Journal of Physics: Conference Series

PAPER • **OPEN ACCESS**

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To cite this article: Desmond Daniel Chin Vui Sheng *et al* 2024 *J. Phys.: Conf. Ser.* **2721** 012010

Journal of Physics: Conference Series **2721** (2024) 012010 doi:10.1088/1742-6596/2721/1/012010

SOUND ABSORPTION OF MICROPERFORATED PANEL MADE FROM POLYLACTIC ACID (PLA)

Desmond Daniel Chin Vui Sheng[1*], Musli Nizam Bin Yahya[2], Nazli Bin Che Din[3], Nur Aisyah Bin Mohamad Nazam[4], Keng Yinn Wong[5], M. R. M. Asyraf[6], Vignesh Sekar[7]

[1] Applied Mechanics Research and Consultancy Group (AMRCG), Faculty of Mechanical Engineering, Universiti Teknologi Malaysia, 81310 Johor Bahru, Johor, Malaysia.

[2] Department of Transport Engineering Technology, Faculty of Engineering Technology, Universiti Tun Hussein Onn Malaysia, Pagoh Higher Education Hub, 84600 Pagoh, Johor, Malaysia.

[3] The Centre for Building, Construction & Tropical Architecture (BuCTA), Faculty of Built Environment, Universiti Malaya, 50603 Kuala Lumpur, Malaysia.

[4] Faculty of Mechanical Engineering, Universiti Teknologi Malaysia, 81310 Johor Bahru, Johor, Malaysia.

[5] Air-Conditioning Engineering Research Group (ACER), Faculty of Mechanical Engineering, Universiti Teknologi Malaysia, 81310 Johor Bahru, Johor, Malaysia.

[6] Engineering Design Research Group (EDRG), Faculty of Mechanical Engineering, Universiti Teknologi Malaysia, 81310 Johor Bahru, Johor, Malaysia.

[7] Department of Mechanical Engineering, Saveetha Engineering College, Thandalam, Chennai, 602 105, India.

Corresponding author's email address : daniel.chin@utm.my

Abstract. The microperforated panel (MPP) is a unique panel that has evolved from the traditional perforated panel. Previously, the perforated panel was mainly used as a protective cover for porous materials. The MPP absorbs sound through the viscous effect around its perforated holes. However, traditional MPPs are typically made from metallic materials that are not environmentally friendly. In contrast, polylactic acid (PLA) is a biopolymer extracted from natural resources such as corn and sugarcane. When buried in soil, PLA degrades naturally with the assistance of soil bacteria and fungi, making it an eco-friendly choice. In this study, 3D printing method was utilized to produce MPP using PLA as the material. The sound absorption performance of PLA MPP was compared to steel MPP, which served as the benchmark. Interestingly, the sound absorption performance of PLA MPP was found to be comparable to that of steel MPP. This highlights PLA as a viable material for MPP production, aligning with the global goal of environmental preservation and Sustainable Development Goal (SDG) 12, which emphasizes responsible consumption and production.

1. INTRODUCTION

In recent times, the microperforated panel (MPP) is one of the renowned panel-type sound absorbers. It is widely recognized that Professor Dah You Maa was the first researcher to report the potential of MPP to be used as a sound absorber due to its unique sound absorption properties [1]. In earlier days, a perforated panel was used for sound absorption purposes. Yet, the sound absorption properties of the perforation panel were insufficient, and therefore, the capacity of the perforated panel was downgraded to a trivial protective cover for a porous sound absorber, as the porous sound absorber greatly enhances its sound absorption performance [2, 3]. The perforated panel has insufficient acoustic resistance, mostly due to the larger perforated hole area. The idea of MPP is to reduce the perforated hole area to millimeter size and alter the perforation ratio, panel thickness, and air gap thickness accordingly to improve the acoustic resistance and, in turn, refine its overall sound absorption performance [4]. It was found that the sound absorption performance of MPP was superior compared to the perforated panel, and if the MPP is designed properly according to the acoustic condition of the environment, MPP has the potential to replace porous sound absorber as its performance is almost on par at the targeted frequency [5].

The MPP must be rigid enough as the flexibility of the panel might influence the overall sound absorption performance and hence, to date, metallic material is still widely used as the primary material in producing MPP [6]. However, the production of metallic material may harm the environment as its primary process emits huge amount of heat to the environment and might lead to the accretion of environmental temperature globally [7]. Apart from that, mining of metallic material may also contribute to the deterioration of environmental conditions over time. Therefore, researchers and acousticians are searching for alternative materials for producing MPP without neglecting the importance of preserving the environment.

Polymer is one of the alternatives for producing MPP. Several polymers, such as polyester (PE) and polypropylene (PP), have been used to produce MPP [8, 9]. Yet, these polymers are not biodegradable, and the raw material to produce these polymers was extracted from petrochemical resources [10]. Biodegradable polymers are gaining a lot of interest among researchers in recent times. Polylactic acid (PLA) is the most famous biodegradable polymer, often used for 3D printing. PLA is derived from natural resources such as starch or sugarcane [11]. PLA is also often used to produce biocomposite with natural fibers such as kenaf, coir, and wood [3, 12-17]. Hence, PLA can be considered a good alternative to replace polymers derived from petroleum resources.

This paper used PLA as raw material in producing the MPP. The 3D printing process, specifically fused deposition modeling (FDM), was employed to produce PLA MPP. Impedance tube method was implemented to obtain the sound absorption coefficients of PLA MPP, and the sound absorption performance of PLA MPP was compared to steel MPP. This study highlights the viability of using biodegradable polymer PLA in producing MPP, aligning with the 12th Sustainable Development Goal (SDG), emphasizing responsible consumption and production.

2. MATERIAL AND EXPERIMENT

Table 1. Basic properties of PLA.

Density	1.24 g/cm^3
Tensile Strength	50 MPa
Tensile Modulus	3.5 GPa
Melting Temperature	175 °C

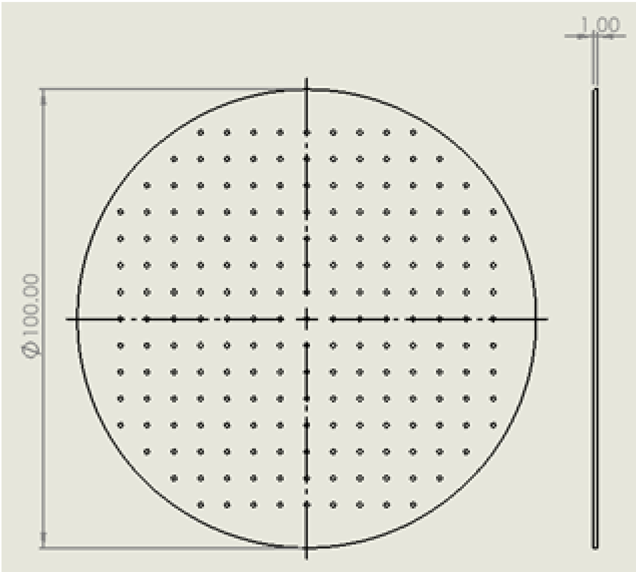

Figure 1. SolidWorks design of the MPP in this study.

As highlighted in the previous section, PLA will be used to produce MPP samples in this study. Table 1 presents the basic properties of PLA used in this study. The 3D printing process (FDM) was employed to produce MPP samples. FDM 3D printing is one of the most popular methods due to its versatility in printing complex structures with minimal setup and less tedious procedure [18]. Apart from that, FDM 3D printers are also capable of printing samples with various materials, such as PLA, PP, and acrylonitrile butadiene styrene (ABS). The MPP was first designed using SolidWorks, and the SolidWorks file was then converted to gcode for 3D printing. Figure 1 shows the SolidWorks design of the MPP sample in this study. The MPP has an outer diameter of 100 mm (following the inner size of the impedance tube) and a thickness of 1 mm. The perforation ratio was 2 %, and the perforation diameter was 1.5 mm. This study set the infill density to 20% with hexagon as the printing fill pattern. The printing speed was 60 millimeters per second, and the extruder temperature was 210 °C. The temperature of the printing platform was 50 °C to promote better adhesion for the printed samples [19]. The sound absorption coefficients of the 3D printed samples were determined using an impedance tube (B&K Type AFD 1001). The test was carried out based on the ISO 10534–2 standard. The frequency range was set from 400 to 2000 Hz, and the air gap thickness can be altered accordingly by adjusting the movable piston behind the impedance tube.

3. RESULTS AND DISCUSSION

Figure 2 shows the sound absorption coefficients of PLA MPP samples with different air gap thicknesses (10 mm, 20 mm, and 30 mm). Based on the results obtained, the maximum sound absorption coefficient of the PLA MPP samples was recorded at 1345 Hz, with a value of 0.96. The sound absorption coefficient of the PLA MPP samples slightly deteriorates with the increment of air gap thickness. When the air gap thickness was set at 20 mm, the maximum sound absorption coefficient of the PLA MPP samples was recorded at 962 Hz, with a value of 0.93. Meanwhile, the sound absorption coefficient recorded was 0.91 at 825 Hz when the air gap thickness was 30 mm.

MPP has a distinctive sound absorption coefficient pattern with one single peak, often known as the reverse bell shape, similar to the normal distribution graph pattern, albeit that the graph is not symmetrical in both sides. This pattern occurs due to the viscous effect surrounding the perforated hole area. When the frequency was below the peak sound absorption frequency, the friction between the air molecules and the perforated hole's surface area was less intense; hence, the sound absorption recorded was quite low. As the frequency increased, the friction between the air molecules and the surface of the perforated hole increased, and hence, a higher sound absorption coefficient was recorded until it reached the peak sound absorption performance. As the frequency of sound bypassed the peak sound absorption coefficient frequency, the friction between the air molecules and the surface of the perforated hole reduced and led to the decrement of sound absorption performance. The peak sound absorption performance frequency is known as the resonance frequency, where the maximum sound absorption performance of MPP occurs. The decrement of sound absorption performance with the increment of air gap thickness is considered normal. MPP can be treated as a mass-spring model (the air molecules around the surface of the perforated hole are equivalent to mass, and the air gap is equivalent to spring). When the air gap increases, the spring's stiffness reduces, reducing the sound absorption performance of MPP and shifting the peak sound absorption to a lower frequency range.

Figure 3 shows the sound absorption coefficient of PLA MPP and steel MPP with 30 mm air gap thickness. Results indicated that PLA MPP had a more prominent peak sound absorption coefficient, while steel MPP had a lower peak sound absorption coefficient (0.80 at 783 Hz). However, the peak frequency for PLA MPP was at a higher range than steel MPP. It can also be noted that the sound absorption bandwidth of PLA MPP was wider compared to steel MPP.

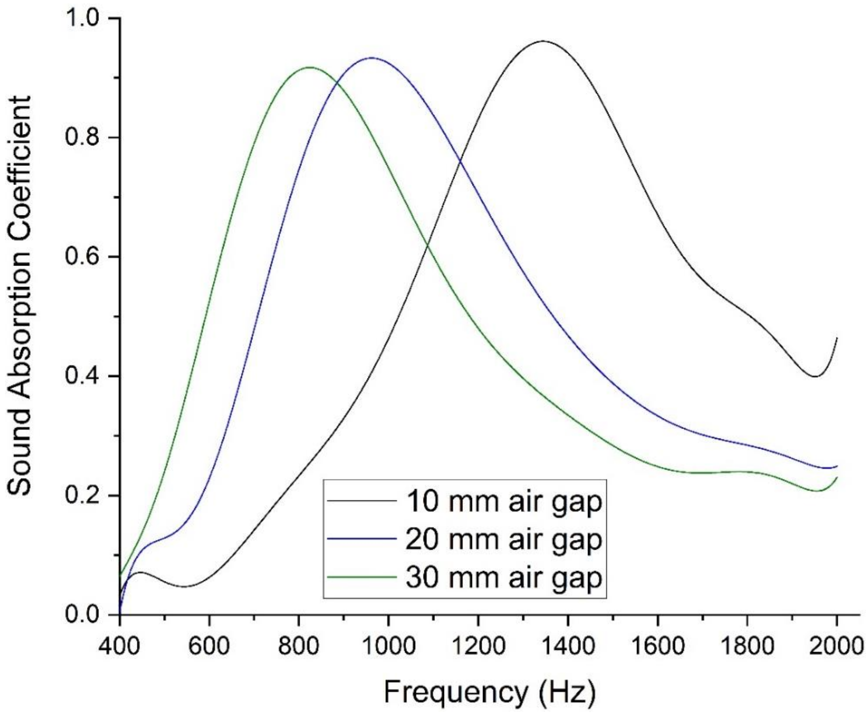

Figure 2. Sound absorption coefficients of PLA MPP samples with 10 mm, 20 mm, and 30 mm air gap thickness.

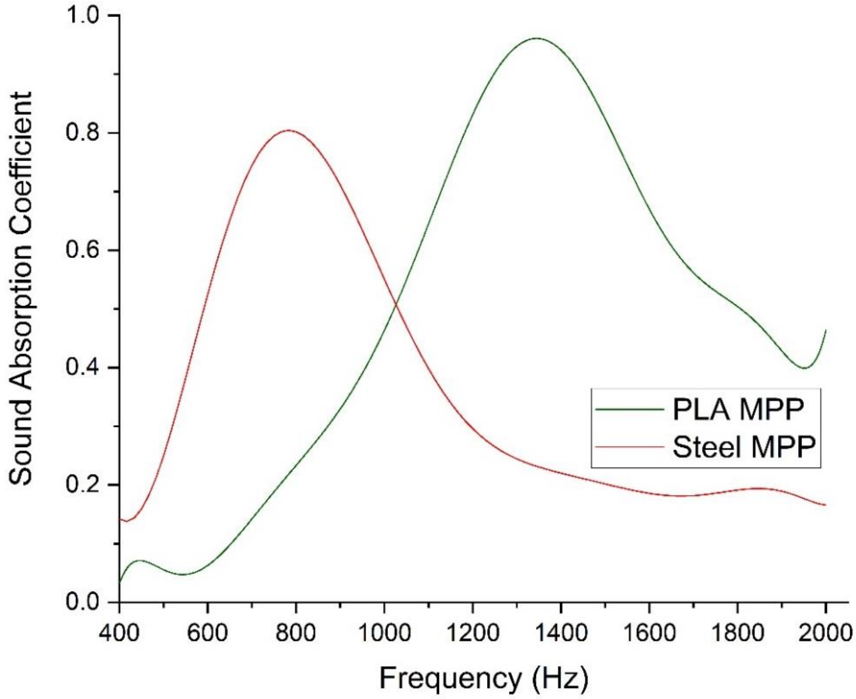

Figure 3. Sound absorption coefficient of PLA MPP and steel MPP with 30 mm air gap thickness.

4. CONCLUSION
This study presented the PLA MPP sound absorption performance produced by the 3D printing method. PLA MPP recorded the highest sound absorption coefficient at 1345 Hz, with a value of 0.96. The sound absorption coefficient diminished slightly with the increment of air gap thickness, which is a normal phenomenon in the case of an MPP absorber. It was also noted that the sound absorption performance of PLA MPP was higher than steel MPP, whereby the peak sound absorption performance of steel MPP recorded was 0.80 at 783 Hz. This study showed that PLA material has considerable potential to be used to produce biodegradable MPP. The usage of PLA is also in line with SDG 12, which emphasizes responsible consumption and production.

ACKNOWLEDGEMENTS
The author would like to express gratitude to Universiti Teknologi Malaysia for the support provided under the UTMER grant (Reference No: PY/2023/01803, Cost Center No: Q.J130000.3824.31J72). Additionally, the author extends thanks to the Faculty of Mechanical Engineering, Universiti Teknologi Malaysia, for granting access and permission to utilize the 3D printer available in the laboratory.

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