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Application and Analysis of the New Functional Materials of Foam Aluminum

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Abstract. As a typical metal foams materials, aluminum foam which is a new type of functional materials has excellent properties of sound absorption and damping. In view of its complex internal micro-structure, on the basis of microcosmic cell theory, the paper set a BCC model of sound absorption of aluminum foam that can control its structure and size parameters such as porosity and aperture in micro-structural. The paper gets parameter factors of aluminum foam structure and size and studies its effect to sound absorption of aluminum foam though micro-modeling and proceeds experiment verification. Its turn out that this BCC model can apply to the research of aluminum foam sound absorption, and it can control the sound absorption of aluminum foam through controlling the microcosmic size of aluminum foam cell.

1 Introduction

Metal foam material is a new multi-functional materials, because of relatively low density, high specific strength, high specific surface area than a relatively continuous dielectric material properties, but also has high strength, high temperature, aging, etc. is better than traditional absorption characteristics of the material, has been increasingly used in the field of sound absorption foam metal material structure and pore controllable metal skeleton composed by cellular pore structure is divided into two kinds of open and closed cells, the main difference between the two is that the former is a continuous three-dimensional pore structure through the latter contains a lot of independent existence of pores. Effects of physical parameters of the flow of foamed metal material is mainly spread porosity, pore size, and flow resistance [1]. Acoustic wave propagation modeling foam metal can be in two ways: modeling and micro-macro modeling. Macro modeling is to use the average volume of semi-empirical formula to describe the sound wave propagation characteristics, microscopic methods by considering the special geometry of microscopic metal foam to simulate the propagation of acoustic waves trace details. In this paper, the typical aluminum foam metal

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foam material for the study, aimed at establishing a microscopic model of metal foam to study the effects of structural parameters controllable metal foam flowing communication.

2 Establishment and Analysis of Model

Aluminum foam having a small internal organizational structure, its internal cell spacing between cells is extremely small, and therefore due to the viscous effects of the fluid drag force due to significant acoustic viscous force. This structure also has a dual role, not only can reduce the sound the propagation velocity of sound waves can also put energy into heat by damping.

3 Modeling

Suppose aluminum foam through hole structure, its skeleton by a number of nodes and connections cubic unit cell composed of numerous internal unit cell according to certain rules periodically arranged combination of open-cell foam material directly on the micro structure of BCC simulation model can be used [2], its structure diagram shown in Figure 1. Model as follows, assuming spherical hole and have the same volume, which are located in the center of the cubic unit cell vertex and location of each unit cell of the cubic volume of the matrix material minus the top center of the sphere and the cube 8 penalty holes, the remaining structure is the skeleton. For open-cell foam material, the sphere radius must be greater than half the side length of the cube, the unit cell of the microstructure shown in Figure 2. The unit cell structure is simple and can reflect the characteristics of the actual foam structure.

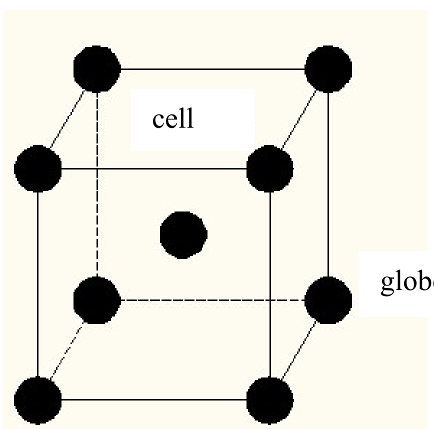

Fig.1 Schematic of the BCC model

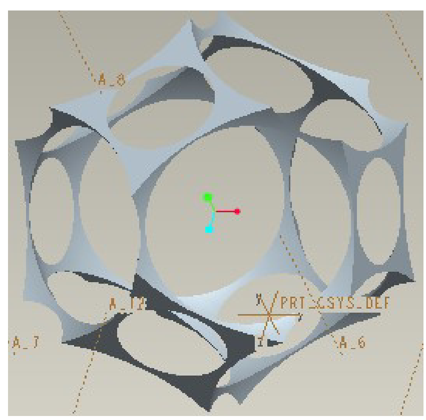

Fig.2 Microscopic model of foamed Aluminum

By analyzing unit cell structure can be obtained, for a unit cell, body hole is V_f 。

$$V_f = 2[\frac{4}{3}\pi R^3 - \frac{\pi}{3}(4R+s)(2R-s)^2 - 2\pi(R-\frac{a}{2})^2(R+\frac{a}{2})] \tag{1}$$

Where: R is the radius of the sphere,

a is cube side length,

s is located on the ball with a straight center distance.

For input surface, the fluid area A_f

$$A_f = \pi R^2 - 2\left[2R^2\cos^{-1}\left(\frac{s}{2R}\right) - \frac{1}{2}s\sqrt{4R^2 - s^2}\right] + \pi\left(R^2 - \frac{a^2}{4}\right) \tag{2}$$

Solid area $A_s = a^2 - A_f$

According to the model the size of the opening ratio of expression can be obtained:

$$\beta = \frac{V_f}{V} = \frac{2\left[\frac{4}{3}\pi R^3 - \frac{\pi}{3}(4R+s)(2R-s)^2 - 2\pi\left(R-\frac{a}{2}\right)^2\left(R+\frac{a}{2}\right)\right]}{a^3} \tag{3}$$

Can be set $R = xa$, For the calculation of the porosity $s = \frac{\sqrt{3}}{2}a$

$$\beta = \frac{2\pi}{3a^3}\left[-\left(4ax + \frac{\sqrt{3}}{2}a\right)\left(2ax - \frac{\sqrt{3}}{2}a\right)^2 - 6\left(ax - \frac{a}{2}\right)^2\left(ax + \frac{a}{2}\right) + 4(ax)^3\right] \tag{4}$$

$$\beta = \frac{2}{3}\pi\left(-24x^3 + (6\sqrt{3}+9)x^2 - \frac{3\sqrt{3}+6}{8}\right) \tag{5}$$

Porosity and $x = R/a$ relations following chart

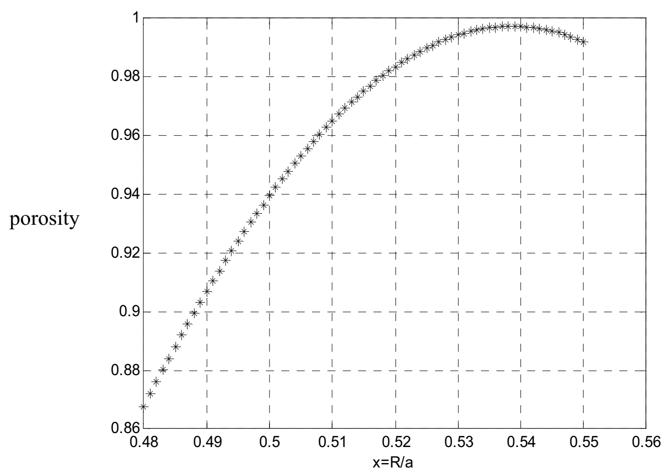

Fig.3 The relationship chart of porosity and size coefficient of proportionality

4 Acoustic analysis

Aluminum foam material having interconnected pores, when the sound wave incident to the aluminum foam surface acoustic wave incident on a portion of the material matrix skeleton spread within the structure, part of the material into the hole in which the spread within the media, the formation of two characteristic modes of the wave field. Since it is assumed material with respect to the fluid medium is rigid, sound can propagate in the structure than the spread in the media rarely, is negligible, only consider the sound wave propagation in the dielectric fluid that is material holes.

Sound waves enter the material inside the hole, causing vibrations in porous media, due to friction and viscous drag, some acoustic energy will be converted into heat and wear and tear; In addition, holes in medium compressive deformation done at acoustic pressure, the medium temperature changes, and because the matrix metal material having good thermal conductivity, and acoustic energy caused by thermal conduction losses [3]. In conclusion, a certain degree of viscosity and thermal conductivity is the basic mechanism of aluminum foam sound absorption.

When sound waves incident on the surface of aluminum foam in each unit cell aperture radius incident surface material (ie pore radius) is set, unit cell cycle-type arrangement, the incident surface acoustic wave propagating along the vertical direction similar to the low Reynolds number of Poiseuille flow. The boundary conditions can be set: cell surface velocity is zero, the polygon boundary shear stress cycle is 0, continuous cycle boundary interface velocity gradient. The model for the finite length of the tube model approximation. Aperture length of cell size, take a cylindrical coordinate system can be obtained in which the equations of motion [5]

$$j\omega\rho_0 u - \frac{\eta}{r}\frac{\partial}{\partial r}\left(r\frac{\partial u}{\partial r}\right) = -\frac{\partial p}{\partial z} \tag{6}$$

Complex sonic density value

$$\tilde{\rho} = \rho_0\left[1 + \left(3^2 + \frac{\kappa^2}{2}\right)^{\frac{-1}{2}} - j\frac{8}{\kappa^2}\left(1 + \frac{\kappa^2}{32}\right)^{\frac{-1}{2}}\right] = \rho_0 X \tag{7}$$

Compression modulus

$$K_T = P_0\left(1 - \frac{\gamma - 1}{\gamma}\frac{1}{X}\right)^{-1} \tag{8}$$

Acoustic impedance ratio

$$Z = \sqrt{K_T \tilde{\rho}} \tag{9}$$

Speed of sound

$$c = \sqrt{K_T / \tilde{\rho}} \tag{10}$$

The above formula $\kappa = d\sqrt{\frac{\omega\rho_0}{4\eta}}$

For aluminum foam in which the capillary tube, though it is no combination of rules cavity arrangement, it features single-tube model can still be used to express, but need to be included affect the porosity and structure constants and other parameters.

Foam compression modulus:

$$K = \frac{1}{\beta} K_T = \frac{1}{\beta} P_0 (1 - \frac{\gamma - 1}{\gamma} \frac{1}{X})^{-1} \tag{11}$$

$$X = 1 + (3^2 + \frac{\kappa^2}{2})^{\frac{-1}{2}} - \frac{8}{j\omega\rho_0 r^2}(1 + \frac{\kappa^2}{32})^{\frac{-1}{2}} \tag{12}$$

So the foam material and the acoustic impedance and sound velocity, respectively. According to the theory of the structure of Krichhoff available, no cavity after metal foam material impedance:

$$Z_l = \frac{1}{j}\sqrt{\rho\kappa}\cot(\omega l / \sqrt{K/\tilde{\rho}}) \tag{13}$$

Sound absorption coefficient

$$\alpha = \frac{4R_l \rho_0 c_0}{(R_l + \rho_0 c_0)^2 + X_l^2} \tag{14}$$

5 Calculation

Sound absorption coefficient according to the formula, which contains three variables, namely, porosity, pore size and material thickness. Determine any two variables, you can determine the impact of the third variable absorption coefficient. Now by calculating the pore diameter and the thickness of the known aluminum foam, under the laws of different porosity absorption coefficient. Under standard conditions, air density, air volume specific heat ratio, viscosity coefficient of atmospheric pressure, the speed of sound in air, taking aluminum foam pore size, material thickness, were calculated by computer simulation porosity 0.5,0.6,0.7 0.8, the absorption coefficient of the material, the results shown in Figure 4. Figure 5 is at a certain frequency range 800Hz, the thickness of a certain relationship between aperture foam aluminum sound absorption coefficient and porosity.

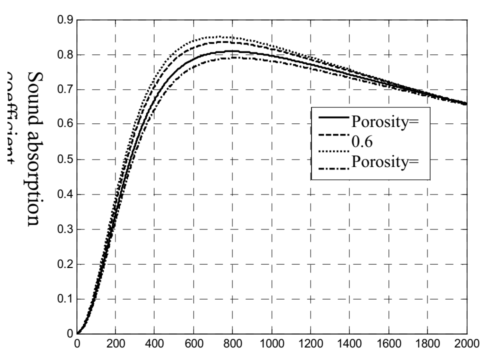

Fig.4 Relationship between sound-absorption coefficient and porosity

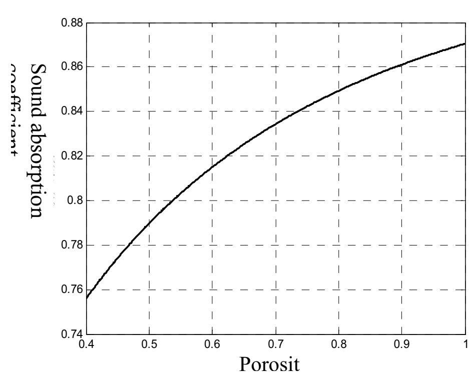

Fig.5 Relationship between sound-absorption coefficient and porosity in 800Hz

The porosity is a component of the metal foam material in the pore volume occupied by the total volume of material is an important parameter affecting the flow of metal foams spread, especially have an important impact on the absorption of sound propagation of acoustic waves, appropriate porosity can obtain excellent sound absorption effect. Flow voids in the foam metal materials with different size and porosity of the propagation and acoustic absorption characteristics are very different. As can be seen from Figures 4 and 5 with the increase of the porosity, the peak absorption coefficient increases, and the resonance frequency corresponding to the high-frequency extension.

Also the greater the porosity, the greater the sound absorption coefficient. This is because when the pore size and porosity certain, more complex internal structure of the foam, the higher the coefficient tortuous porosity, pore fluid medium with sonic vibrations, since the unit cell skeleton of friction and viscous drag of air so that part of the acoustic energy converted into thermal energy loss, the porosity, the greater the pore torturous, partly due to the higher dissipation. As mentioned equation (3) and (4), the porosity of the material can be obtained according to the microscopic cell size parameters, namely by controlling the micro structure of aluminum foam cell size control its porosity thereby affecting the absorption coefficient.

6 Summary

In this paper, a model of micro microscopic BCC structure based on aluminum foam to study the micro structure of metal foams, metal foams in propagation by controlling cell size parameters to control the metal foam material from the micro-level research Sonic sound structural parameters pore size, thickness, porosity, etc. to optimize the absorption properties of the material, and analyzed by calculating the porosity of aluminum foam get influence on sound absorption properties, can be obtained by controlling the micro structure of aluminum foam cell size to control the porosity rate thereby affecting its absorption properties. This article is only a preliminary study of sound propagation in microscopic modeling needs further research.

7 Acknowledgments

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