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MAGNETICALLY CONTROLLED SOUND ABSORPTION BY MEANS OF A COMPOSITE ADDITIVELY MANUFACTURED MATERIAL

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Abstract

A composite additively manufactured material for controlled sound absorption is proposed. The operation of the material is based on its changeable microgeometry with steel balls that modify propagation of acoustic waves when subject to an external magnetic field. Both numerical predictions and experimental verification is provided.

1. Introduction

Porous materials are known for their exceptional acoustic properties. In rigid foams the energy of acoustic waves is dissipated due to a visco-thermal interaction between air particles and a solid skeleton. Given the microgeometry of a conventional porous material, the acoustic characteristics like sound absorption and insulation are dependent solely on the material thickness for the same excitation conditions. However, the concept of an adaptable additively manufactured sound absorber was introduced and discussed in [1, 2]. The idea is based on the modification of material microstructure, keeping its outer dimensions unchanged. It turned out possible by designing a specific periodic shape of a rigid skeleton and inserting to the pores small steel balls that redirect air-flow to wide or narrow internal channels by gravity or centrifugal forces. In this way, one affects the intensity of visco-inertial and thermal phenomena resulting in different sound absorption spectra.

This contribution is an extension to the previous work and presents another method for a controlled steel ball relocation. Instead of gravity or centrifugal forces, a neodymium magnet is applied to influence the position of balls trapped in the pores. Two configurations studied in the previous papers [1, 2] are obtained by placing the magnet close to the bottom or lateral sides of a square 3D printed impedance tube extension containing the adaptable material sample and hung vertically on a wall: vertical state V—with balls clogging the wide channels in the direction of incidence and forcing more tortuous air-flow through narrow oblique channels, and horizontal state H—with balls closing wide channels perpendicular to the direction of incidence and allowing less tortuous air-flow mainly through wide channels parallel to the direction of incidence to happen. In addition to these two extreme situations, the proposed magnetic relocation technique opens new possibilities in achieving intermediate absorption states.

2. Methods

The research was conducted using the cuboidal material sample and the square impedance tube extension (see Figure 1) produced in the SLA and FDM additive manufacturing technologies, respectively [3]. A Brüel & Kjær equipment was utilised to perform measurements. The hybrid multiscale modelling technique [4] was applied to evaluate homogenised equivalent-fluid properties based on a periodic unit cell (see Figure 1) representative for the material. Two Helmholtz problems were solved in the $30 \times 30 \times 60$ mm rectangular domain using the homogenised properties to calculate the sound absorption coefficient resulting from the V and H states. The finite-element analyses were run in the open-source FEniCS software [5].

3. Results

Figure 1 presents the experimental and computational sound absorption coefficient values obtained for two material states H and V. In general, the higher the values, the more energy of acoustic waves is dissipated within the material. A substantial difference in performance is observed between the states, and the state V with a higher microstructural tortuosity is shown to yield better overall absorption. However, if applicably controlled, the material offers sound absorption at the level of 0.7 and higher for frequencies ranging from about 550 Hz to 1.1 kHz and from 1.9 kHz to 6.4 kHz, as confirmed by the measurements.

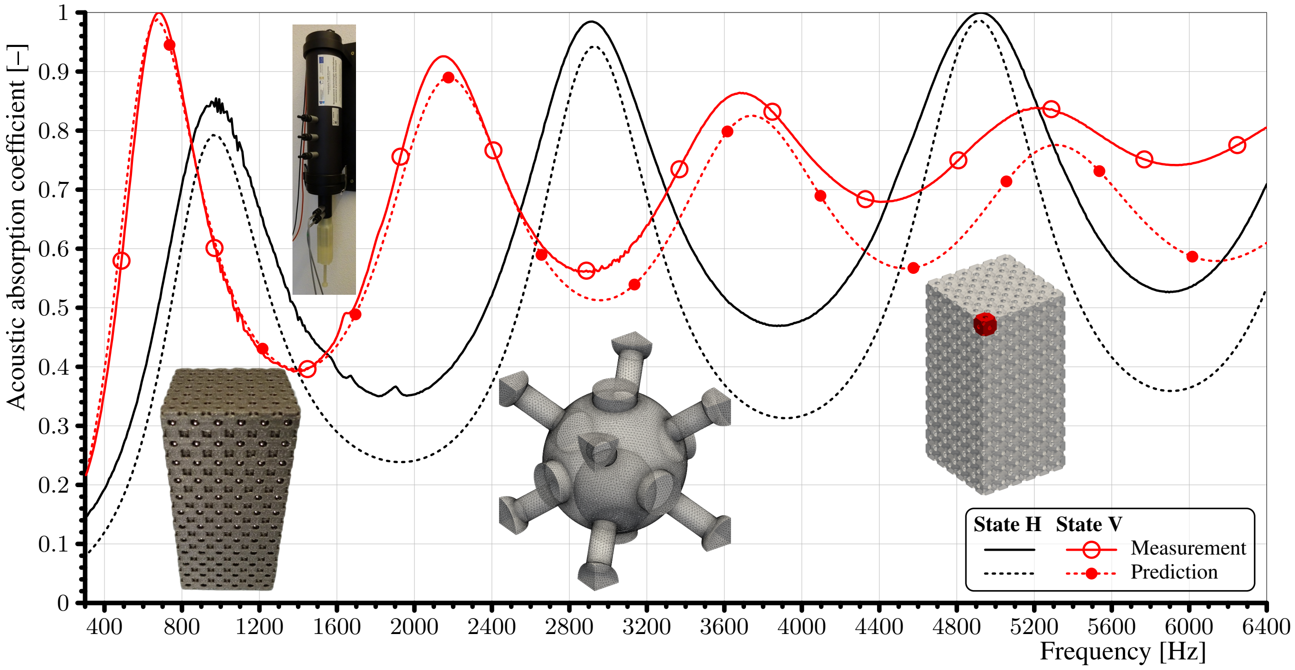

Figure 1: Normal incidence sound absorption coefficient spectra for a 60 mm-thick material layer in both V and H ball configurations. The insets in the figure show (from left to right): the additively manufactured sample, the impedance tube with the square 3D printed extension, the periodic unit cell used in calculations, the computer model of a sample with a single periodic skeleton component highlighted.

4. Conclusions

A composite material for magnetically controlled sound absorption was presented. Its cuboidal sample was additively manufactured and tested in an impedance tube. The normal incidence measurements of acoustic pressure indicate that the sound absorption spectrum in the material depends on the position of steel balls within its microstructure. The balls were moved by placing the sample in an external magnetic field. Two extreme states were investigated in which the balls were attracted in two mutually perpendicular directions: along as well as transversely across the direction of incidence. The experimental results were predicted with good accuracy using multi-scale modelling.

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