Sound Absorption Performance of Sustainable 3D-Printed Micro-Perforated PLA Panels

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Abstract

In the current study, the sound absorption performance of 3D-printed PLA micro-perforated panels fabricated via fused deposition modelling was evaluated. During evaluation, thickness was kept constant at 1 mm while pore diameter was varied as 0.4 mm, 0.6 mm, 0.8 mm, and 1 mm. For experimentation, the two-microphone impedance tube method was used in accordance with ASTM E1050, over a frequency range of 50 to 5000 Hz. Tests were conducted for variation of both perforation diameter and back air cavity (30–70 mm). The results show that the sample with 0.8 mm diameter and 50 mm air gap gives the best performance (average SAC of 0.865 across the 500–2000 Hz speech intelligibility range). These finding confirms 3D printed MPP made by PLA as a good option for tunable indoor noise control applications.

Keywords: Sound absorption Coefficient; Micro-perforated panel; PLA; 3D printing, FDM; Impedance tube

1. Introduction

Noise control in built environments demands effective sound-absorbing solutions that are tuneable, sustainable, and manufacturable with precision. Micro-perforated panels (MPPs) backed by an air cavity behave as distributed Helmholtz resonators, absorbing sound through viscous dissipation in sub-millimetre perforations [1]. 3D printing enables fabrication of MPPs with precise sub-millimetre geometries unattainable by conventional methods, and has been applied to open-porous structures, sonic crystals, and porous polycarbonate absorbers [2,3]. Polylactic acid (PLA), a bio-based thermoplastic, has recently emerged as a printable MPP material with performance competitive with metallic panels [4,5]. This study systematically investigates how hole diameter and back air gap independently govern the acoustic performance of FDM-printed PLA MPPs.

2. Materials and Methods

2.1. Sample Fabrication

Four circular PLA MPP samples (diameter 34.7 mm, thickness 1 mm) were fabricated using an Anycubic Kobra 3 FDM printer equipped with a 0.2 mm nozzle, PLA Pro filament (3D Galaxy), 100% infill density, print temperature 210^0 C, and 0.1 mm XY compensation. Each sample have 94 equi-spaced perforations in a polar array with 3 mm centre-to-centre spacing. Only the hole diameter was varied across samples as 1.0, 0.8, 0.6, and 0.4 mm, yielding porosities of 7.81%, 5.00%, 2.81%, and 1.25% respectively. Samples are designated HxTyGz (hole dia. x mm, thickness y mm, air gap z mm).

2.2. Acoustic Testing

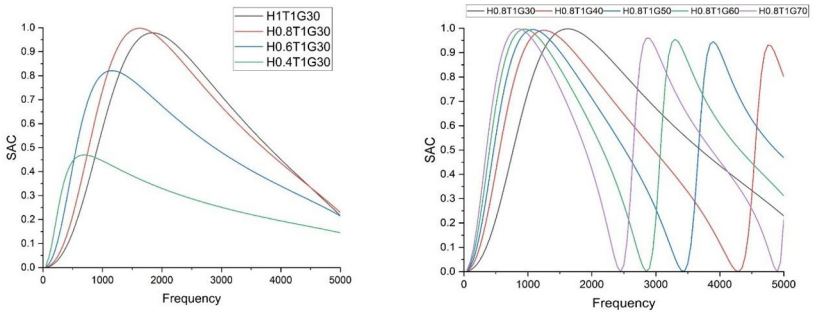
Normal-incidence sound absorption coefficients were measured using an Alpha Acoustics two-microphone impedance tube (35 mm diameter, 50-5000 Hz) following ASTM E1050. Microphones at 65 mm (X1) and 35 mm (X2) from the sample captured incident and reflected pressure waves, processed via the transfer function method. Tests were conducted at ~25 C with a fixed source level of 100 dB. The back air gap was first fixed at 30 mm to assess the effect of porosity, then varied from 30 to 70 mm for the optimal sample.

3. Results

Figure 1 presents SAC versus frequency for all four samples at a 30 mm air gap. All samples show a single broad absorption peak characteristic of Helmholtz resonator behaviour [1]. H0.8T1G30 (5% porosity) achieves a peak SAC of ~1.0 at ~1500 Hz - the highest among all configurations. Table 1 summarises average SAC values for both the porosity study and the air gap study. As air gap increases from 30 to 70 mm (Figure 1, inset concept), the primary peak shifts from ~1500 Hz to ~850 Hz and secondary resonance peaks emerge due to higher-order quarter-wavelength modes, consistent with Maa's MPP theory [1].

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[a] Effect of porosity

[b] Effect of Air Gap

Figure 1. SAC vs. frequency for tested Configurations

Table 1. Average SAC across frequency bands for porosity and air gap studies.

Sample	Avg SAC 50-5000 Hz	Avg SAC 500-4000 Hz	Avg SAC 500-2000 Hz
H1T1G30	0.568	0.703	0.692
H0.8T1G30 *	0.583	0.720	0.780
H0.6T1G30	0.488	0.592	0.729
H0.4T1G30	0.282	0.321	0.409
H0.8T1G40	0.557	0.642	0.857
H0.8T1G50 **	0.588	0.624	0.865
H0.8T1G60	0.580	0.660	0.846
H0.8T1G70	0.541	0.657	0.585

** Best porosity configuration. ** Best air gap configuration (highest SAC in 500-2000 Hz band).*

4. Discussion

The 0.8 mm hole diameter (5% porosity) gives the best performance as it optimally balances acoustic resistance and reactance: Results shows that, smaller holes create too much resistance while larger holes reduce viscous losses and shift the peak to higher frequencies which is consistent with Maa's classical MPP theory [1] and prior PLA MPP studies [4,5]. The 50 mm air gap maximises SAC in the 500-2000 Hz speech intelligibility range (IEC 60268-16: >60% of intelligibility information), Fig 1.b highlights that larger gaps are less effective in this critical band. Thus, 3D printing enables manufacturing of sub-millimetre geometries with higher repeatability, which offers sustainable alternative to metallic MPPs [2,3].

5. Conclusion

3D printed PLA MPP's with a pore diameter of 0.8 mm and 50 mm back air cavity achieves an average SAC of 0.865 in the critical 500-2000 Hz speech intelligibility range which confirms that 3D-printed PLA MPPs are easy alternative sustainable solution for indoor noise control applications.

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