Research on mechanical properties of metal rubber based on planar lattice design

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Abstract. Metal rubber is a common vibration is olation material. Because the arrangement of the internal spiral coil will affect the mechanical properties of the metal rubber, this paper draws on the crystal lattice theory in metallurgy, changes the mesoscopic arrangement of the spiral coil through the design of the two-dimensional blank plane lattice structure, and prepares three kinds of lattice structures, and optimizes the mass ratio of the three metal rubber lattice structures, so as to improve the average stiffness and energy dissipation coefficient of the metal rubber. The quasi-static compression experiments passed. The results show that the triangular lattice structure design can reflect the good average stiffness, and the square lattice structure design can obtain the maximum energy dissipation coefficient. The study confirms that the fabrication of metal rubber materials based on planar lattice design is an effective way to improve stiffness and energy dissipation.

Keywords: Metal rubber, Planar lattice, Mass ratio, Lattice structure, Energy dissipation coefficient.

1. Introduction

As a vibration isolation material, metal rubber has a wide range of applications in the field of vibration isolation in the petroleum industry [1-2]. The mechanical properties of the spiral coil in the metal rubber are complex, so its mechanical properties depend on the arrangement of the spiral coil [3]. Huang Kai [4] designed an automatic layup equipment to change the hooking method between the spiral coils, Xia Yuhong [5] studied the influence of the direction of the spiral coil on the properties of metal rubber components, and Hu Jialin [6] prepared an experiment of multi-metal wire rubber materials. Dong Wanyuan [7]. compared the compression characteristics of wire mesh and metal rubber materials. Li Jingfei [8]. Wang Yuanjing [9] designed a gradient porous alloy material to study the influence of gradient structure on compressive properties. Yang Zeling [10] improved the compressive performance of the material by optimizing the gradient topology of the lattice structure. Ren Xiaoyu [11] studied the effects of various lattice structures on the mechanical properties of porous materials. In view of this, this paper draws on the lattice theory of metallurgical crystals [12] to design different types of two-dimensional planar lattices, and proposes a method of mass ratio of lattice structures to achieve an effective way to improve the stiffness and energy dissipation performance.

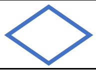
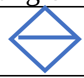
2. Flat lattice design scheme

In this chapt, austenitic stainless steel wire with a wire diameter of 0.2mm is selected, and the wire is wound into a spiral coil with a diameter of 2mm by a wire winding machine, and is stretched to a constant pitch of 2mm by equidistant stretching.

2.1. Research on the topological relationship of stamping and forming

Table 1 shows the three lattice types designed according to the planar lattice structure, and only the smallest repeating unit is required to describe the geometric features of each lattice.

Table 1. Planar lattice scheme

lattice type	square	lozenge	triangle
Symbol			
numbering	1	2	3
lattice structure	α	β	γ

2.2. Cold press forming

The metal rubber blank is put into the inner cavity of the mold for stamping and forming. The basic parameters of the metal rubber specimen: the relative density is 0.2, the size is a cylindrical specimen with a height of 10mm, and the inner and outer diameters are 10mm and 30mm respectively.

3. Performance parameters

The ratio of the maximum load to the deformation amplitude is the average stiffness:

$$K = \frac{F_{\max}}{X_{\max}} \tag{1}$$

F_{max} is the recovery force at the maximum deformation, X_{max} is the deformation amplitude.

Energy dissipation coefficient η is an important parameter to measure the shock bsorption performance of metal rubber:

$$\eta = \frac{\Delta W}{W} \tag{2}$$

ΔW is a cyclic loss of energy; W is the maximum variable situational energy.

4. Test Method

4.1. Test equipment

During the quasi-static loading and unloading test, a pre-compression force of 20N is added to the test block, the loading and unloading rate is controlled to be 1mm/min, the loading direction is consistent with the force direction of the specimen when it is cold-pressed and formed, and the test data are processed for many times in the range of 0mm ~ 3mm.

4.2. Quasi-static compression test

The results of the quasi-static compression test of the metal rubber with three planar lattice structures are shown in Fig 4. It can be seen that there are obvious differences in the hysteresis curves of the metal rubber with the three planar lattice structures under the same loading conditions. Among the three kinds of lattice metal rubber, the bearing capacity of metal rubber specimen 1 is the smallest, the bearing capacity of specimen 2 is centered, and the bearing capacity of specimen 3 is the largest.

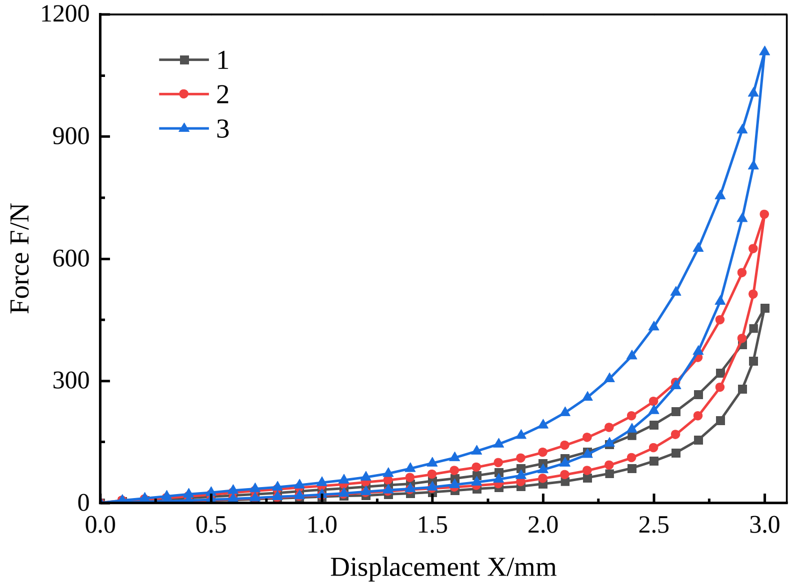


Figure 1. Metal rubber force-displacement curve under different dot matrix structures

As can be seen from Fig. 1, the stiffness of the metal rubber is the largest in the γ lattice structure, and the stiffness is the smallest in the α lattice structure. The lattice structure is able to change the stiffness characteristics of the metal rubber.

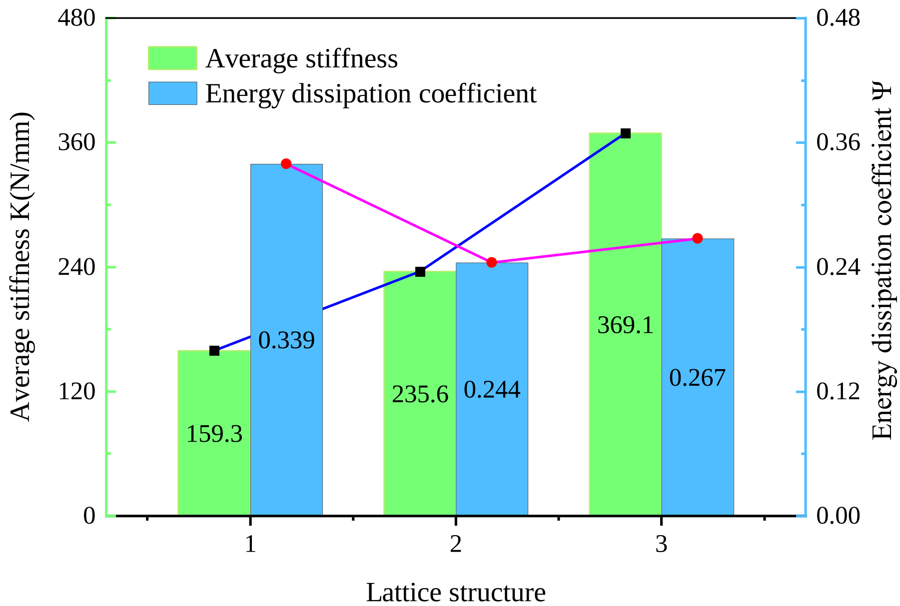


Figure 2. Lattice structure-average stiffness and energy dissipation coefficient

As can be seen in Fig 2, α lattice structure has the best energy dissipation capacity, and β lattice structure has the worst energy dissipation capacity. This is due to the fact that the metal rubber wires α lattice structure are sparsely spaced and have the least stiffness, resulting in the largest energy dissipation coefficient. Compared with the β lattice structure, the γ lattice structure has more adequate contact with the wire, so under the same compression, the energy consumption of the metal rubber cancels the maximum elastic energy storage increment, so the energy dissipation coefficient is greater than that of the β lattice structure.

5. Tests of mass ratio of different lattice structures

5.1. Mass ratio scheme of different lattice structures

In some cases, both good load-bearing capacity and excellent energy dissipation capacity are required. Therefore, a method of mass ratio of different lattice structures is proposed to study its mechanical properties, and the test scheme is shown in Table 2, 3, 4.

Table 2. α-β lattice structure mass ratio scheme

numbering	1	4	5	6	2
Lattice structure	α	α/β	α/β	α/β	β
Mass ratio	1	2	1	0.5	1

Table 3. α-γ lattice structure mass ratio scheme

numbering	1	7	8	9	3
Lattice structure	α	α/γ	α/γ	α/γ	γ
Mass ratio	1	2	1	0.5	1

Table 4. β-γ lattice structure mass ratio scheme

numbering	2	10	11	12	3
Lattice structure	β	β/γ	β/γ	β/γ	γ
Mass ratio	1	2	1	0.5	1

5.2. Quasi-static compression test of metal rubber with different mass ratios

Compression test was performed on Table 2, 3, 4, is shown in Fig 3. As can be seen in Figure (a), all the metal rubber prepared from the α lattice is at the bottom, all the metal rubber prepared from the γ lattice is at the top, With the increase of the mass ratio of the lattice structure of the β, The load-bearing capacity of the metal rubber is also increased.

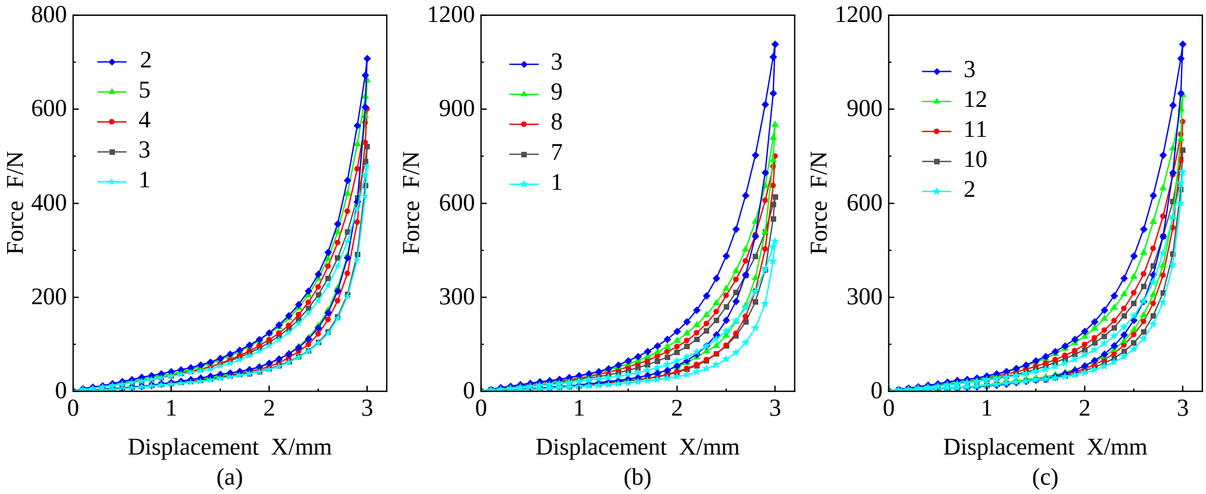


Figure 3. Force-displacement curves of metal rubber under the mass ratio of lattice structure

As can be seen in Fig. (b), all the metal rubber prepared from the α lattice is at the bottom, all the metal rubber prepared from the γ lattice is at the top, the apex of the γ lattice increases, and the bearing capacity of the metal rubber increases.As can be seen in Figure (c), all the metal rubber prepared from the β lattice is at the bottom; all the metal rubber prepared from the γ lattice is at the top, the apex of the γ lattice increases, and the bearing capacity of the metal rubber increases.

(1) Effect on average stiffness

Fig 4 shows the average stiffness curve, and it can be seen from Fig. (a) that in the mass ratio of α-β, with the increase of the mass of the lattice structure of the β, the stiffness of the metal rubber also increases. As can be seen from Figure (b), in the mass ratio of α-γ, with the increase of the mass of the γ lattice structure. Figure (c) Similarly.

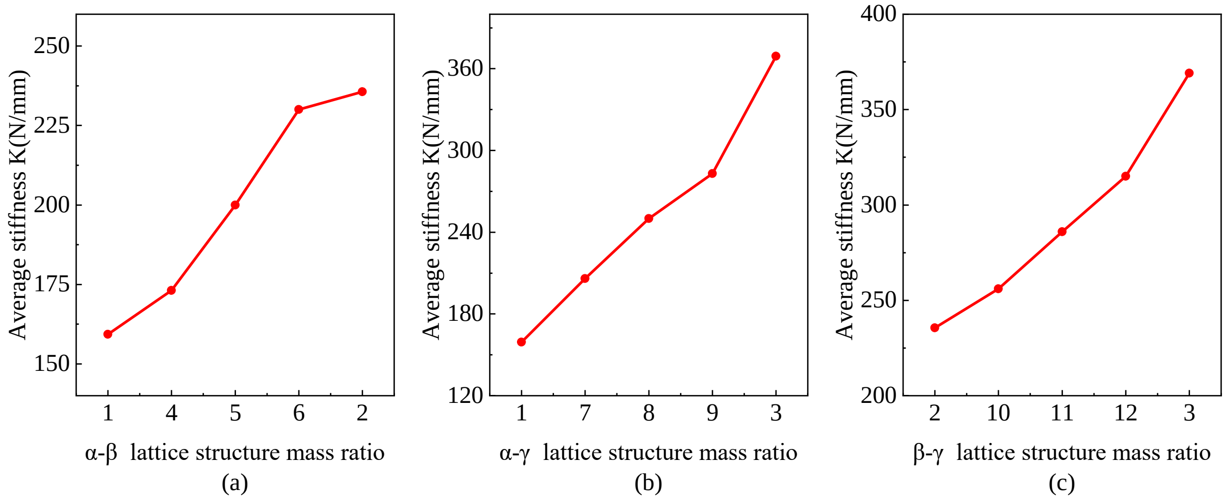


Figure 4. Mass ratio-average stiffness of lattice structure

(2) Effect on the energy dissipation coefficient

It can be seen from Fig. 5(a) that in the mass ratio of α-β, with the increase of the mass of the β lattice structure, the energy dissipation coefficient of the metal rubber gradually decreases, indicating that with the increase of the β-mass ratio, its stiffness increases significantly, resulting in the maximum elastic energy storage of the material offsetting the increase of energy consumption, and the loss factor gradually decreasing. It can be seen from Fig. (b) that in the mass ratio of α-γ, with the increase of the mass of the lattice structure of the γ, the energy dissipation coefficient of the metal rubber decreases first and then increases, indicating that with the increase of the mass ratio of the γ lattice structure, its energy consumption increment is less than the maximum elastic energy storage increment, and γ the lattice structure further increases, its energy consumption increment is greater than the maximum elastic energy storage increment.

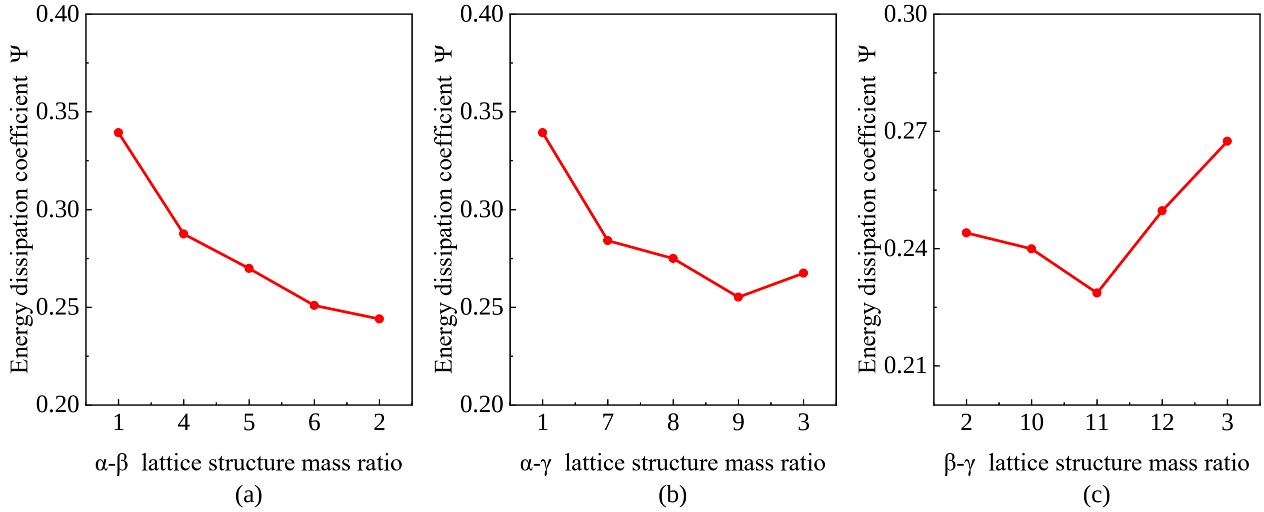


Figure 5. Mass ratio-energy dissipation coefficient of lattice structure

It can be seen from Figure (c) that in the β-γ mass ratio, with the increase of the mass of the γ lattice structure, the energy dissipation coefficient of the metal rubber decreases first and then increases, indicating that when the mass of the lattice γ the metal rubber is less than β, its maximum elastic energy storage offsets the increase of energy consumption, and when the γ lattice mass is greater than β, the increase of its maximum elastic energy storage is less than the increase of energy consumption.

6. Summary

I By designing different types of two-dimensional blank planar lattices, the internal lattice structure of the metal rubber is guaranteed to remain unchanged during cold pressing, so as to maintain stable mechanical properties. Among the three lattice structures based on the planar lattice design, the metal rubber of the triangular lattice structure has the best stiffness. In order to ensure that the stiffness and energy dissipation performance are improved at the same time, the combination of mass ratios of different lattice designs achieves excellent energy dissipation capacity when meeting the stiffness requirements.

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