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Herewith we certify that the paper with the title

"Acoustic absorption behavior of closed-cell aluminum foams and sandwich panels"

A. Babakhani, M. Golestanipour, M. S. Abravi, M. Malek Jafarian, A. Sadeghi Aval

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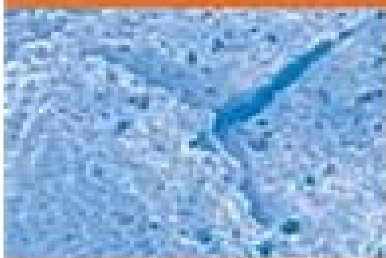

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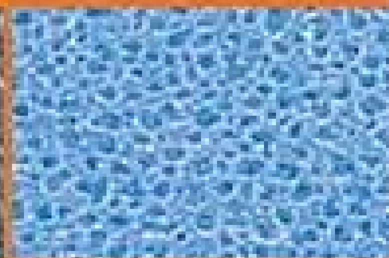

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Physical, chemical, mechanical, thermal and optical properties

Utilization of basalt and glass waste for the production of porous ceramic bodies

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The aim of this study was to characterize ceramics processing glass waste and evaluate its suitability as an alternative ceramic raw material for the production of porous technical ceramic bodies. Basalt, SiC and glass wastes were used as raw materials. Several formulations were prepared and sintered at different temperatures. The sintered samples were characterized to determine their porosity, water absorption, firing shrinkage and mechanical strength.

Physical, chemical, mechanical, thermal and optical properties

Acoustic absorption behavior of closed-cell aluminum foams and sandwich panels

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Sound absorption characteristic of the aluminum foam sheets and sandwich structures composed of Aluminum foam core and Aluminum face-sheet was investigated in this paper. The absorption coefficient of the structures was measured in different thicknesses by the transfer function method. Compared with the single aluminum foam, the sandwich panel shows a significant improvement in sound absorption if the single foam and the sandwich panel have a same thickness of sample. The effect of structural parameters such as pore size of the aluminum foam on the sound absorption performance is significant.

Acoustic absorption behavior of closed-cell aluminum foams and sandwich panels

A. Babakhani[1], M. Golestanipour[2,1], M.S. Abravi[2], M. Malek Jafarian[2], A. Sadeghi Aval[2], H. Amini Mashhadi[2]

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The closed-cell aluminum composite foams reinforced by different volume fractions of SiC particles were manufactured with the direct foaming route of melt using different content of $CaCO_3$ foaming agent. The relative density of produced foams changed from 0.17 to 0.27. Sound absorption characteristic of the aluminum foam sheets and sandwich structures composed of aluminum foam core and aluminum face-sheet was investigated in this paper. The absorption coefficient of the structures was measured in different thicknesses and relative densities by the transfer function method. Compared with the single aluminum foam, the sandwich panel shows a significant improvement in sound absorption if the single foam and the sandwich panel have a same thickness of sample. The effect of structural parameters such as relative density and thickness of the aluminum foam on the sound absorption performance is significant.

Introduction

Metallic foams have lately attracted considerable attention as a lightweight structural components and energy absorption parts in automobile, railway and aerospace industries. Metal can be foamed in many methods. Direct foaming route of melt using foaming agent are quite suitable for industrial production because of their handleability and low cost, but the cell structure of metallic foams is irregular and the cell size is inhomogeneous [1-8].

Compared with conventional materials, aluminum foams have the advantages of low density, high stiffness against impact, low thermal conductivity, magnetic shielding, and fine damping. So, they have become one of the fields in high-tech materials research over the world. Most of previous researches on aluminum foams were focused only on the mechanics and energy absorption and rarely were studied the acoustics especially sound insulation property. Because of its special structure, aluminum foam has great potential application in the fields such as sound insulation and noise reduction [9,10].

The purpose of this work is manufacturing and to study the sound insulation properties of closed-cell aluminum composite foams and sandwich panels and to investigate the relationship of relative density and foam thickness on sound absorption in a constant frequency.

Materials and experimental techniques

Materials

Commercial A356 cast aluminum alloy was used as a base material. The reinforcement phase consisted of SiC particles with purity of 98.0 wt.% and mean mass particle size of 10 mm. Heating SiC particles for 1 h at 950°C and then for 2 h at 650°C in a conventional air furnace was carried out to improve the wettability between SiC_p and Al melt by removing adsorbed gases from the surface of particles. $CaCO_3$ powders with purity of 99.5 wt.% and 5mm average size were used as blowing agent. $CaCO_3$ powders were also heat-treated at 200°C for 2 h to remove humidity and adsorbed gases from the surface and improve wetting properties and dispersion of $CaCO_3$ powders in molten metal. Scanning Electron Microscope (SEM) micrograph of heat-treated SiC particles and $CaCO_3$ powders are respectively shown in Fig. 1a and 1b.

Processing methodology

SiC_p reinforced aluminum matrix composite slurry was prepared by conventional stir-casting techniques at 650-680°C, and then it was poured into a steel mould to obtain a composite ingot. This ingot was melted again at 650-700°C and then it was stirred at 650°C. The rotational speed of the stir-equipment was 1400 rpm. A content of 1 wt% of magnesium was subsequently introduced into the melt. After $CaCO_3$ powders were added into the melt swirl, the melt was stirred unceasingly for less than 1 min and then held at 710-730°C for several minutes to allow $CaCO_3$ blowing agent to decompose and release CO_2 gas. The foamed melt was removed quickly from the furnace and cooled immediately in air. Different amounts of $CaCO_3$ (1, 3 and 5 wt.%) and SiC particles (5, 10 and 15 vol.%) was selected to produce composite foams with different relative densities and mechanical properties.

Oxides of aluminum and magnesium (assuming that Mg was introduced into the melt) form during decomposition of the $CaCO_3$ and associated reaction with the melt. These oxides form on the inner surfaces of the cells created during foaming and they apparently help to stabilize the cells against coarsening and coalescence. They also inhibit the migration of ceramic particles to these surfaces [6].

Relative density (ρ/ρ_s) and dimension of each test specimen are listed in Table 1. Term ρ/ρ_s, which is called the relative density of composite foams, indicates the ratio of the density of composite foams to the density of cell wall material.

Testing of sound insulation property

Scanning electron microscopy by means of a LEO 1450VP (35 kV) system and optical microscopy with an Olympus PM3 microscope were carried out to observing the cell structure and evaluate the distribution of SiC particles in Al/SiC_p composite foams.

Sound insulation properties of the aluminum foams and sandwich panels are tested with a special setup in a constant frequency of 10 Hz. Fig. 2 is the sketch map of sound absorption testing apparatus. Fig. 3 is the specimen picture during sound absorption testing. The sound pressure signals of the receiving room and emitting room are collected through Sony sound forge 6.0 analytical apparatus and software. The sound reduction index (R) measurements are performed according to ISO 140/3 procedure [11].

Results and discussion

Microstructural features

The microstructure of no. 2F produced composite foam with relative density of 0.20 is shown in Fig. 4. It can be found that the structure of cells is uniform (Fig. 4(a)) and SiC particles uniformly distribute in the cell wall of composite foams (Fig. 4(b)).

Sound insulation property

The random-incidence sound reduction index (R) can be evaluated from the following approximate equation, where R_0 is the vertical incidence sound reduction index; m is the surface density of board material and f is the frequency [12].

1) $R=R_0-5\text{ dB}=20\log(m\times f)-48\text{ dB}$

The sound reduction index (R) measurements of aluminum foams and sandwich panels are listed in Table 2. Effect of relative density and thickness of aluminum foams and sandwich panels on sound reduction index (R) are investigated below.

3.3.1. Effect of thickness

Thickness of aluminum foams plays an important part in sound insulation. Eq. (1) indicates that the sound reduction index (R) is influenced mainly by surface density and frequency. When frequency is fixed, the relation between R and m are logarithmic, from which it can be concluded that sound reduction index (R) of aluminum foams increases with the addition of surface density, but the increasing trend becomes mild. Owing to the direct proportional relation between surface density and thickness of boards, the sound reduction index (R) of sandwich panels of different thickness grows larger when thickness is added, but does not increase equivalently with the evenly added thickness. When the thicknesses of aluminum foam sandwich panels are 10, 35, 45, and 60 mm, the corresponding sound reduction indices (R) are 30.19, 32.22, 33.01, and 33.51 dB, respectively, the rising trend tempered (Fig. 5). Thus the increase of sound insulation property cannot be achieved by adding the thickness of aluminum foam sandwich panel blindly. Excess increasing the thickness of aluminum foam to enhance its sound insulation property is a waste of material.

In sandwich panels (specimens' no. 7S and 8S) the thickness of each aluminum face-sheet is 1 mm. A significant increase of sound reduction index (about 28%) can be achieved by adding the face-sheets and making aluminum foam sandwich panel in a constant foam thickness and density (Fig. 5).

3.3.2. Effect of relative density

Fig. 6 is the sound insulation property of aluminum foams with a constant thickness of 10 mm in different relative densities. The sound reduction index (R) increases obviously from 28.40 to 30.19 dB when the relative density of aluminum foam is added from 0.17 to 0.27. The increasing trend of the sound reduction index (R) gradually becomes mitigated. The reason why the addition of density results in the increase of the sound reduction index (R) can also be explained by Eq. (1): just like the addition of thickness, the addition of density can also increase the surface density of aluminum foams which leads to the increase of sound reduction index (R). aluminum foam sandwich panel (relative density=0.27) already has fine sound insulation effect (with R 30.19 dB) in practical situation, and further increasing of density cannot raise the sound reduction index (R) obviously, as a result there is no necessity to enhance the sound insulation property of aluminum foam by adding the density.

Conclusions

(1) Experiments with aluminum foams of different thicknesses display that the sound reduction index (R) increases with the addition of thickness in a constant density, but the increasing trend becomes mitigated.

(2) At the same thickness, the sound reduction index (R) of aluminum foams increase with increasing density.

(3) A significant increase of sound reduction index can be achieved by making aluminum foam sandwich panel in a constant foam thickness and density.

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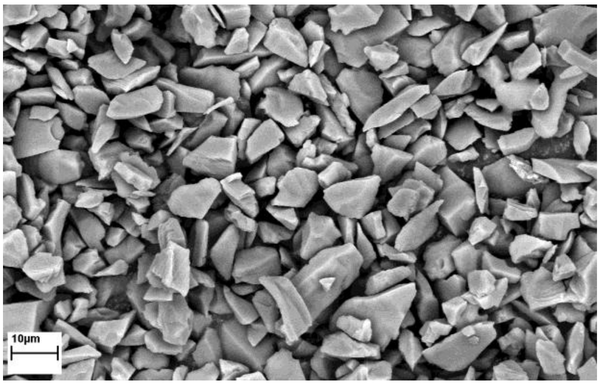
Figures



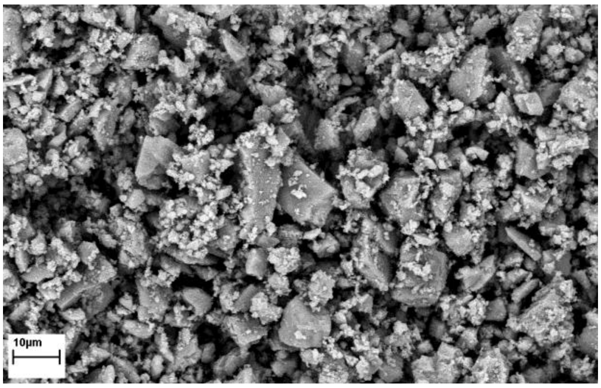


Figure 1: SEM micrograph of heat-treated a) SiC particles and b) CaCO3 powders

Figure 2: Sketch map of sound absorption testing apparatus

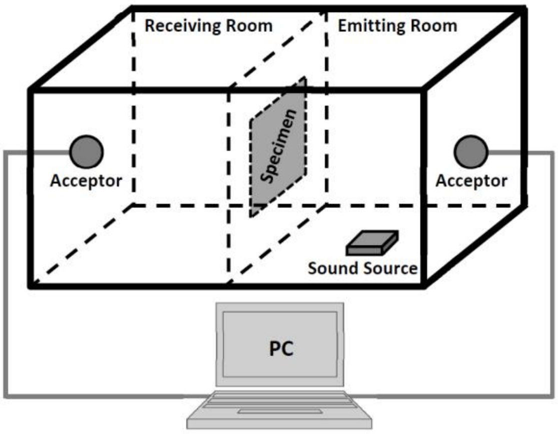
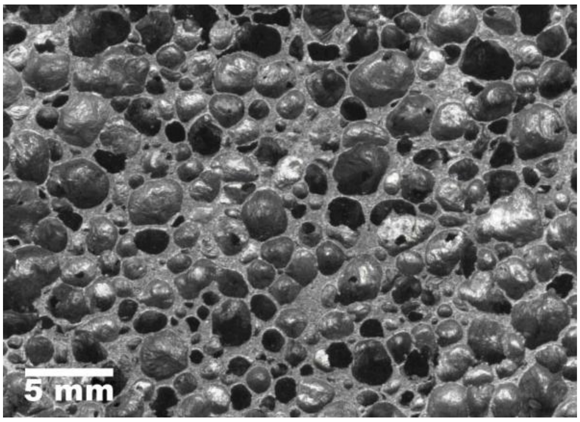


Figure 3: Specimen during sound absorption testing

Figure 4: a) Optical microscope and b) SEM microstructure of produced composite foam with relative density of 0.20



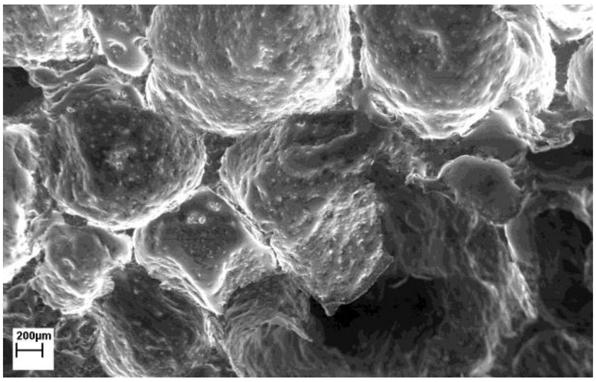


Figure 5: Effect of foam thickness on the sound reduction index (R) of aluminum foams and sandwich panels

Figure 6: Effect of relative density on the sound reduction index (R) of aluminum foams

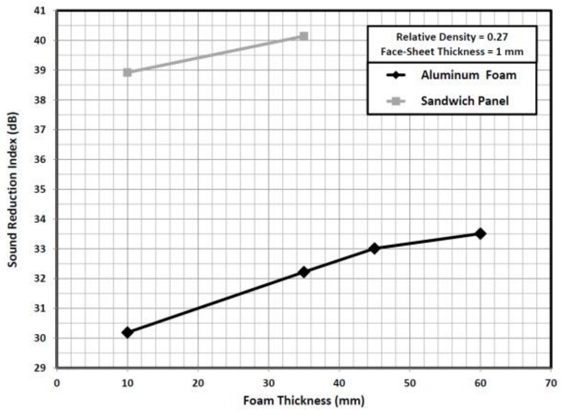


Figure 8

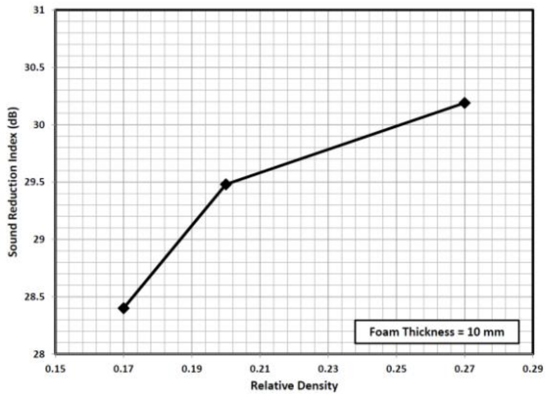


Figure 9

Tables

Table 1. Parameters of test specimens.

Specimen	Density (g/cm^3)	Relative density (%)	Foam thickness (mm)	Face-sheet thickness (mm)	Length × Width (mm × mm)
1F	0.46	0.17	10	-	180 × 180
2F	0.55	0.20	10	-	180 × 180
3F	0.73	0.27	10	-	180 × 180
4F	0.73	0.27	35	-	180 × 180
5F	0.73	0.27	45	-	180 × 180
6F	0.73	0.27	60	-	180 × 180
7S	0.74	0.27	10	1	180 × 180
8S	0.74	0.27	35	1	180 × 180

F = Foam sheet
S = Sandwich panel with aluminum foam core and aluminum face-sheet

Table 2. The sound reduction index (R) of test specimens.

Specimen	Relative density (%)	Foam thickness (mm)	R (dB)
1F	0.17	10	28.40
2F	0.20	10	29.48
3F	0.27	10	30.19
4F	0.27	35	32.22
5F	0.27	45	33.01
6F	0.27	60	33.51
7S	0.27	10	38.92
8S	0.27	35	40.14