Simulation of acoustic performance of ceramic foam based on COMSOL

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Abstract. Ceramic foam has excellent properties such as high porosity, high temperature resistance, chemical corrosion resistance and good thermal stability. It is widely used as liquid metal filter, high temperature gas and ion exchange filter, catalyst carrier, environmental material, heat insulation material, sound absorption material, biological material and so on. This paper first introduces the principle of the ceramic foam as an acoustic material, and then establishes the impedance tube model based on COMSOL software. The influence of thickness, pore size, porosity and material on the sound absorption properties of the foam ceramics is simulated and analyzed.

1. Introduction

Ceramic foam is a new material with high specific area, high porosity, low density, low thermal conductivity, selective permeability to liquid and gas medium, and energy absorption and damping properties. The porous channels are interconnected with labyrinth three dimensional network structure porous body, in molten metal, gas liquid filtration, purification and separation, chemical catalytic carrier, and sound absorption. Shock absorption, advanced thermal insulation materials, biological materials, special wall materials and sensor materials play an important role, which are widely used in environmental protection, energy, chemical industry, biology and other fields.

Foam ceramics have large number of pores in three-dimensional spatial network structure. After the sound wave is introduced into the porous body, the air in the pore will vibrate and the ceramic tendons will rub. Due to the viscous effect, sound waves change into heat and disappear, so as to achieve the effect of absorbing sound. With the intensification of noise pollution and the enhancement of people's awareness of environmental protection, sound absorbing materials will develop rapidly. It is still a hot topic to explore and adopt new processes to broaden the sound absorbing frequency band and enhance the sound absorption performance of foam ceramics. At the same time, researchers need to strengthen the research on application technology of sound absorbing foam ceramics and improve their industrialization level.

This paper first introduces the principle of the ceramic foam as an acoustic material, and then establishes the impedance tube model based on COMSOL software. The influence of thickness, pore size, porosity and material on the sound absorption properties of the foam ceramics is simulated and analyzed, which can provide an optimized direction for the preparation of high foam absorbing ceramics.
2. The THEORY of ceramic foam acoustics

2.1. Sound absorbing material
As a sound-absorbing material, the main factors affecting its sound absorption characteristics are the air flow resistance porosity and structure factor of the material itself. At present, Zwikker-Kosten model and Stinson model are commonly used to describe the viscous effect and thermal interaction between air and hole wall. Takahara has studied the sound absorption characteristics of porous ceramic materials with micro particles. The main influencing parameters are the average diameter of particles, porosity, material thickness and cavity thickness behind the particles.

Only porous ceramics with connected pores, more than 60% porosity, pore size of 20~150 μm and high mechanical strength can be used as sound absorption materials.

2.2. Sound insulation material
Different from sound absorption materials, porous ceramics with closed pore structure can be used as sound insulation materials. When sound waves propagate to the surface of materials, most of them are reflected, and the transmitted sound waves are greatly reduced, so as to play the role of sound insulation. Porous ceramics have sound insulation performance, excellent fire resistance and weather resistance, which make it more and more widely used in transformer, theater sound insulation, and high-rise buildings and other occasions with high fire requirements.

2.3. Muffler material
In recent years, porous metal materials with rigid skeleton structure have been used in Anechoic lining. The characteristics of porous materials under high temperature and high sound pressure level have been widely studied. The calculation model of surface acoustic impedance of materials with hard wall backing is obtained, but the research as blocking muffler is very few. Porous ceramic muffler was first used in 1980s to control exhaust jet noise. It has been applied to the exhaust ports of core shooting machine, press, box dividing machine and box poking machine driven by compressed air in casting and forging workshop, and the noise elimination effect is more than 30dB (A).

3. COMSOL impedance tube model
As shown in Figure 1 is the schematic diagram of the impedance tube model in COMSOL, with a diameter of 10cm and a length of 40cm. The upper end surface of the cylindrical pipe is provided with a sound pressure loading surface, and the lower end surface is provided with a reflector free surface. The foam ceramic material is placed at the front end of the total reflection surface, and the contact surface between the air and the foam ceramic is a sound solid coupling surface. In the middle position of the pipeline, two field points are set up to read the sound pressure and particle velocity at the place, and the sound absorption coefficient of the ceramic foam can be calculated according to the transfer function.

![Fig 1. Schematic diagram of impedance tube model](image)
In the simulation model, the foam ceramic can be built with COMSOL porous material model, and materials such as AL2O3 or SiC can be selected. Based on the above impedance tube model, the effects of thickness, pore size, porosity and material on the sound absorption properties of foam ceramics are simulated and analyzed.

4. Simulation analysis of foam ceramics
The initial parameters of the foam ceramic model are porosity 60%, thickness 40mm and pore size 400um. A control variable method is adopted to change the parameters of the model and analyze its influence on the sound absorption properties of porous ceramic foam. The porosity can be 20%, 40%, 60%, 80%; the thickness can be 20 mm, 40 mm, 60 mm; the pore size can be 200 μm, 400 μm, 600 μm, 800 μm. The simulation results are shown in Fig. 2, Fig. 3 and Fig. 4.

As shown in Fig. 2, the larger the thickness of the foam ceramic, the more the absorption peak moves to the low frequency, and the better the overall sound absorption performance. It can be seen from Fig. 3 that when the frequency is less than 700Hz, the smaller the aperture is, the greater the sound absorption coefficient is; when the frequency is greater than 700Hz, the sound absorption coefficient with an aperture of 200 μm decreases, and the high-frequency performance decreases compared with the large aperture. As shown in Fig. 4, the greater the porosity of foam ceramics, the greater the absorption coefficient and the peak value of absorption peak.

![Fig 2. Effect of thickness on sound absorption properties of ceramic foam](image1)

![Fig 3. The effect of pore size on the sound absorption properties of ceramic foam (where Slbj is a hydraulic radius, the size of which is 1/4 of aperture).](image2)
Fig 4. Effect of porosity on sound absorption properties of ceramic foam

In addition, this paper also simulated and compared the sound absorption properties of ceramic foam with different materials. The results showed that the sound absorption properties of Al2O3 and SIC two kinds of ceramic foam materials were the same, probably because the viscosity coefficient and other physical parameters were close, so there was little difference in the simulation of sound field, and further test comparison was needed.

5. Conclusions
The impedance tube model is established based on COMSOL software. The influence of thickness, pore size, porosity and material on the sound absorption properties of foam ceramics is simulated and analyzed. The larger the thickness of foam ceramic, the more the absorption peak moves to the low frequency, and the better the overall sound absorption performance. When the frequency is less than 700Hz, the smaller the aperture is, the greater the sound absorption coefficient is; when the frequency is greater than 700Hz, the sound absorption coefficient of 200 μm aperture decreases, and the high-frequency performance decreases compared with the large aperture. The greater the porosity of foam ceramics, the greater the absorption coefficient and the peak value of absorption peak.

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