Analysis of Vibration Characteristics of the Cylindrical Shell Filled With the New Type of Lattice

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Abstract. Using the method of finite element simulation, we study the cylindrical shell filled with new lattice with vibration in the working environment. The effect of the radius of the rod and the thickness of the ring on the natural mode shape of the lattice-filled cylindrical shell is analyzed. The results show that the change of the rod radius and the ring thickness can change the natural vibration mode of the cylindrical shell, in which the rod radius has greater influence and better effect. The research results have guiding significance for the use of cylindrical shell filled with this new type of lattice.

1. Introduction

The three-dimensional lattice material is a new kind of lightweight material that was developed at the beginning of this century and consists of ordered spatial lattices. It has the multi-functional characteristics of porous materials, and also has good bearing capacity, which fully embodies the material-structure-functional integrated design concept, and provides a way for diversified design to achieve different functions and application requirements. The lattice structure is applied to the cylindrical shell is a typical example. During the use of the lattice-filled cylindrical shell, resonance may occur due to the influence of the external vibration environment. Therefore, the vibration issue of the lattice-filled cylindrical shell is receiving more and more attention.

The vibration of the cylindrical shell has important applications in the field of engineering, which have been discussed by many researchers. Leissa [1] has a detailed review of the vibration of cylindrical shells. There are also many researchers who use wave method to analyze and study the cylindrical shells. For example, Wang [2] and Zhang [3] used wave method to study the natural frequency of a finite-length cylindrical shell. Zhao [4] used the energy method to calculate the vibration frequency of the vertical and horizontal stiffened composite cylindrical shell, and discussed the influence of the parameters' change of the stiffened structural on the vibration. Chen Liming [5] analyzed that the lattice sandwich cylindrical shell has better mechanical properties than the traditional honeycomb one.

A new type of lattice has been designed for the large temperature change in the working environment [6], which can use the geometric relations to achieve low/zero thermal expansion, in the vertical direction when temperature changes greatly. The cylindrical shell filled with this kind of lattice can achieve low/zero thermal expansion in the vertical direction when the temperature changes greatly. In this paper, the cylindrical shells filled with low/zero thermal expansion lattices are modeled

and analyzed by ANSYS. The influence of the lattice parameter on the mode of the lattice-filled cylindrical shell is studied to provide guidance for the application of the lattice material.

2. Three-dimensional model

The lattice cell is shown in Figure 1a). Figure 1b) is cylindrical shell filled with the new type of lattice. Figure 1c) is a partial enlarged view of cylindrical shell filled with the new type of lattice.
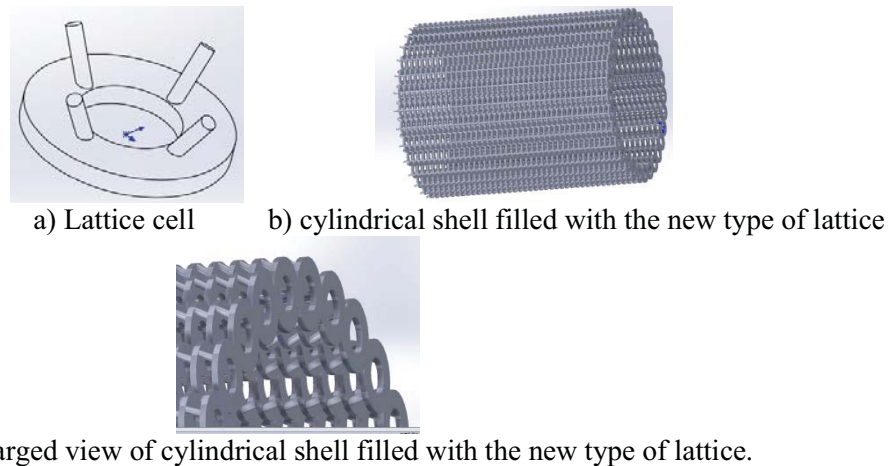

a) Lattice cell   b) cylindrical shell filled with the new type of lattice

c) Partial enlarged view of cylindrical shell filled with the new type of lattice.

Figure 1. Lattice structure.

The cylindrical shell filled with the new type of lattice is used in aerospace components requiring high precision. In the process of use, the vibration of the environment will also affect the accuracy of the cylindrical shell, which is solved by studying the vibration characteristics of the cylindrical shell filled with the lattice.

The total length of the lattice-filled cylindrical shell studied in this paper L=100mm, Outside diameter D_1=78mm, inside diameter D_2=62mm; the annular outer diameter of the lattice cell d_1=8mm, inside diameter d_2=4mm, the angle of inclination of the rod θ=48°. The applied software is ANSYS Workbench, the material is Stainless Steel, the elastic modulus E is 193GPa, the Poisson's ratio is 0.31, and the density is 7750kg/m^3. This paper studies the vibration of the lattice-filled cylindrical shell with one fixed end and one free end. The diameter of the inner ring of the cell, the size of the outer diameter and the inclination angle of the rod are kept unchanged. The influence of the changes of the ring thickness and the rod radius on the first three orders mode of the cylindrical shell is studied.

3. Effect of lattice parameters on vibration characteristics of cylindrical shells

3.1. Effect of Ring Thickness on the Mode of the Lattice-Filled Cylindrical Shell

Keeping the rod radius (r=4mm) constant, changing the ring thickness, the values are respectively 6mm/7mm/8mm/9mm/10mm/11mm/12mm. Table 1a) shows the effect of the ring thickness on the first three natural frequencies of the cylindrical shell; Table 1b) shows the effect of the ring thickness on the deformation of cylindrical shell in the first three orders resonance.

Table 1a). The first three natural frequencies of the cylindrical shell at different ring thicknesses.

Ring thickness /mm	6	7	8	9	10	11	12
First-order frequency /Hz	993.02	1048.2	1060.6	1108.6	1119.2	1154.4	1176.6
Second-order frequency /Hz	995.54	1049.8	1061.8	1109	1119.9	1154.8	1177.3
Third-order frequency /Hz	1532.5	1666.2	1712	1756.4	1771.9	1773.5	1791.4

Table 1b). The first three resonance maximum deformation of cylindrical shell at different ring thicknesses.

Ring thickness /mm	6	7	8	9	10	11	12
First-order deformation /mm	1.071	1.048	1.036	0.991	0.950	0.915	0.881
Second-order deformation /mm	1.070	1.048	1.036	0.990	0.951	0.915	0.882
Third-order deformation /mm	1.065	1.016	1.020	1.394	1.328	1.280	1.229

It can be seen that In terms of natural frequency, which gradually increases with the ring thickness. With the increase in the thickness of the ring (6 to 12mm), the first three orders' frequency increased by 18.5%, 18.3%, and 16.9% respectively. In terms of maximum resonance deformation, which changes with the increase of the ring thickness, with the increase of the ring thickness (6~12mm), the first three orders' maximum deformation decreased by 17.7%, 17.6%, and -13.3% respectively.

3.2. The Influence of the Rod Radius on the Mode of the Lattice-Filled Cylindrical Shell
Keeping the thickness of the ring (h=8mm) constant, changing the Rod Radius, the value is respectively 3.0mm/3.5mm/4.0mm/4.5mm/5.0mm/5.5mm/6.0mm. Table 2a) shows the effect of the Rod Radius on the first three natural frequencies of the cylindrical shell; Table 2b) shows the effect of the Rod Radius on the deformation of the cylindrical shell in the first three orders' resonance.

Table 2a). The first three natural frequencies of the cylindrical shell at different Rod Radius.

Rod radius/mm	3.0	3.5	4.0	4.5	5.0	5.5	6.0
First-order frequency /Hz	858.08	996.78	1090	1221.1	1247	1451.2	1458.5
Second-order frequency /Hz	858.52	997.57	1090.8	1223.4	1250.3	1452.3	1461.8
Third-order frequency /Hz	1410.4	1624.3	1734.4	1805	1752.4	1824.9	1815.4

Table 2b). The first three resonance maximum deformation of cylindrical shell at different Rod Radius.

Rod radius /mm	3.0	3.5	4.0	4.5	5.0	5.5	6.0
First-order deformation /mm	1.022	1.005	0.987	0.970	0.932	0.934	0.733
Second-order deformation /mm	1.022	1.005	0.987	0.970	0.933	0.933	0.730
Third-order deformation /mm	0.970	0.996	0.955	1.357	1.318	1.307	0.939

It can be seen that in terms of the natural frequency, which increases with the increase of the rod radius as the rod radius increases from 3.0mm to 6.0mm. The first three orders' frequencies increased by 70.0%, 70.2%, and 28.7%, respectively. The maximum resonance deformation decreased by 28.3%, 28.6%, and 3.2%, respectively. It can be seen that the radius rod has a great influence on the maximum resonance deformation of the lattice-filled cylindrical shell, and at the same time, the degree of influence on the various orders differs greatly.
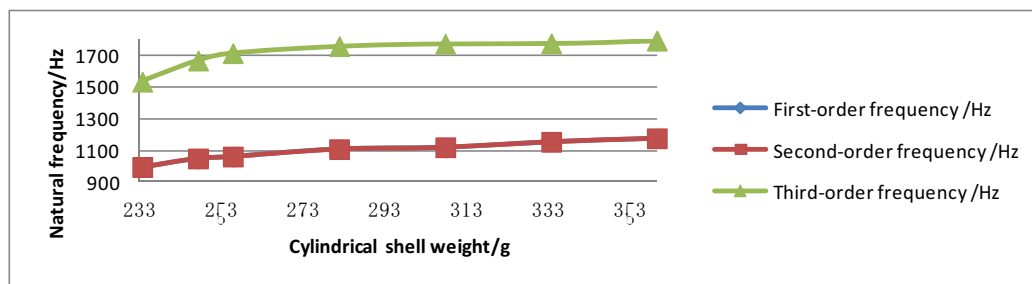
3.3. Relationship between mass and mode of the cylindrical shell under different parameters
Table 3 shows the effect of different lattice parameters on the quality of lattice-filled cylindrical shells. As the Ring thickness increases by two times, the cylinder mass increased by 53.9%; as the rod radius increased by two times, the cylinder shell mass increases by 33.0%.
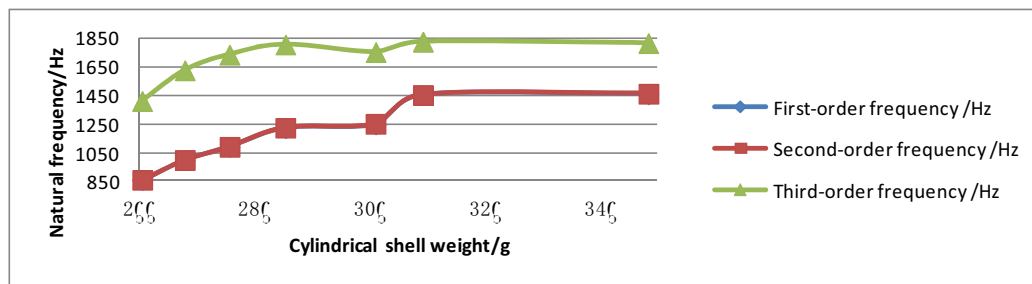
Table 3. Total mass of the cylindrical shell under different lattice parameters.

r=4mm	h/mm	6	7	8	9	10	11	12
	M/g	233.75	247.42	255.92	281.97	307.95	333.91	359.77
h=8mm	r/mm	3.0	3.5	4.0	4.5	5.0	5.5	6.0
	M/g	266.51	273.91	281.67	291.38	307.04	315.25	354.38

Figure 2 shows the relationship between cylinder mass and natural frequency when the ring thickness and the rod radius are changed respectively.

a). Effect of mass on natural frequency when changing ring thickness

b). The effect of mass on the natural frequency when changing the rod radius

Figure 2. Relationship between quality and frequency under different parameters.

It can be seen from the Figure that changing the ring thickness can change the natural frequency of the cylindrical shell slowly and affect the frequency of each order similarly.

Figure 2 shows the relationship between the mass and the resonant maximum deformation of the cylindrical shell when the ring thickness and the rod radius are changed respectively. The radius of the rod has greater influence on the natural frequency of the lattice-filled cylindrical shell. Changing the rod radius can obviously change the natural frequency of the cylindrical shell. When the rod radius reaches 5.5mm, changing the rod radius has little effect on the natural frequency of the cylindrical shell, and the natural frequency does not change with the rod radius.

As can be seen from the Figure 3, in terms of improving the resonance deformation, the resonance deformation of first two orders increase with the rod radius or the ring thickness, At the same time, it can be seen that the regulation effect of the rod radius is better than that of the ring thickness, but the difference is not significant. The third order shows that the resonance deformation rapidly increases first and then gradually decreases. At the same time, it was found that using a method that changes the ring thickness can result in a lighter quality.
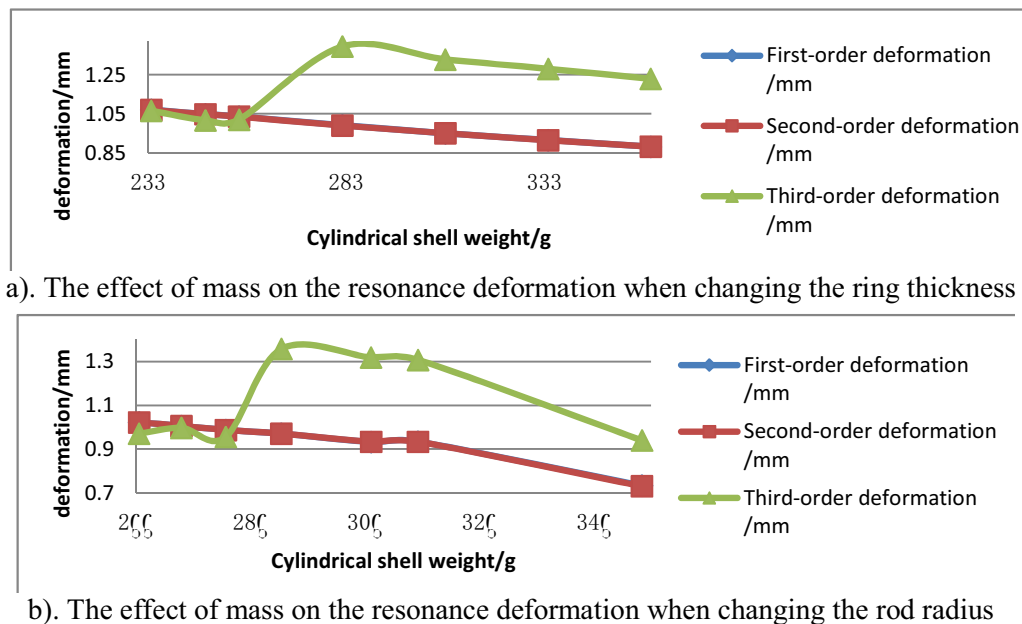
a). The effect of mass on the resonance deformation when changing the ring thickness

b). The effect of mass on the resonance deformation when changing the rod radius

Figure 3. Relationship between mass and resonance deformation under different parameters.

4. Conclusion

Using ANSYS, the influence of the new lattice parameters on the vibration performance of the lattice-filled cylindrical shell was analyzed. The method of controlling variables is used to analyze the influence of their parameters on the mode of the lattice-filled cylindrical shell, while keeping the ring thickness or the rod radius unchanged.

(1) In terms of changing the natural frequency, the rod radius has a greater influence on the natural frequency of the cylinder, and the frequency range that can be designed is wider. The disadvantage is that changing the rod radius is impossible to change the quality of the cylinder within a large range, and to a certain extent, cannot achieve the purpose of light weight.

(2) In terms of changing the resonance deformation, the influence of the rod radius and the ring thickness on the maximum deformation of the cylindrical shell is almost the same, but reducing the ring thickness can obviously reduce the quality of the cylindrical shell.

(3) In practical use, the natural frequency of the cylindrical shell can be obviously changed by changing the rod radius member. When considering the requirements of lightening, it can be achieved by changing the ring thickness. The combination of these two parameters can be used to design a better lattice-filled cylindrical shell that meets actual conditions.

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