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Research Article

Simulation on Factors Influencing the Acoustic Performance of the Micro-Perforated Panel

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Abstract

Noise pollution is becoming a serious threat as they cause severe health and psychological problems. Advancement in the field of acoustics had kept the effects of noise pollution in control. One such advancement is the use of Micro-Perforated Panels (MPP) to control noise pollution. Acoustic performance of the MPP is mainly influenced by factors like thickness, perforation size and distance between the perforations. Matlab simulation was performed to understand the effect of varying the thickness, perforation size and distance between the perforations on acoustic performance of the MPP using MAA model. MPP with a thickness of 2mm, perforation size of 0.5mm and distance between the perforations of 3mm exhibits a maximum Sound Absorption Coefficient (SAC) of 0.95 at around 5kHz. This study will be resourceful for the researchers who are about to fabricate the MPP and optimizing its acoustic performance.

Keywords: Acoustics; Noise pollution; Micro-perforated panel; Matlab simulation; Sound absorption coefficient

Abbreviations: MPP: Micro-Perforated Panels; SAC: Sound Absorption Coefficient

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Introduction

Noise pollution is one amongst the major pollution around the world. Needless to say, noise pollution is bound to escalate and become more distressing over time [1]. In recent years, acoustical conditions of the environment have become a crucial aspect in building a workplace. Therefore, lots of different building designs had been applied into building a better acoustical workplace environment. However, they are not economical viable for enhancing the acoustical condition of a built workplace. Hence, micro-perforated panel was introduced to improve the acoustic condition of the built workplace. Micro-perforated panel has its advantages over traditional sound absorbing materials [2]. Maa proposed the first MPP model with a thin layer of panel consisting of sub-millimetre perforations on it. MPP is a thin layer of the panel installed in front of a rigid wall with an air gap between [3], as shown in Figure 1.

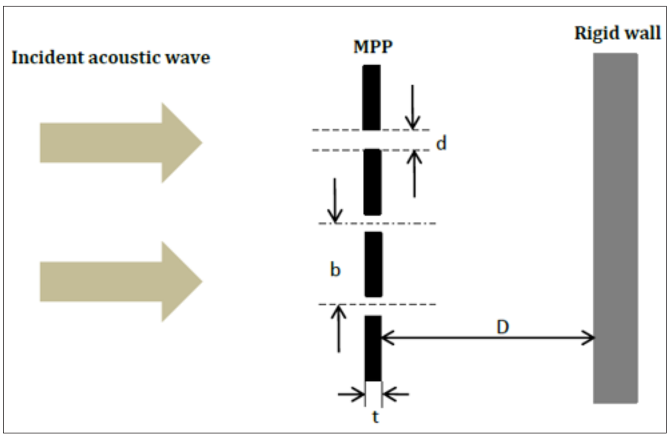

Figure 1: Schematic diagram of MPP.

Maa recommended a model to predict the acoustic properties of the MPP with an error of less than 5%. In the Maa model, the acoustic impedance Z_{pM} can be calculated using Eq. (1) [4].

$$Z_{pM} = R_{pM} + jX_{pM} \quad .....(1)$$

$$R_{pM}=\frac{c_1 t\times 10^{-5}}{pd^2}\left(\sqrt{1+\frac{X^2}{32}}+\frac{Xd\sqrt{2}}{8t}\right) \quad ....(2)$$

$$X_{pM}=0.0185\frac{tf}{p}\left(1+\frac{1}{\sqrt{9+\frac{X^2}{2}}}+\frac{0.85d}{t}\right) \quad ....(3)$$

$$X=C_2\times 10^{-3}d\sqrt{f} \quad .....(4)$$

where, R_{pM} represents the resistance of the MPP, while X_{pM} represents the reactance of the MPP. For non-metal MPP, C_1 and C_2 are the constant values, which are 0.147 and 0.316. The frequency is represented by the symbol f, t is the thickness of the panel, while d represents the diameter of the perforated hole. Lastly, the sound absorption coefficient α can be calculated using Eq. (5) [5].

$$\alpha=\frac{4R_{pM}}{(1+R_{pM})^2+\left[\omega\times X_{pM}-\cot\left(\frac{\omega D}{C_0}\right)\right]^2} \quad .....(5)$$

where, ω is the angular frequency of sound, D is the depth of the air gap, and C_0 is the speed of sound. As seen above, there are factors like thickness, perforation size, distance between the perforations are responsible for acoustic performance of the MPP. Hence, this research was performed to understand the effect of varying these factors on acoustic absorption of the MPP using Matlab simulation.

MATLAB Simulation

Matlab simulation was performed to understand the sound absorption performance of the MPP. Maa's prediction model was translated into MATLAB, and the Sound Absorption Coefficient (SAC) of the MPP was computed. The frequency range was set from 500Hz to 6000Hz. The speed of sound used was 343m/s, and the air gap distance was fixed at 1mm. Three cases listed below in the Tables 1-3 were simulated and the results are discussed.

Table 1: Effect of varying thickness on SAC of the MPP.

Sample	Thickness (mm)	Perforation Size (mm)	Distance between Perforations (mm)
MPP	1	0.5	5
	2	0.5	5
	3	0.5	5

Table 2: Effect of varying perforation size on SAC of the MPP.

Sample	Thickness (mm)	Perforation Size (mm)	Distance between Perforations (mm)
MPP	2	0.25	5
	2	0.5	5
	2	0.7	5

Table 3: Effect of varying distance between the perforations on SAC of the MPP.

Sample	Thickness (mm)	Perforation Size (mm)	Distance between Perforations (mm)
MPP	2	0.5	3
	2	0.5	5
	2	0.5	7

Results and Discussion

Effect of thickness

Figure 2 shows the simulated results of the MPP with varying thickness. It can be seen from Figure 2 that increasing the thickness of the MPP decreases the acoustic absorption and also moves the peak towards the low-frequency range. The increment of thickness actually shifted the peak sound absorption performance from higher frequency range to lower frequency range. This is a typical behavior of any sound absorber actually, whereby thinner absorber is usually used to absorb at high frequency, while thicker absorber is usually used to absorb at low frequency. This is because thinner absorber can only absorb sound with shorter wavelength (which is high frequency sound). Meanwhile, thicker absorber can absorb sound with longer wavelength (which is low frequency sound) but not able to block high frequency sound and so the high frequency sound can just bypass the absorber directly, thus explaining why the peak sound absorption shifted from higher to lower frequency range when the thickness of the MPP increased [6]. MPP of thickness 1mm exhibits a maximum SAC of 0.9 at around 4.5kHz.

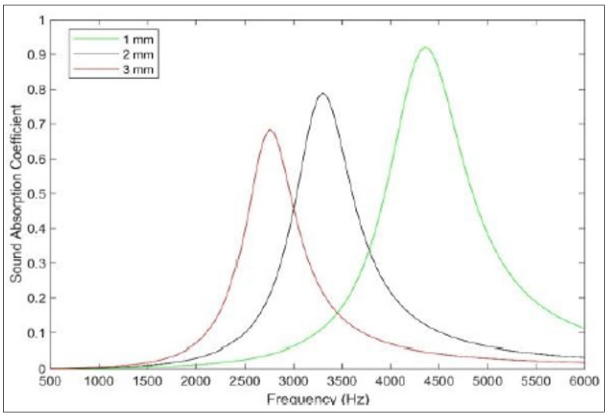

Figure 2: Effect of varying thickness on SAC of the MPP.

Effect of perforation size

Figure 3 shows the simulated results of the MPP with varying perforation size. It can be seen from Figure 3 that, altering the size of perforation affects the acoustic absorption of the MPP. An increase in the size of the perforation increases the acoustic absorption with narrowing of peaks. The smaller the size of perforation, acoustic waves find it harder to enter, leading to reduced acoustic absorption. Acoustic performance of the MPP will reach a certain limit when reducing the perforation size. As you reduce it to a certain size, the acoustic performance will start to drop. This is due to the fact that the MPP no longer possesses enough acoustic resistance to absorb sound. Rather, the incoming sound waves were reflected back instead of passing through the MPP and therefore, reducing the sound absorption of MPP. The larger the perforation size, the acoustic wave moves easier where there will be reduced reactance, which in turn narrows the peak of absorption [7]. Hence, it is better to have the optimum size of perforation in order to maintain both the reactance and resistance of MPP. MPP with a perforation diameter of 0.7mm shows the maximum SAC of 0.9 at around 3.2kHz.

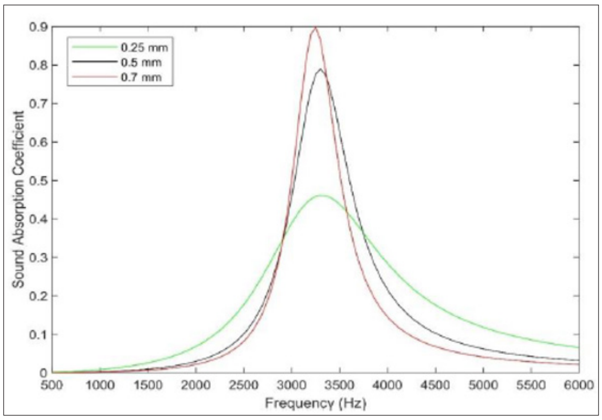

Figure 3: Effect of varying perforation size on SAC of the MPP.

Effect of distance between the perforations

Figure 4 shows the simulated results of the MPP with varying distance between the perforations. It can be seen from Figure 4 that increasing the distance between the perforations decreases the acoustic absorption and also shifts the peaks of absorption towards the low-frequency spectrum. Reducing the distance between the perforation increases the number of perforations at the given MPP, which offers higher reactance [8]. Also, the smaller the distance between perforated holes, the greater the hole interaction effect which eventually boosted the sound absorption performance of MPP. When the distance between perforated holes increased, the hole interaction effect among the perforated holes diminished, and therefore reducing the sound absorption performance of MPP [9]. MPP with a distance between perforations of 3mm shows the maximum SAC of 0.95 at around 5kHz.

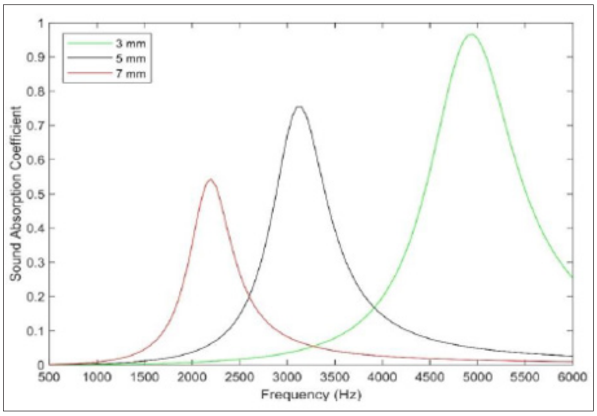

Figure 4: Effect of varying distance between the perforations on SAC of the MPP.

Conclusion

The effect of varying the thickness, perforation size and distance between the perforations had been successfully simulated using Matlab and the results are as follows;

a) Increasing the thickness of MPP shifts the peaks of acoustic absorption towards the low-frequency spectrum with reduced SAC.

b) Increasing the perforation size of the MPP increases the SAC with the peaks getting narrowed.

c) Increasing the distance between the perforations of the MPP shifts the peaks of acoustic absorption towards the low-frequency spectrum with reduced SAC.

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