber damper in axial and radial direction is less than the rubber damper. It can be found that the stiffness ratio of metal rubber damper in the axial and radial average is about 2.89 when the deformation value is 1mm; under the same conditions, the average stiffness ratio of the rubber damper in the axial and radial is about 9.766, which is in line with the performance for damping of the rubber absorber in the radial direction. When the vibration thruster is under different direction of impact, radial resonance frequency of the rubber damper is far less than the axial resonance frequency; while the resonance frequencies of the metal rubber damper in the two directions are similar. So the resonance interval of rubber damper is far greater than the resonance interval of the metal rubber damper.

Compared with figure 2 and figure 3, it can be found that the nonlinear characteristic of the hysteresis loop of metal rubber damper is very obvious in the axial static load test while the nearly linear characteristics in the radial static load test. The reasons are that the metal rubber damper volume is compressed, the density increases, the stiffness increased rapidly with axial loading, which performance is the nonlinear characteristics of hysteresis loop; with radial loading, the metal rubber damper deforms, but the size and density changes little makes the stiffness changes little, so the hysteresis loop is near linear.

### 3.2. Dynamic experiment contrast
3.2.1. Test apparatus
The experimental device is VS-300-2 electric drive vibration system. The system mainly consists of a vibration controller, a vibration generator, a power amplifier, a charge amplifier and a sensor. The experimental principle is shown in figure 4. During the test, the acceleration sensor 7 sends an acceleration signal to the vibration controller 8, the acceleration sensor 2 and 5 collect vibration acceleration signal respectively that are on the shaker 1 and object 4 which is isolated by vibration damper 3.

![Experimental schematic](image)

1- Shaker; 2, 5, 7- Acceleration sensor; 3- Damper; 4- Object isolated; 6- Charge Amplifier; 8- Vibration controller; 9- Power Amplifier.

**Figure 4.** Experimental schematic.

3.2.2. Dynamic experiment results analysis
In order to quantify the ability of transferring vibration of the damper, the transmission rate is introduced here. Smaller transmission rate means better damping effect. Figure 5 and figure 6 show the transmission rate curves of the two shock absorbers under dynamic experiment.

\[ \eta = \frac{2\pi}{\Psi} \]  

**Figure 5.** Transmission rate curve of axial vibration load test.
Figure 6. Transmission rate curve of radial vibration load test.

Figure 5 and figure 6 show that the transmission rate of rubber damper was significantly higher than that of metal rubber damper under the axial and radial load at the resonance frequency, the transmission rate was about 3:1 in axial vibration when the transmission rate was about 4.5:1 in radial vibration, this is because the rubber damper at almost has a damping effect on radial vibration while the metal rubber damper's damping effect is similar in the axial and radial vibration. Experimental results show that the damping effect of the metal rubber damper is better than that of the rubber shock absorber in the over resonance region, the transmission rate and resonance frequency in the vibration protection zone ($\eta < 1$) are larger than those of the rubber damper.

The literature [6] pointed out that good damping system must meet the three requirements of low frequency, small transmission rate when resonance, transmission rate decreases rapidly after passing the resonance region. Figure 5 and figure 6 shows: compared with the rubber damper, the metal rubber damper can't fully meet the three requirements. In order to know the effects on the damping performance of metal rubber damper structure parameters, vibration loading experiments were finished with two different parameters of metal rubber damper, damper transmission rate curves were shown in figure 7.

Figure 7. Transmission rate curve of different structural parameters of metal rubber dampers and rubber damper load test.

Metal rubber damper1: $\rho=1.8g/cm^3, Y=0.17mm$; Metal rubber damper2: $\rho=1.5g/cm^3, Y=0.1mm$. 
It can be seen from figure 7 that the damping performance can be adjusted by adjusting the structural parameters of the metal rubber damper which can be used to achieve the ideal damping effect.

4. Conclusions
Through the experimental comparison of the metal rubber damper and rubber damper, the following 3 conclusions can be drawn.

(1) The bearing capacity, energy consumption, over critical and stability of metal rubber damper is superior to that of the rubber shock absorber.

(2) Metal rubber damper can meet the requirement of engineering application for vibration damping of thrusters.

(3) The structural parameters of metal rubber damper effect its mechanical properties; different metal rubber dampers should be designed for different vibration isolation and vibration. In addition, affected by the nature of itself, metal rubber damper cannot be fully restored to the original shape after impacted, so for the isolated object need precise positioning metal rubber damper should be carefully used.

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