FABRICATION OF ECO-FRIENDLY MICRO-PERFORATED PANEL THROUGH ADDITIVE MANUFACTURING

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1 Introduction

Frequent exposure to high noise levels can lead to a range of adverse health consequences, including diminished relaxation, cognitive impairment, disrupted sleep, cardiovascular disorders, hypertension, and related conditions [1]. The utilization of micro-perforated panels (MPPs) for absorbing sound energy along its propagation path represents a direct and effective engineering solution for noise control. MPPs, characterized by thin plates featuring sub-millimeter perforations and thicknesses below 1 mm [2].

This research introduces an innovative methodology aimed at empowering industry professionals to enhance the cost-competitive production of MPPs. By addressing challenges inherent in conventional manufacturing processes, such as manual preparation and pressing, this approach stands as a significant advancement in the field.

This study aims to achieve three primary objectives: (i) the fabrication of a new natural fiber-reinforced composite micro-perforated panel (NFRC-MPP) using cork fiber and polylactic acid (PLA) employing 3D printing technology; (ii) a comprehensive assessment of its experimental and analytical properties; and (iii) developing a hybrid eco-friendly absorber designed for optimal sound absorption capabilities.

2 Method & Materials

2.1 Fabrication of NFRC- MPPs

To develop optimized MPP absorbers, two distinct of commercial filaments (PLA polymer filament and PLA/ CORKWOOD composite filament), were used. This choice enabled precise monitoring of the acoustic absorption effect of the fibers in NFRC-MPP samples. The standard PLA filament used in this study was IngeoTM Biopolymer 4043D manufactured by Nature Work. Additionally, commercial corkwood filaments (EasyCorkTM by Form Futura®) were employed for 3D printing of the NFRC-MPPs.

The EasyCorkTM filaments consist of a lightweight polymer containing 30 wt.% natural cork fibres and 70 wt.% biodegradable PLA polymer. All the samples were fabricated by printing PLA and PLA/corkwood materials on fixed bed via a FDM 3D printer (Zortrax, Poland, model M200 plus) with the resolution 0.09-0.39 mm per layer. The nozzle temperature was fixed at 210 °C and 230 °C for IngeoTM Biopolymer 4043D and EasyCork respectively.

2.2 Design of Experiment (DoE)

Using the Response Surface Methodology (RSM) technique and the 5-level-3-factor central composite design (CCD) method, the experimental design was determined in order to achieve the highest values of Sound Absorption Coefficient Average (SACA) and the lowest possible manufactured cost (as the two predicted responses) [3]. The method uses mathematical and statistical techniques to analyses and optimize a process in which a response of interest (SACA, Cost) is influenced by several independent design variables (namely perforation diameter (d), panel thickness (t), and distance between the perforations (b).

2.3 Sound Absorption Coefficient Average

The normal incidence sound absorption coefficient of the samples was measured using a two-microphone acoustic impedance tube system (SW420-470, BSWA TECH) in accordance with ISO 10534-2.

The theoretical analysis of the MPP absorber based on Maa's model [2] was conducted using the equivalent electro-acoustic circuit (EAC) under the simplified conditions [4]. As illustrated in Fig. 2, a single MPP layer is positioned at a distance D from a rigid wall.

3 Results

The normal incidence sound absorption coefficients of the MPPA, corresponding to varying gap thickness between the rigid wall and MPPA, were measured and are illustrated in Fig. 3. The results showed that the average sound absorption coefficient of the NFRC-MPP sound absorber is 25% more than that of conventional MPP absorbers. The sample with a perforation diameter of 0.70 mm, a panel thickness of 0.90 mm, and an 8 mm distance between the perforations was selected as the optimal sound absorber.

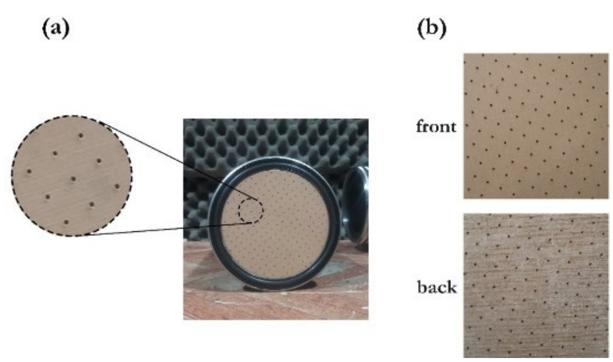

Figure 1: a) MPP Irregular Circular Shapes; b) unsmooth back surface 3D printed NFRC-MPP sound absorber.

Furthermore, variations in hole diameter and perforation distance were observed to have a slight impact on the resonant performance of the MPP. Additionally, increasing the depth of the back cavity from 30 mm to 70 mm reduced the resonant frequency by more than 41%. Hence it is necessary to select a

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suitable value for the back cavity depths [5].
The measurement results for NFRC-MPP panels do not correspond well, with the theoretical data, as shown in Fig. 3. Several reasons may be cited to explain the discrepancy between Maa's model outputs and the experimental results.

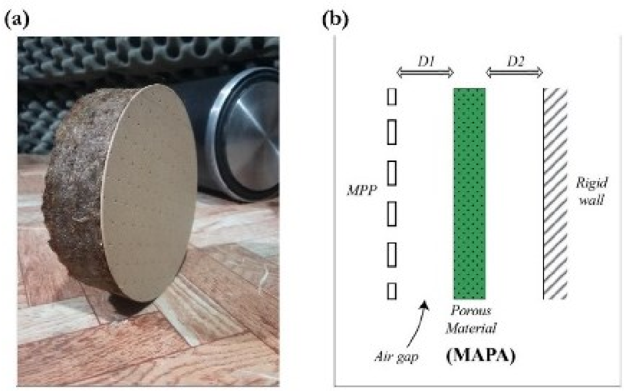

Figure 2: a) MPPA sample; b) the schematic of the sound absorber.

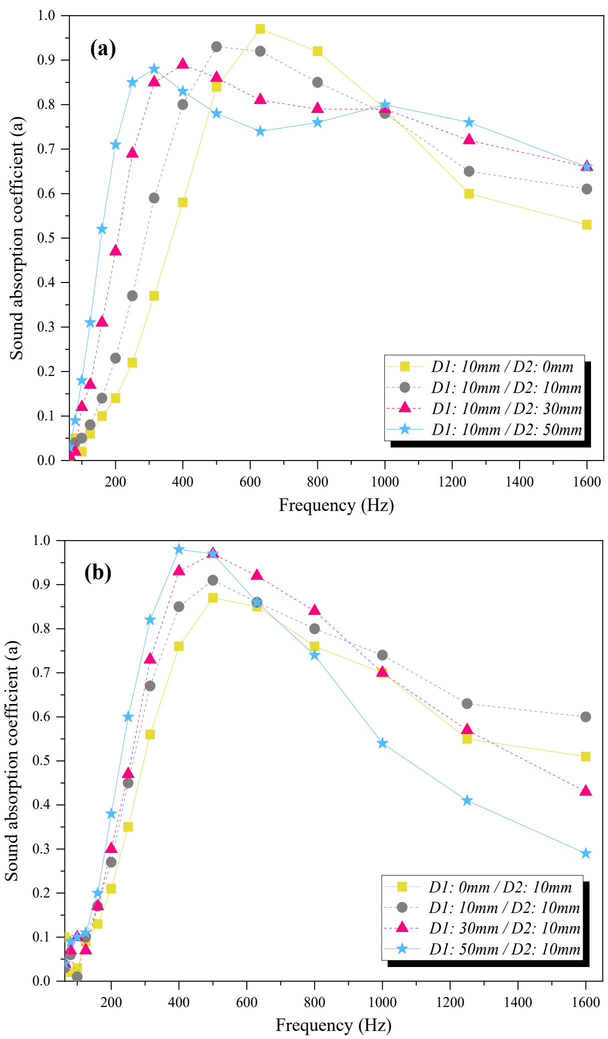

Figure 3: Effect of back cavity depth on sound absorption performance of MAPP A absorber (A: the value of D1 is constant and D2 is variable and B: the value of D1 is variable and D2 is constant).

As shown in Figure 2, the parallel arrangement of two layers of MPP and the addition of an optimized kenaf layer (refer to [6]) behind the MPP, improved the sound absorption.
Figure 3 represents the Effect of back cavity depth on sound absorption performance of MPPA.
The results showed that changing the back cavity depths would slightly affect the resonant frequency of the MPP. Increasing the depth of the back cavity from 30 mm to 70 mm reduced the resonant frequency by more than 41%. Hence, it is necessary to select a suitable value for the back cavity depths.
Previous studies have also shown that among NFRC-MPPs with the same resonant frequency and density, samples with greater interior porosity exhibited superior sound absorption [7]. This is related to the fact that the pores and tortuous structure within MPPs were made from the coconut fibers. therefore, NFRC-MPP simultaneously absorbs the sound energy through two mechanisms of resonance (the associated with the Helmholtz absorber) and viscothermal loss (related to porous materials) [8,9].

4 Conclusions

Smart manufacturing of acoustic panels works as a booster for engineering noise controls and improves the effectiveness of the overall Hearing conservation program.
The values found in this study and those published in the literature for other types of bio composite MPP suggest that Cork fibre MPP has significant potential for use, either alone or in combination with Kenaf materials, as an acoustic conditioning material.

Acknowledgments

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