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Experimental Study on the Vibration Isolation Performance of Metal-Net Rubber Vibration Absorber

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***Abstract*—**Metal-net rubber is a new dry friction damping material, compared with the traditional metal rubber, which has high mechanization degree, and the mechanical performance of metal-net rubber is more stable. Through the sine sweep experiment and random vibration experiment of metal-net rubber vibration isolator, the influence of several important factors such as the lines slope, relative density and wire diameter on the transfer rate, natural frequency and root-mean-square response acceleration of metal-net rubber vibration isolation system, were studied through the method of control variables. Also, several relevant change curves under different vibration levels were derived, and the effects of vibration level on the natural frequency and root-mean-square response acceleration were analyzed through the curves.

***Keywords*—**Metal-net rubber vibration isolator, relative density, vibration level, wire diameter.

I. Introduction

At present, a lot of research work has been carried out on the traditional metal rubber [5]-[7]. Though the dry friction of the metal wire, huge amounts of energy was consumed [1]. Meanwhile, the metal rubber has perfect adaptability in harsh environments [2]. Since it is metal material, the metal rubber had wide temperature adaptive range, high corrosion resistance, make up some defects of rubber. The metal rubber is widely used as the damping and sealing component. There is big difference between metal-net rubber and traditional metal-rubber in processing technology. Traditional metal-rubber exists in lots of manual process such as manual wrapped metal wire. It is difficult to guarantee the uniformity of the distribution of metal wire [3]. The forming process of metal-rubber has a serious influence on its mechanical stability. The processing of metal-net rubber is divided into three parts. First, metal wire was woven into metal-net by specific rules. Second process is the rolling of metal-net stripe. Final part is stamping forming with specific mold. The manufacturing process of metal-net rubber is greatly improved, which has high mechanization degree, and the mechanical properties of metal-net rubber are better.

II. The Experiment Material

The metal-net rubber used in the experiment was developed and manufactured independently by our laboratory. The schematic of specimen shape is shown in Fig. 1. A means long side length; B, short side length; D, the large inner diameter; d, small inner diameter; H_1, height of specimen; H_2, part height of the large inner diameter. Dimension parameters of specimen are shown in Table I.

Fig. 2 shows the lines slope schematic of specimen. Lines slope of 0º and Lines slope of 15º were used in this experiment. Two kinds of specimen were shown in Fig. 3.

TABLE I
Dimension Parameters Of Specimen (Unit mm)

A	B	D	d	H_1	H_2
29.2	29.2	11.0	9.0	19.0	8.5

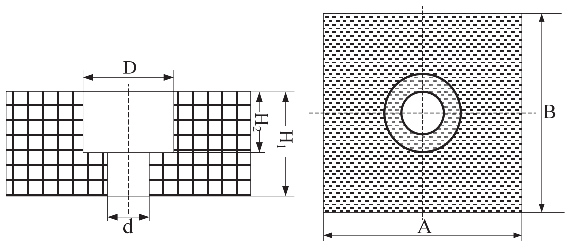


Fig. 1 Schematic of specimen shape

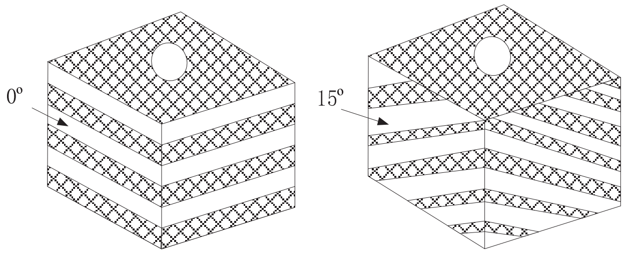
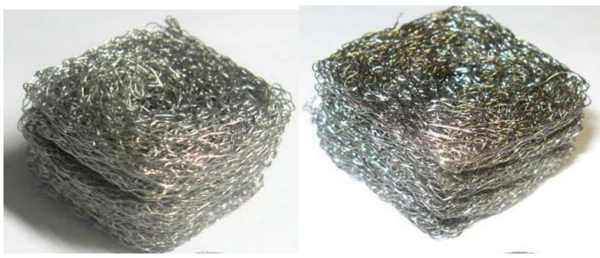


Fig. 2 Schematic of lines slope



(a) Lines slope of 0º (b) Lines slope of 15º

Fig. 3 Metal-net rubber

III. The Principle of Vibration Test

Fig. 4 is the schematic diagram of vibration experiment. Vibration experiment incentive system used in this paper is DCS-3200-36-08 system. This system adopts the international advanced technology and it has many characteristics as stable

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frequency, low total harmonic distortion and strong bearing capacity. Signal acquisition system is Vib'SYS system of BOP (Beijing Opto-Electronics Technology Co., Ltd). When testing, the relevant parameters of the test are set up in the vibration test software on the computer first. The vibration control device transmits signal to a power amplifier. The signal amplified by power amplifier is transmitted to the shaking table, then the vibration isolator can acquire steady vibration load. A piezoelectric acceleration sensor is placed on the vibration isolator. And the vibration table is used to measure acceleration response. Vibration control device and signal acquisition instrument are connected with the computer. Then test data can be measured and stored through the computer.

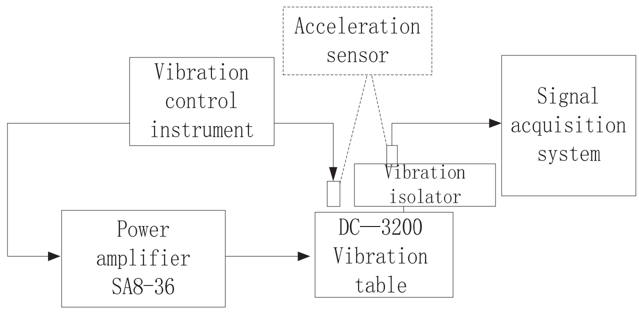

Fig. 4 Schematic diagram of vibration experiment

IV. The Result of the Sine Sweep Experiment

In the sine sweep experiment, the transfer rate of acceleration is used as the character of transformation of vibration isolator. Acceleration sensor was used to collect signal. The ratio of output acceleration and input acceleration was used as the transfer rate [4].

$$\eta = \frac{a_{out}}{a_{in}} \tag{1}$$

a_{out} is the output acceleration, a_{in} is the input acceleration.

The range of the sine sweep experiment is 5-400 Hz. The shaking table is mainly controlled by acceleration; since the input acceleration is constant. In the early stage, the vibration is controlled by displacement. When the acceleration reached the certain value, the vibration is controlled by acceleration. Through the sine sweep experiment with the vibration levels of 1g-5 g, we studied the influence of relative density and wire diameter effect on the transfer rate, natural frequency. The compression amount has a great effect in the compression mechanical properties

A. The Lines Slope Effect in the Transfer Rate and Natural Frequency

Parameters of specimens under different lines slope are shown in Table II. Fig. 5 is transfer rate-frequency curve of different lines slope when vibration test level is 2 g. As shown in Fig. 5, transfer rate-frequency curve under 0º lines slope is on the left and the peak of transfer rate is lower than the curve under 15º lines slope. So, vibration isolation performance under 0º lines slope is better. Fig. 6 is relationship between natural frequency and vibration level under different lines slope. As seen in the figure, the natural frequency of the vibration isolator not changed so much with the increase of the test level. The natural frequency of the vibration isolator with 0º lines slope is obviously lower than the vibration isolator with 15º lines slope. Since the increasing of lines slope increases the natural frequency and the stiffness of the metal-net rubbers, we can increase lines slope from 0 to 15 to increase the natural frequency and the stiffness of the metal-net rubbers.

TABLE II
Parameters of Specimens under Different Lines Slope

Lines slope	Relative density	Wire diameter (mm)
0º	0.20	0.20
15º	0.20	0.20

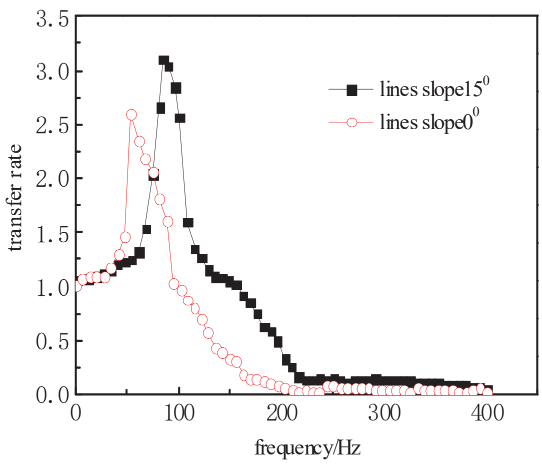

Fig. 5 Transfer rate-frequency curve of different lines slope

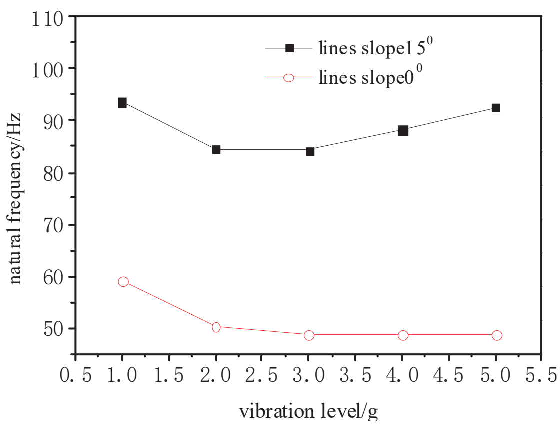

Fig. 6 Relationship between natural frequency and vibration level under different lines slope

B. The Relative Density Effect in the Transfer Rate and Natural Frequency

The metal-net rubber specific parameters under different relative densities are shown as Table III. Transfer rate-frequency curve of different relative densities is shown in Fig. 7. As seen in the figure, when relative density is 0.18, the metal-net rubber is under the soft characteristics stage, the peak transfer rate is small, As the relative density increasing, the hard characteristics of the metal-net rubber significantly enhanced. The transfer rate-frequency curve moves to the right. The peak transfer rate boosts. Natural frequency-vibration level curve with different relative densities is shown in Fig. 8. With the increase of relative density, the natural frequency improves. The reason is that the stiffness is boosts sharply with the relative density improving. And the natural frequency keeps constant.

TABLE III
PARAMETERS OF SPECIMENS UNDER DIFFERENT RELATIVE DENSITIES

Relative density	Iines slope	Wire diameter (mm)
0.18	15º	0.20
0.20	15º	0.20
0.25	15º	0.20

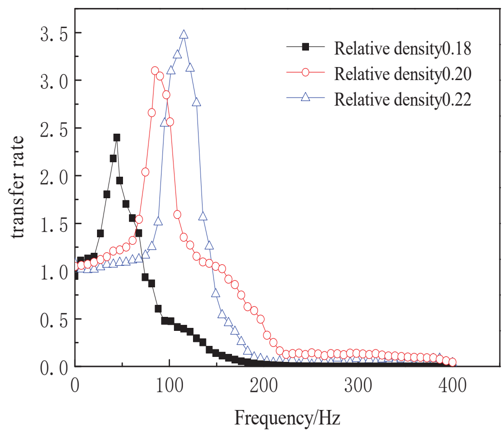

Fig. 7 Transfer rate-frequency curve of different relative densities

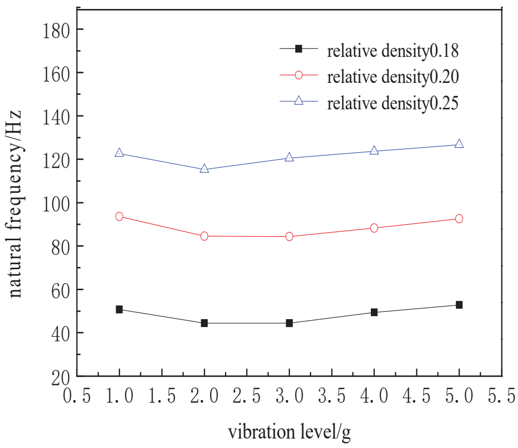

Fig. 8 Relationship between natural frequency and vibration v level under different relative densities

C. The Wire Diameter Effect in the Transfer Rate and Natural Frequency

The metal-net rubber specific parameters under different wire diameters are shown as Table IV. Transfer rate-frequency curve of different wire diameters is shown in Fig. 9. As the wire diameter increasing, the transfer rate-frequency curve moves to the right. The peak transfer rate improves gradually. The result shows that the vibration isolation performance significantly reduces. Natural frequency-vibration level curve with different wire diameters is shown in Fig. 8. With the increase of wire diameter, the natural frequency improves, the flexural rigidity increases, the stiffness of metal-net rubber grows, which can lead to the increasing of natural frequency.

TABLE IV
PARAMETERS OF SPECIMENS UNDER DIFFERENT WIRE DIAMETERS

Wire diameter (mm)	Relative density	Iines slope
0.10	0.20	15º
0.15	0.20	15º
0.20	0.20	15º

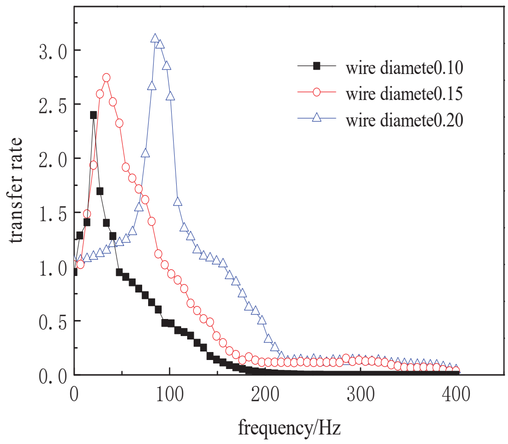

Fig. 9 Transfer rate-frequency curve of different wire diameters

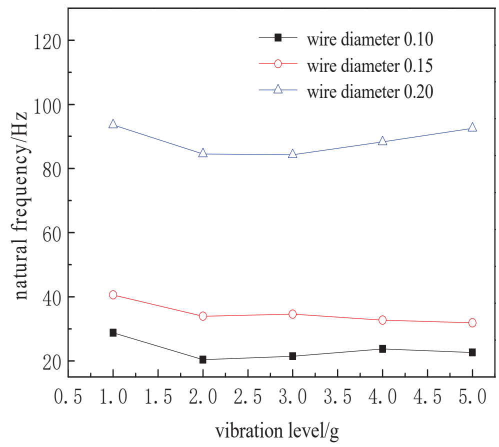

Fig. 10 Relationship between natural frequency and vibration level under different wire diameters

V. THE RESULT AND ANALYSIS OF THE RANDOM EXPERIMENT

In this paper, the average control method is adopted in the random vibration test. It has a monitoring channel and a control channel. As shown in Fig. 11, power spectral density of the input acceleration can be divided into three stages. The ascending slope is 6 dB/oct, the decreasing slope is -6 dB/oct, the frequency range of random vibration is 10-2000 Hz, the initial power spectral density is 10-2000 Hz and in the flat spectrum stage power spectral density is ω_0 . Power spectral density of random vibration are shown in Table V.

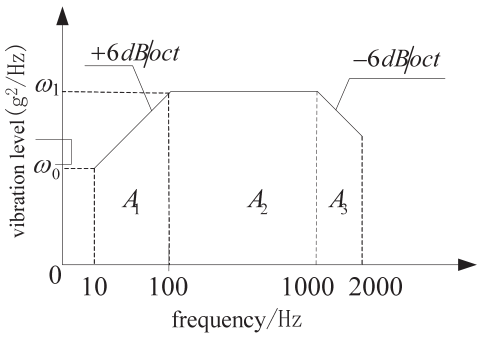

Fig. 11 The test control spectrum of Random vibration

TABLE V
POWER SPECTRAL DENSITY OF RANDOM VIBRATION

Vibration level	ω_0(g²/Hz)	ω_1(g²/Hz)
5g	0.01743	0.44
8g	0.04461	1.12
10g	0.06971	1.74
12g	0.1004	2.51

A. The Lines Slope Effect in the Root-Mean-Square Response Acceleration

The root-mean-square response acceleration-vibration level curve of under different relative densities is shown in Fig. 13. As the relative densities increasing, the root-mean-square response acceleration improves gradually. The vibration isolation performance significantly reduces and root-mean-square response acceleration increases linearly with the growing of vibration level.

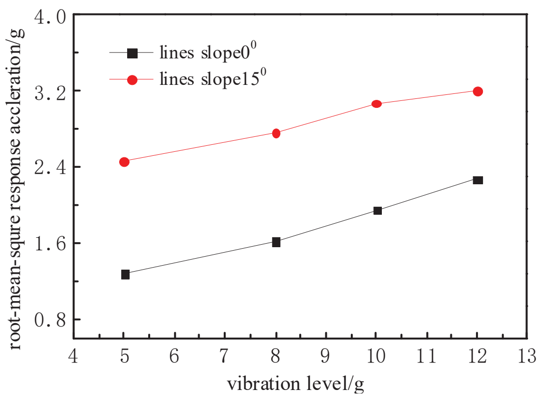

Fig. 12 Relationship between root-mean-square response acceleration and vibration level under different lines slope

B. The Relative Density Effect in the Root-Mean-Square Response Acceleration

The root-mean-square response acceleration-vibration level curve with different relative densities is shown in Fig. 13. As the relative densities increases, the root-mean-square response acceleration rises, the vibration isolation performance declines. Root-mean-square response acceleration increases linearly with the growing of vibration level.

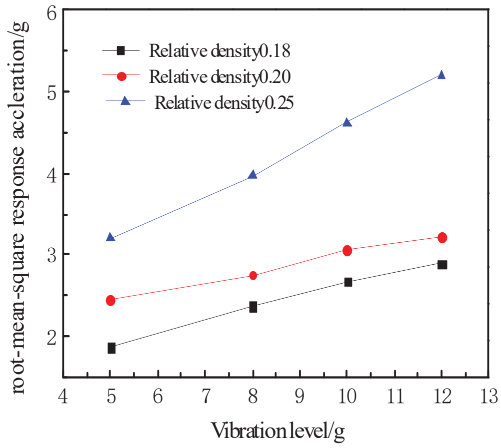

Fig. 13 Relationship between root-mean-square response acceleration and vibration level under different relative densities

C. The Lines Slope Effect in the Root-Mean-Square Response Acceleration

The root-mean-square response acceleration-vibration level curve of under different wire diameters is shown in Fig. 14. As the wire diameter increases, the root-mean-square response acceleration grows, the vibration isolation performance descends.

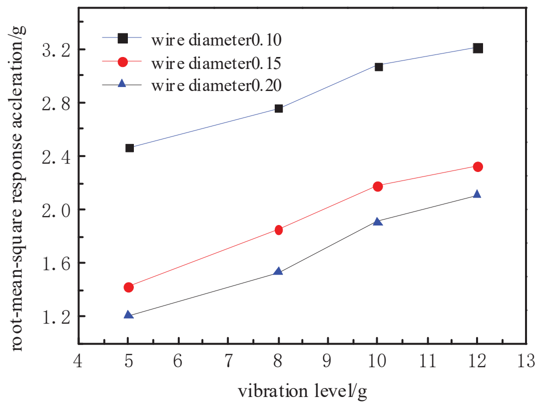

Fig. 14 Relationship between root-mean-square response acceleration and vibration level under different wire diameters

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