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Acoustic properties of a porous polycarbonate material produced by additive manufacturing

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ABSTRACT

This paper aims to investigate the acoustic properties of porous polycarbonate material (PPM) fabricated by additive manufacturing, and the feasibility to tailor artificial porous sound absorbing material is studied. Four PPM samples with different perforation angles were printed by using a 3D printer. Polycarbonate material was used, and the samples were printed with 25.4 micrometre layer resolution. Their sound absorption coefficient was experimentally measured using the two-microphone impedance tube method. It was found that with increased the perforation angle and constant porosity, the sound absorption was decreased. The results indicated that by adjusting the perforation angle and the airgap behind the sample, significant sound absorption can be achieved in the low frequencies where conventional porous materials may not be that effective. The results obtained in this paper provide a new approach for the fabrication of new porous sound absorbing materials.

1. Introduction

Porous sound absorbing materials are widely used in the acoustic design of buildings, vehicles, ships, and aircraft. Porous material is popular for noise control because of the ease of use, the range of possible designs and flexible combinations, and the fact that no extra energy input is required. In order to reduce the environmental implications and human health issues associated with the use of conventional porous materials [1–3], the use of innovative porous materials for noise control is necessary, and they have been extensively investigated in the past few years.

Aiming at understanding the acoustic performance of porous fibrous materials and establishing a database, Wang and Torng [4] have experimentally investigated porous fibrous materials manufactured from glass fibre or mineral wool. Ersoy and Kucuk [5] characterized an industrial tea-leaf-fibre waste material for its sound absorbing properties. Similarly, the acoustic properties of bio-luffa-fibre were measured by Koruk and Genc [6]. Besides natural fibre materials, the acoustic sound absorption coefficient of open-cell polyolefin-based, poly (ethylene-*co*-octene) foam, and poroelastic porous foams were also examined [7–10]. Arenas et al. [11] designed an acoustic absorbing material for highway noise barriers using co-combustion bottom ash. The sound absorption characteristics of different porous metal materials were also quantified in the literature [12–16].

The acoustic properties of various porous materials created by different manufacturing methods were already studied and documented. However, so far, the sound absorption of porous polycarbonate material (PPM) produced by additive manufacturing has not been well presented in the literature [4–16]. This paper investigates the acoustic properties of 3D printed (3DP) PPM and the feasibility of the fabrication of the porous sound absorbing material by additive manufacturing.

2. Material and methods

2.1. Materials and test samples

The VisiJet-SL Materials (Clear), supplied by 3D-Systems/Australia (Australia), is used in this study. It consists of 50% propylene carbonate and 50% mixed triarylsulfonium salts, and the density is 1.12 g/cm^3. Four PPM samples, namely 3DP-1, 3DP-2, 3DP-3, and 3DP-4, are printed by using a professional 3D printer (ProJet 7000), which is purchased from 3D-System Inc. (USA). All samples are printed with 25.4 micrometre layer resolution; their accuracy is 0.0254–0.05 mm per 25.4 mm of part dimension. In this study, the model interior is defined as solid, the thickness and diameter of the samples are 10 mm and 29 mm, and the pore diameter is 0.8 mm as shown in Fig. 1. The perforation angle, θ of the 3DP-1, 3DP-2, 3DP-3 and 3DP-4 are 0°, 15°, 30° and 45°, respectively. The samples had an average constant porosity $\phi = 7.4\%$.

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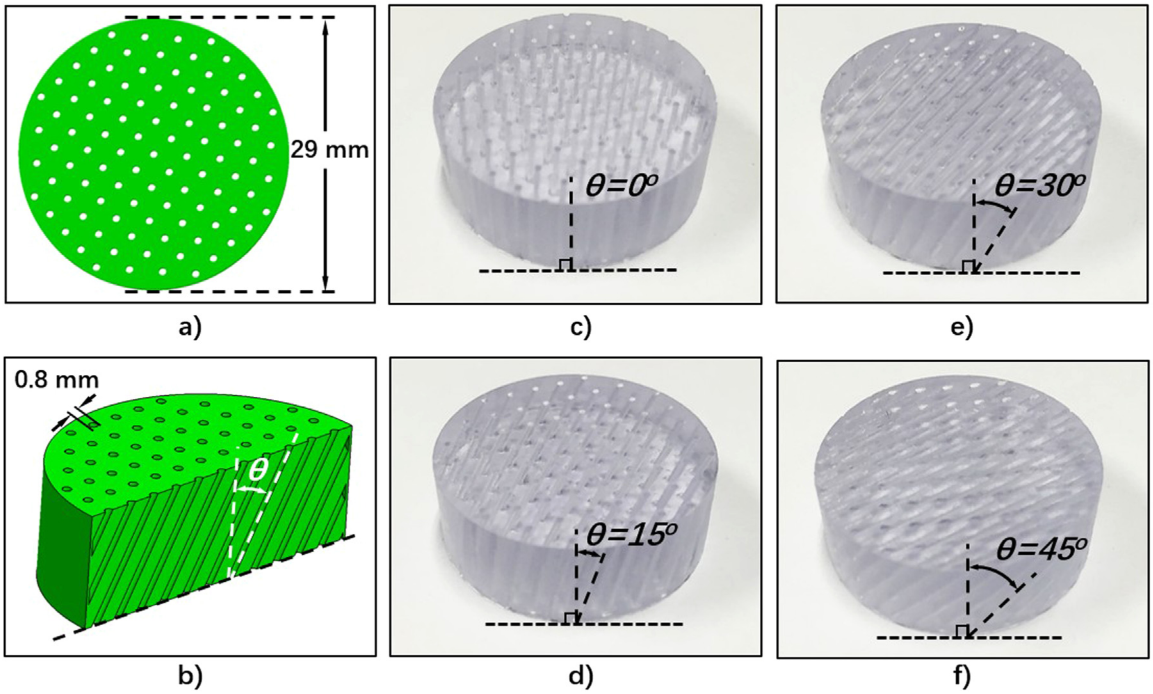

Fig. 1. PPM samples: design of test samples (a) and (b), 3DP-1 with $\theta=0°$ (c), 3DP-2 with $\theta=15°$ (d), 3DP-3 with $\theta=30°$ (e) and 3DP-4 with $\theta=45°$ (f).

2.2. Sound absorption coefficient measurement

Fig. 2 shows the measurement setup in the laboratory, where the Brüel and Kjær impedance tube and Pulse LabShop are used in this study. The two-microphone transfer function method is used according to ASTM E1050-12 standard [17]. In this method, the complex sound reflection coefficient R of a test sample is calculated from the corrected acoustic transfer function H_{12}. According to Chung and Blaser's [18] results, the complex sound reflection coefficient is:

$$R = \frac{H_{12} - e^{-jks}}{e^{jks} - H_{12}} e^{2jk(l+s)} \quad (1)$$

where the wave number $k=2\pi f/c$, l is the distance between Mic 2 (Fig. 2) and the front of the test sample, s is the distance between the two microphones. The specific impedance ratio $Z/\rho c$ and the normal incidence sound absorption coefficient α_n are then calculated by [17–19]:

$$\frac{Z}{\rho c} = \frac{1 + R}{1 - R} \quad (2)$$

$$\alpha_n = 1 - |R|^2 \quad (3)$$

where ρ and c are the density and speed of sound in the air, respectively. It should be noted that the normal sound absorption coefficient indicates the ability of the porous material to absorb sound energy in different frequency bands.

Furthermore, in order to understand the effect of an airgap on the sound absorption coefficient of PPM, the following two cases were investigated. One case had an airgap behind the samples in the impedance tube and the other had no airgap.

3. Results and discussion

The sound absorption coefficients of the PPM samples in the range from 500 to 6000 Hz are shown in Fig. 3. It can be seen that the sound absorption coefficient curves of the four PPM samples have a similar shape. The peaks of their sound absorption coefficients lie in the frequency range from 2000 Hz to 4000 Hz. Note that the 3DP-1 with perforation angle $\theta=0°$ has the highest sound absorption coefficient at the frequency of 3328 Hz. The results show that the increase of the perforation angle gradually decreases the peak sound absorption coefficient of the PPM sample

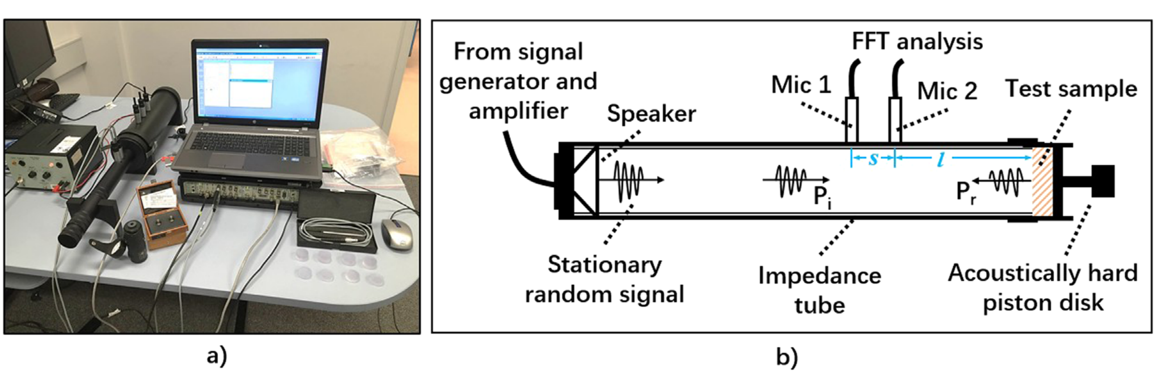

Fig. 2. Acoustic sound absorption coefficient measurement: measurement setup in the laboratory (a) and schematic of two-microphone impedance tube method (b).