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On the acoustical properties of metallic hollow sphere structures (MHSS)

W. Pannert, R. Winkler, M. Merkel *

University of Applied Sciences Aalen, Department of Mechanical Engineering, Beethovenstr. 1, 73430 Aalen, Germany

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ABSTRACT

Well-known advantages of cellular metals are their high ability for energy absorption, good damping behavior and sound absorption at a high specific stiffness. This paper has a focus on the absorption coefficient representing the acoustical property. The absorption coefficient is analysed experimentally by an impedance tube. Results fit well to theoretical investigations described by Champoux and Allard.

1. Introduction

Regarding the acoustical properties of an engineering material the reflection and the absorption coefficient are seen as essential. The physical background is based on the assumption that an incoming plane wave is reflected at the boundary between two acoustical different materials due to the differences in the acoustic impedances Z of the involved materials. While I_{in} represents the intensity of the incoming wave, I_{ref} the intensity of the reflected wave and I_{trans} the intensity of the transmitted wave, the reflection coefficient r and the absorption coefficient α are coupled by the following relations [1,2]:

$$I_{ref} = |r|^2 * I_{in} \text{ and } I_{trans} = \left(1 - |r|^2\right) * I_{in} = \alpha * I_{in}. \quad (1)$$

The absorption coefficient α varies with frequency and angle of the incident wave. For a given material it is a function of the material thickness, density, pore size and flow resistance.

2. Experimental setup

2.1. Theoretical background of measurement procedure

There are mainly two types of methods to determine the acoustic absorption coefficient — the reverberation room and the impedance tube. A reverberation room is used if the absorption coefficient is of interest for all angles of incoming waves. Large samples are needed (up to 10 m^2). The absorption coefficient of normally incident waves can easily be measured by an impedance tube. We used the second method, since it is faster, generally reproducible and in particular requires relatively small samples. There are two different impedance tube methods available. The transfer function method is a relatively recent development. A broadband noise signal is used as sound source. A detailed description of this method is given in DIN EN ISO 10534-2. The transfer function method is based on the fact that the sound reflection factor r at normal incidence, can be determined from the measured transfer function H_{12} between two microphones, which are positioned in front of the material at distances x_1 and x_2,

$$r = \frac{H_{12} - H_{in}}{H_{ref} - H_{12}} \cdot e^{j2k_o x_1}. \quad (2)$$

H_{in} and H_{ref} are the complex transfer functions of the incoming resp. reflected wave, k_0 is the wave vector and x_1 is the distance between the material and the nearest microphone.

2.2. Sample preparation and measurement

Two different samples of MHSS are investigated, MHSS 113 and MHSS 86 with 2.5 mm resp. 1.5 mm sphere-diameter (Fig. 1). The measurement is done with an impedance tube whereas the frequencies range from 500 Hz to 3500 Hz, (Fig. 2).

* Corresponding author. Tel.: +49 73 61 576 2133; fax: +49 73 61 576 2270.
E-mail addresses: Wolfram.Pannert@htw-aalen.de (W. Pannert), Rolf.Winkler@htw-aalen.de (R. Winkler), Markus.Merkel@htw-aalen.de (M. Merkel).

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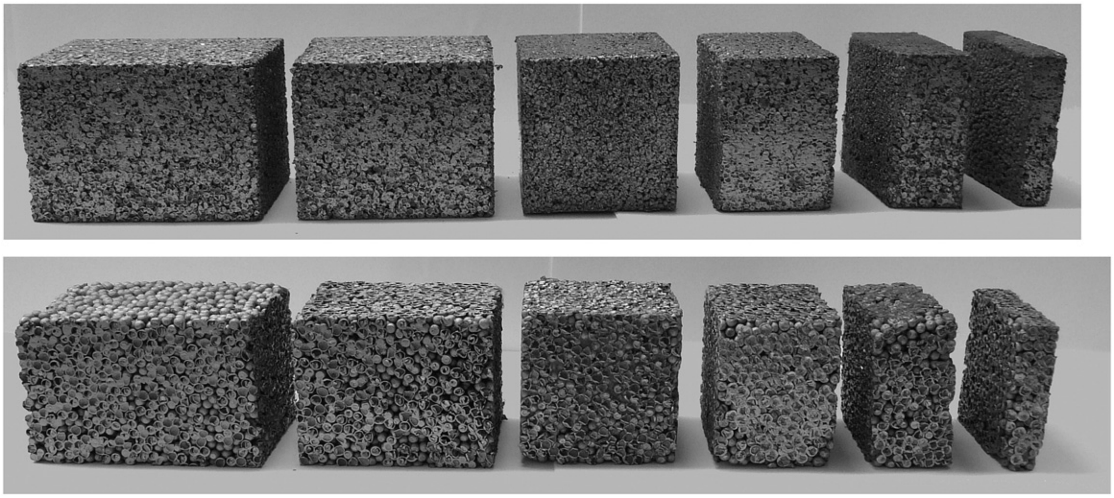

Fig. 1. MHSS 86 and MHSS 113: samples with different thickness: from 10 mm to 60 mm.

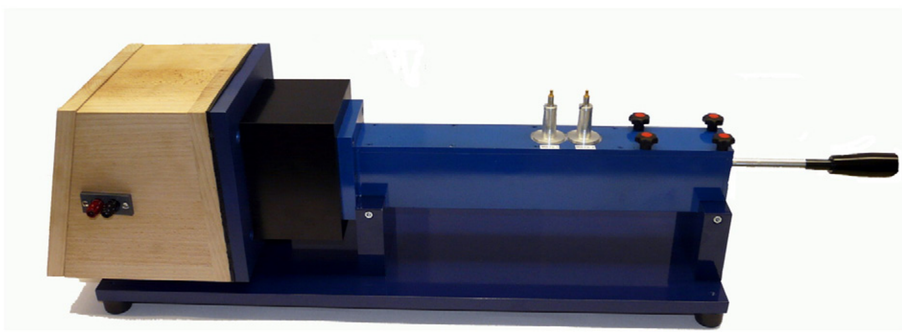

Fig. 2. Experimental setup: impedance tube (500 Hz–3500 Hz).

2.3. Comparison with theory of sound in porous media

Porous materials consist of a solid frame and a fluid (gas). According to the simple Rayleigh-model of a porous absorber, the viscosity of the fluid is responsible for the energy dissipation due to friction between the fluid and the frame. The flow-resistance parameter Ξ describes this relation. Solving the wave-equation with appropriate boundary conditions, the complex frequency dependent impedance $Z(\omega)$ of an absorber with thickness d can be written as [1]:

$$Z(\omega) = -j\rho c\frac{\sqrt{\chi}}{\sigma}\sqrt{1 - j\frac{\Xi\sigma}{\omega\rho\chi}} \cdot ctg(k_a d). \tag{3}$$

Parameters are defined as: k_a wave number in the absorber; ρ: density of air; c: speed of sound in air; σ: porosity; χ: structure form

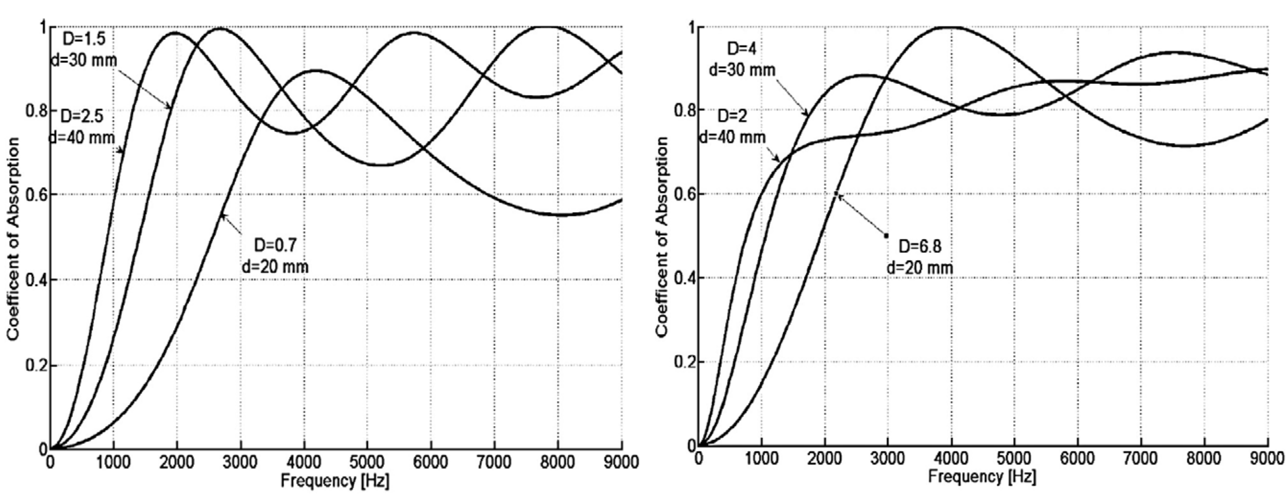

Fig. 3. Curves based on theory of Rayleigh with variations in parameter D and thickness d.