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Preparation of a New Type Open-hole Aluminum Foam sample for Sound Absorption Coefficient Experiment

Hui Li, Yong Zhang*, Min Xing, Yanan Xu

School of Mechanical Engineering, Shandong University of Technology, Zibo 255000, China
**Corresponding Author*

ABSTRACT. *In this paper, a new method of preparing open cell aluminum foam by Low-Pressure Infiltration and calcium oxide particles has been developed creatively. By means of X ray microscopic analysis, it can be seen that mixed grout mixed with anhydrous ethanol and calcium oxide powder in the particles reduces the porosity of the compact structure and makes the connection between grains more closely. The porosity can be accurately controlled by the mass-volume direct calculation method of porosity. Calcium oxide particles in particles and aluminium complexes can be quickly removed by using ammonium chloride aqueous solution heated above 70 C. According to the requirement of sound absorption coefficient test, three kinds of test samples of porosity were prepared.*

KEYWORDS: *Calcium oxide seepage particles; Open-hole aluminum foam; Porosity; Sound absorption coefficient; Test samples*

1. Introduction

Aluminum foam material integrates various functions, in particular, it has structural advantages in being used as a sound absorbing material, so it's been a hot topic of research [1]. Aluminum foam can be roughly divided into two types, closed-hole and open-hole, due to the open-hole aluminum foam material has the characteristics of hole structure size stability and good broadband sound absorption performance[2], it is suitable for the occasion of noise elimination.

So far, the selection of infiltration particles for preparing open-hole aluminum foam materials can be roughly divided into four types, respectively are sodium chloride particle[3-9], urea granules[10,11], soluble MOD particles[12], and SHP ball particles[13]. This paper creatively selected calcium oxide as infiltration particle[14-16], the porosity of aluminum foam is adjusted by mixing a mixture of anhydrous ethanol and calcium oxide powder on its surface, This method breaks the technical bottleneck that the existing methods can only make the porosity change between 50% and 70%[17]. In this paper, the effect of mixed slurry on the structure of

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compact infiltration particles and open-hole aluminum foam was studied by three-dimensional X-ray microscope. In this paper, three kinds of porosity test samples were prepared by using the new method of aluminum foam preparation, it lays a foundation for its application in the muffler field.

2. Materials and methods

Fig.1 shows the low-pressure infiltration device used in the preparation of open-hole aluminum foam for sound absorption coefficient test. Using this device, the complex of aluminum and particle was prepared, after cutting, cutting process and particle removal, the test samples were obtained.

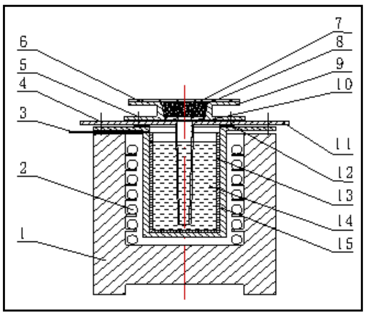

Figure.1 Schematic Diagram of Low Pressure Infil Tration Device

1-Well type resistance furnace;2-Resistance wire; 3-Intake-tube; 4-Sealing bolt; 5-Positioning bolt; 6-The top cover plate;7-Calcium oxide particle; 8-Inner mould; 9-Outer mould; 10-Small asbestos seal ring; 11-Lift tube; 12-Large asbestos seal ring;13-Graphite lining; 14-Molten aluminum; 15-Crucible

2.1 The Selection of Infiltration Particles and the Influence on the Compacted Structure after Mixing in Slurry

The melting point of calcium oxide particles is 2927℃, has dense structure, the shape of particles remaines unchanged at 750℃preheat, therefore, compared with the four types of particles mentioned above, it has advantages in performance, with appropriate process measures, calcium oxide particles can be easily removed from the complex of aluminum and particles by means of an aqueous solution, therefore, calcium oxide particles were selected as infiltration particles in this paper.

In order to study the effect of mixed slurry of ethanol and calcium oxide on the compact structure of calcium oxide infiltration particles, two sets of comparative samples were designed to facilitate the detection of 3d X-ray microscopy. Two transparent plastic flask containers of the same size were selected , as shown in Fig.2.

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Figure.2 Physical Drawing of 1# Sample and 2# Sample

Firstly, the size of calcium oxide particles was selected as 2.00~2.50mm (between 8 mesh and 10 mesh sieve), double particles of the same weight (32g) were prepared, one portion was placed directly into the container on the left, the height of particle accumulation is about 5mm higher than the open plane of the container, the top of the particle was pressed to keep level with the open plane, and the $1^{\#}$ sample without slurry is obtained. Then the other portion of the granules mixed into a mixture of 3g fine calcium oxide powder (> 300 mesh) and 1.5g alcohol in a container on the right side, follow the same procedure above to get $2^{\#}$ sample mixed with slurry.

The two samples prepared above have the same compactness, the porous compact structures of the two samples were analyzed by three-dimensional X-ray microscopy, the effect of mixed slurry with ethanol and calcium oxide powder on porous compact structure of calcium oxide particles was studied.

2.2 The Process Parameters of Aluminum Foam Preparation and the Preparation of Three Kinds of Porosity Test Samples

During sample preparation, calcium oxide particles were mixed with slurry made of anhydrous ethanol and calcium oxide powder in a certain proportion, then were put into the bottom of the inner mould laid stainless steel screen. The particles above the upper surface of the inner mould are compacted with a compaction device, so that the upper surface of the compacted particles is flush with the upper surface of the inner mould, then put the inner mould into the preheating furnace to preheat to the specified temperature, keep warm for 2 hours, it is quickly installed into the outer mould cavity of the device, the aluminum liquid in the crucible is pressurized by controlling the compressed air through the intake pipe, the aluminum liquid flows along the Lift tube to fill the mould and solidification, the complex of aluminum and particle was obtained.

Refer to the research results of literature[15,16], The process parameters for complex preparation were selected as follows: liquid aluminum melting temperature 720℃; infiltration pressure 0.04MPa; granule preheating temperature 700℃.

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When the sound absorption coefficient of aluminum foam was test, since each porosity test sample is subdivided into two types: low frequency (ф100×8mm) and high frequency (ф30× 8mm), therefore, 69.0%, 71.0% and 73.0% three kinds of porosity were designed in this paper, corresponding low frequency and high frequency samples with corresponding porosity were labeled as $3^{\#}$ and $4^{\#}$, $5^{\#}$ and $6^{\#}$, $7^{\#}$ and $8^{\#}$ samples, respectively. The purpose is to study effect of porosity on sound absorption coefficient when the sample with a certain pore size (2.00~2.50mm) and thickness (8mm).

When three samples were prepared, direct mass-volume calculation of porosity was used to determine the total mass of particles and fine powders [25], the porosity θ of calcium oxide particles in this calculation is shown in Eq. (1).

$$\theta = (1 - \frac{M}{V \cdot \rho_S}) \times 100\% \quad (1)$$

where, M is total mass of calcium oxide particles and fine calcium oxide powder (g); V is the volume of the inner cavity of the inner mould (cm3); ρ_s is the density of calcium oxide particles (g/cm3). The ρ_s of calcium oxide particles is 1.32g/cm3.

Since anhydrous ethanol will be burned off during the later preheating process, so the amount of ethanol added had no effect on the porosity of the sample. For three samples, the quality of particles, powders and alcohol in the preparation of selected samples through calculation is shown in table 1.

Table 1 Quality of Each Component Selected in the Preparation of Three Porosity Samples

Sample No.	Grain(g)	Powder(g)	Alcohol(g)	Porosity(%)
$3^{\#}$,$4^{\#}$	394.1	34.0	115	69.0
$5^{\#}$,$6^{\#}$	404.9	35.2	120	71.0
$7^{\#}$,$8^{\#}$	416.7	36.2	125	73.0

Fig.3 Shows a Physical View of a Composite of Aluminum and Particles Prepared on the Low Pressure Infiltration Device Using the Above Process Parameters.

Figure.3 Physical View of a Complex of Aluminum and Particles

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2.3 Calcium Oxide Particle Removal Method

Fig.4 Shows the Schematic Diagram of the Calcium Oxide Particle Removal Device Adopted in This Paper.

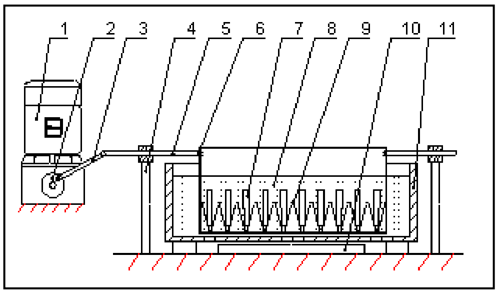

Figure.4 Schematic Diagram of the Particle Removal Device

1-Motor; 2-Eccentric; 3-Connecting rod; 4-Guide bracket; 5-Guide bar; 6-The sample basket; 7-sample; 8-Ammonium chloride solution; 9-Isolation net; 10-The heating container; 11-Induction cooker

When the calcium oxide particles were get rid of, firstly, many of composites of aluminum and particles processed to the sample size were placed in the isolation net of the device, and reacts the chemical reaction of Eq. (2).

$$CaO+H_2O=Ca(OH)_2 \quad (2)$$

The calcium hydroxide produced by this reaction is not highly soluble (0.16 g 20℃ can only be dissolved), and as the temperature increases, the solubility decreases (0.15 g 30℃ can only be dissolved), therefore, in this paper, ammonium chloride was deliberately added into the water of the removal device to generate an aqueous solution of ammonium chloride. Ammonium chloride aqueous solution reacts with calcium hydroxide in Eq. (3).

$$Ca(OH)_2+2NH_4Cl=CaCl_2+2H_2O+2NH_3\uparrow \quad (3)$$

The reaction produces calcium chloride and ammonia,calcium chloride is highly soluble in water (20℃ to 37.2 g), and as the temperature increases, the solubility will increase significantly (100 ℃ to 77.3 g), the resulting ammonia can escape from the solution, so the calcium oxide particles in the complex can be successfully removed.

The removal solution temperature was determine to above 70℃, while the removal solution was heated by the heating furnace of the device, the sample basket was moved back and forth in the horizontal direction by the electric motor through the eccentric wheel and the connecting rod, the diffusion rate of reaction products in chemical reaction was accelerated to accelerate the removal of particles. Generally, particles can be removed within 5 to 6 hours, and qualified test samples can be

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obtained after cleaning with water.

2.4 Three-Dimensional X - Ray Microscopic Examination and Analysis of Two Samples

The porosity of the test sample was calculated by the total mass added to the particles and fine powder in Eq. (1), to test the accuracy of this calculation method, the $4^{\#}$ and $8^{\#}$ samples were examined and analyzed by 3d X-ray microscope. Fig. 5 shows a physical picture of two test samples.

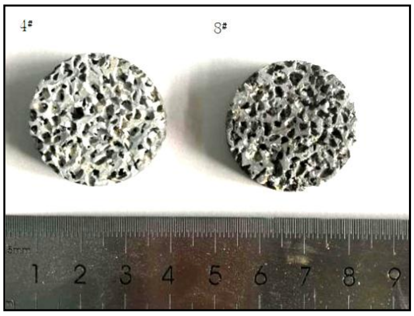

Figure.5 Physical Pictures of $4^{\#}$ and $8^{\#}$ Samples

3. Results and discussion

3.1 Analysis of the Influence of Slurry on the Compact Structure of Calcium Oxide Particles

The 3d X-ray microscopic examination of the sample was entrusted to Auying Detection Technology (Shanghai) Co., LTD. The samples were tested by a high-resolution 225kV microfocus industrial CT detection system, the equipment model is Y.CT Modular.

Fig. 6 is a three-dimensional X-ray micrograph of the four-view of the 1# sample fault, its porosity tested is 41.58% and the contact tightness between pores (the total surface area of the pore relative to the total volume of the sample) is 7.40.

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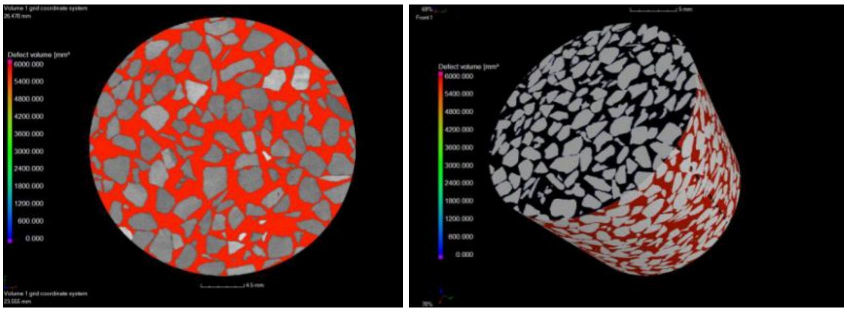

Figure.6 Three-Dimensional X-Ray Micrograph of the Four-View of the 1# Sample Fault

Fig.7 Is a Three-Dimensional X-Ray Microscopic Four-View of the 2# Sample Fault, Its Porosity Tested is 38.71% and the Contact Tightness between Pores is 6.32.

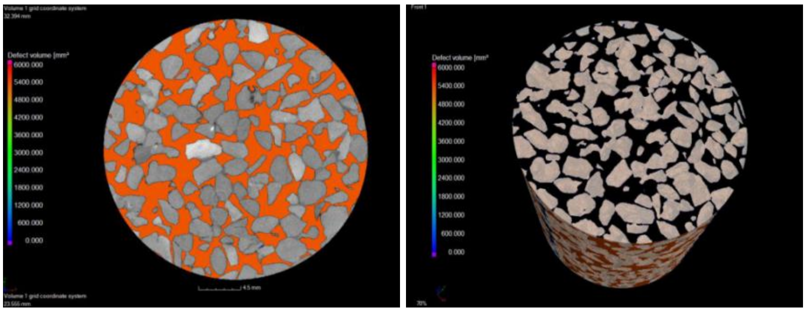

Figure.7 Three-Dimensional X-Ray Microscopic Four-View of the 2# Sample Fault

The contact tightness between the pores of 1# sample is 7.40, which is greater than 6.32 of 2# sample, this problem was explained by establishing the contact model of three elliptical particles that has or not has slurry, as shown in Fig.9.

The three particles in Fig.7 (a) have three contact points, which are labeled as A,B and C respectively, when a layer of slurry is evenly mixed on the surface of particles, the contact points of A, B and C can be maintained after the particles are compacted in Fig.8 (b), But the alcohol in the slurry on the surface of the particles has not yet evaporated, the slurry has no strength, so it was squeezed away and dispersed around the contact point between the particles, therefore, the

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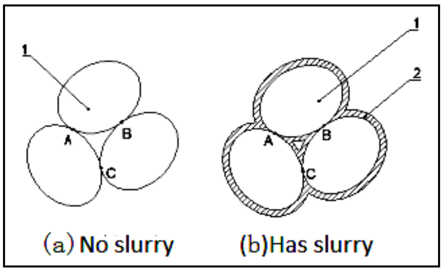

1-calcium oxide particle; 2-slurry; a,b,c- particle contact poins

Figure.8 Model of Interparticle Contact

Contact between particles changed from point to surface, which reduced the total surface area and volume of pores in 2# sample, and thus reduces the numeric value of contact tightness between the pores. Therefore, the smaller the numeric value is, the closer the interparticle bond will be.

The addition of slurry not only increases the weight and volume of particles, but also makes the connecting channel between particles become the surface contact, which increases the removal channel of particles and facilitates the removal of particles and easy to obtain the open-hole aluminum foam material, which can improve the situation that particles are not easy to be removed in the preparation process using the traditional infiltration method.

Since the porosity of the porous compact structure of calcium oxide particles studied in 3.1 above is exactly the volume ratio of aluminum, the mixing of slurry on the surface of particles will reduce the porosity of the granular compact structure, so also increase the porosity of aluminum foam.

3.2 X-Ray Microscopic Examination Results and Analysis of the Calculated Results

Fig.9 Is a Three-Dimensional X-Ray Microscopic Four-View of the 4# Sample Fault, Its Porosity Tested is 68.91% and the Contact Tightness between Pores is 4.41.

The porosity of 1# sample is 41.58%, this is because even though the sample have the same degree of compactness, both should have the same porosity, however, since the mixed slurry in 2# sample increases the volume of particles and reduces the volume of pores in the granular compact structure, the porosity of 2# sample is smaller.

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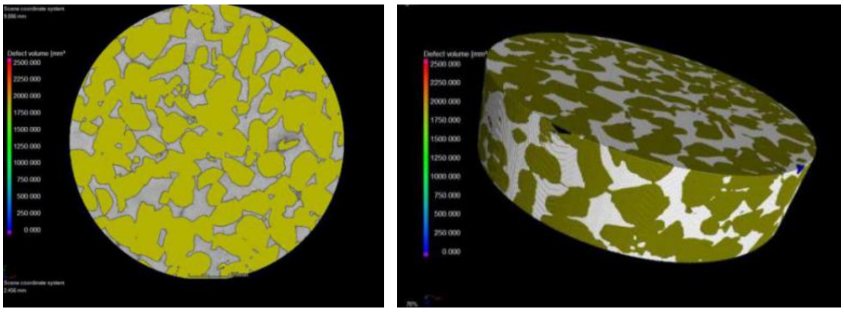

Figure.9 Three-Dimensional X-Ray Microscopic Four-View of the 4# Sample Fault

The porosity of $4^{\#}$ sample was calculate by the Eq.(1) as 69.0%, and from the sample of the X-ray microscopic test results, the porosity of $4^{\#}$sample was 68.91%, this indicates that there is an exact correspondence between the porosity values of the both, so the use of this preparation method can realize the quantitative accuracy control of porosity in the aluminum foam materials.

3.3 Physical Pictures of Three Groups of Test Samples

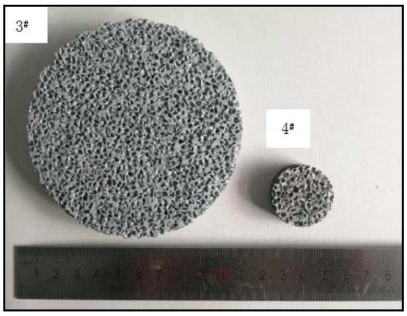

Figure.10 Physical Drawing of the 3# and 4# Samples

Fig.10 is a Physical Drawing of the 3# and 4# Samples. the 5# and 6#, 7# and 8# Samples Look Basically the Same as the 3# and 4# Samples.

4. Conclusions

(1) On the low pressure infiltration device, using calcium oxide as infiltration particles, choosing aluminum liquid temperature of 720℃, infiltration pressure of 0.04 MPa, the particles preheating temperature of 700℃, as the preparation of process parameters , can get the qualified samples of open-hole aluminum foam.

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(2) According to the X-ray microscopic analysis, the porosity of the compact structure of the particles was reduced by mixing the slurry mixed with anhydrous ethanol and calcium oxide powder in the particles, it makes the connections between the particles tighter, so the channel for particle removal was increased, and easy to obtains the open-hole aluminum foam.

(3) Using ammonium chloride aqueous solution heated to above 70 ℃ can quickly remove the calcium oxide in the composite of aluminum and particles.

(4) Through X-ray microanalysis of samples, it can be seen that the porosity of aluminum foam is improved due to the addition of mixed slurry in the particles, and the sample porosity can be precisely controlled by using the direct mass-volume calculation method of porosity.

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