Sound Absorption Analysis on Micro-Perforated Panel Sound Absorber with Multiple Size Air Cavities

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***Abstract*--** **Micro-perforated panel (MPP) sound absorber has been widely used for the noise reduction and is considered a promising alternative to the traditional porous materials. The acoustic performance of MPP sound absorber depends on 4 major design parameters, such as perforation diameter, air cavity depth, distance between perforations, and thickness of MPP. In this experimental study, analysis of sound absorption coefficient of the MPP sound absorber with multiple size air cavities was conducted. There are 4 groups multiple size of air cavity to be investigated. Results show the first and second major peaks of sound absorption coefficient curve are changing inversely when D_2 is getting higher. The frequency band of the major peaks will shift as changing the D_2. This phenomenon also had been observed by others research as the air cavity becomes deeper, the peak value is getting higher and it will shift to the lower frequency band.**

***Index Term*--** **Micro-perforated panel (MPP), sound absorption, sound absorber, and air cavity.**

I. Introduction

Acoustic treatment always is the concern issue for the noise control engineer. The choosing of acoustic treatment material is a bother stage for those engineers who need to consider all the aspect of designs, such as environment, cost, effectiveness, and reliability. Obviously, the porous type of materials are the promising significant for the acoustic insulation solution [1]. However, porous materials are limited for the clean, high temperature and humidity environment as its fibers will cause dusty and deteriorate in the harsh environment. Thus, acoustic engineers are trying to find out the alternative material to replace the porous materials which well performance as fiber materials.

Micro-perforated panel or also known as MPP is considered an alternative material for the acoustic treatment purposes. The basis and design of MPP was studied by Maa. He established the theoretical and investigated the performance of MPP at 1970-an [2, 3]. MPP sound absorber is a simple design of structure. It is formed by a panel with sub-millimeter diameter of perforation and backed with air cavity. Although there are no any fibrous materials are applied on it for improving its acoustic treatment performance, it still provides the promising sound absorption performance. Since MPP can be manufactured by the thin metallic materials, there also is no issue for application in the harsh environment.

The mechanism of MPP sound absorber is based on Helmholtz resonator principle and its performance depends on the parameters of the MPP sound absorber, such as perforation diameter, air cavity depth, pitch of perforation, and thickness of MPP. However, one of the drawbacks of MPP sound absorber is the sound absorption performance limit to a narrow band of frequency domain. Thus, some of the researchers studied on the parameters of MPP in order to extend the frequency bandwidth. However, most of these efforts make the system much more complex and difficult to fabricate, like multi-size of perforation in a panel and multi-layer of MPP [4-8] sound absorber.

In this study, multiple depths backing wall are used to obtain multiple size air cavity depths. It is expected the sound absorption performance of the MPP sound absorber will become better and broader frequency bandwidth under these configurations. It is considered a simple and cost saving method as it reduces the complexity of MPP sound absorber configuration and delivers the better performance of sound absorption.

II. Theory

MPP sound absorber consists of a micro-perforated panel and a backing air cavity which can be modeled with electro-acoustical equivalent circuit as shown in Figure 1.

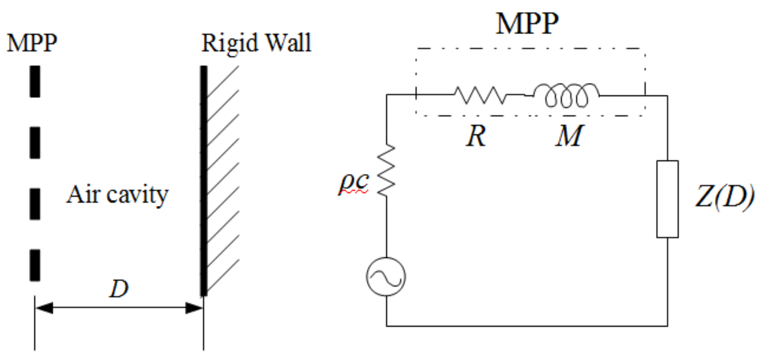

Fig. 1. Typical configuration of an MPP sound absorber (left) and its electro-acoustical equivalent circuit (right) [2]

The sound absorption performance of an MPP can be defined by specific acoustic impedance normalized by air characteristic acoustic impedance, $\rho_0 c$, and panel porosity, σ.

$$Z_{MPP} = R + jM \tag{1}$$

where

$$R = \frac{32\mu t}{\rho_0 \sigma c d^2}\left[\sqrt{1+\frac{x^2}{32}} + x\frac{\sqrt{2}d}{8t}\right] \tag{2}$$

$$M = \frac{\omega t}{\sigma c}\left[1 + \frac{1}{\sqrt{3^2 + x^2/2}} + 0.85\frac{d}{t}\right] \tag{3}$$

The MPP acoustic impedance, Z_{MPP} consists of real and imaginary parts, which are the acoustic resistance, R and acoustic reactance, M respectively. For equations (2) and (3), the perforation constant, $x = d\sqrt{\rho_0 \omega / 4\mu}$. It is defined as the ratio of perforation diameter to the viscous boundary layer thickness of the air in the perforation. Typically, MPP sound absorber is formed by an MPP in front of a solid surface and with an air cavity of thickness D between them. The acoustic impedance of air cavity, Z_C behind the MPP is defined as below

$$Z_c = -j\left[\left(\frac{\omega}{c}\right)D\right] \tag{4}$$

The acoustic impedance of the MPP sound absorber is given by

$$Z = Z_{MPP} + Z_c \tag{5}$$

Finally, the sound absorption coefficient α can be calculated by the equation below

$$\alpha = 1 - \left|\frac{Z-1}{Z+1}\right|^2 . \tag{6}$$

III. Methodology

In this study, the MPP was made from aluminium with thickness is 1 mm. the perforation diameter is 0.9 mm and the distance between perforations are 15 mm. Figure 2 shows the aluminium MPP. There are 4 design parameters will affect the MPP sound absorption performance, such as thickness of MPP, diameter of perforation, distance between perforations, and air cavity depth. For this study, air cavity depth is changed by following the configuration as shown in Figure 3. In the experiment, 3 of the design parameters of MPP are remaining similar except for the air cavity depth. Table 1 shows the 3 design parameters value for the MPP. The detail of air cavity depth configuration is shown in Table II.

Table I
Design parameters for MPP

MPP Design Parameters, (mm)		
Distance bet. perforation, ***D***	Diameter of perforation, ***a***	Thickness of MPP, ***t***
15	0.9	1

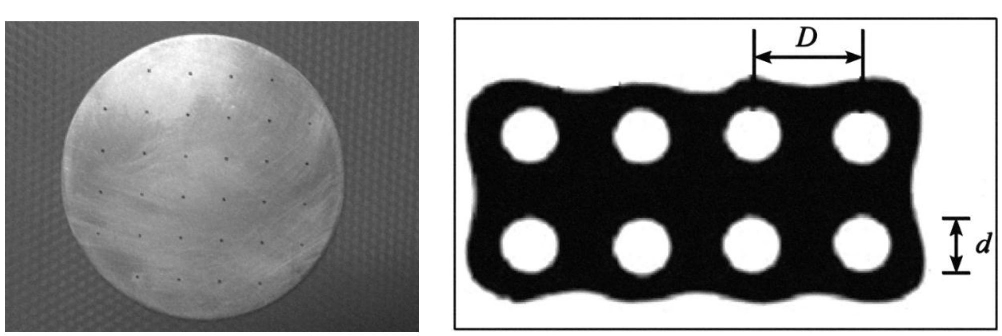

Fig. 2. Aluminium MPP

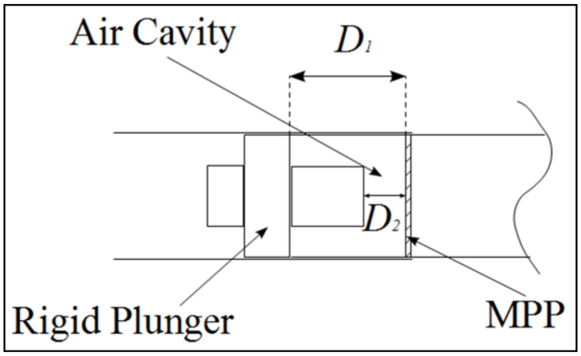

Fig. 3. Configuration of air cavity depth manipulation

Table II Data collection set for different air cavity depth

Name	Air cavity depth, (mm)	
	D_1	D_2
Group 1	30	30
Group 2	60	30
	60	60
Group 3	90	30
	90	60
	90	90
Group 4	120	30
	120	60
	120	90
	120	120

In this experimental study, sound absorption coefficient is taken as the parameter to determine the acoustic performance of MPP sound absorber. ISO 10534-2 [9] standard is used for the MPP sound absorber sound absorption coefficient measurement. In the measurement setup, the impedance tube was used, it is 105 mm for diameter and the length is 1420 mm. It is made from brass and the random noise source is used in the measurement. The rigid plunger is adjusted to form multiple size air cavity depth behind MPP at the end of impedance tube. The rigid plunger is special designed for the multiple air cavity depth adjustment. The MPP is cut into same circular size with the impedance tube and fitted into the tube. During the measurement process, the noise signals picked by the microphones mounted on the tube are sent to the computer-controlled data acquisition unit for the calculation of the sound absorption coefficient of MPP sound absorber.

III. Result and Discussion

In this study, there are 4 groups of measurement set for the multiple size air cavity as shown in Table 2. For the air cavity depth alternation, the D_1 should follow the constraint $D_1 \geq D_2$. For the following section, the sound absorption coefficient measurement result of MPP absorber is listed and discussed.

Group 1 (D_1 = 30 mm) – Sound absorption coefficient Measurement

Based on Figure 4, there is consists of one curve on the graph as only one combination available for this group, D_2 = 30 mm. From the graph, it is observed that 2 major peaks occur at frequency 430 Hz and 590 Hz, the sound absorption coefficient are 0.89 and 0.83 respectively. Besides, there is a deep valley occurs at the frequency 575 Hz. For Group 1, it is found that the MPP sound absorber gives the quite good sound absorptivity for the lower frequency range, which is in between 350 Hz to 800 Hz. The sound absorption coefficient is 0.5 and above except for the range of valley. For the frequency 600 Hz and above, it shows the sound absorption coefficient is getting decreasing where it is same with trend of theoretical study [2, 3].

Group 2 (D_1 = 60 mm) – Sound absorption coefficient Measurement

Figure 5 shows the sound absorption coefficient of MPP sound absorber with D_2 = 30 mm and D_2 = 60 mm. The blue dotted curve and red solid curve are the measurement data for D_2 = 30 mm and D_2 = 60 mm respectively. Based on Figure 5, both curves from different depth of D_2 show the similar trend and the sound absorption coefficient is decreasing for the frequency higher 400 Hz. It is found that the major peak for D_2 = 60 mm drop at 325 Hz and shift to lower frequency compare with major peak of D_2 = 30 mm. It is considered a normal phenomenon for the peak value will shift to the lower frequency range as air cavity depth becomes higher.

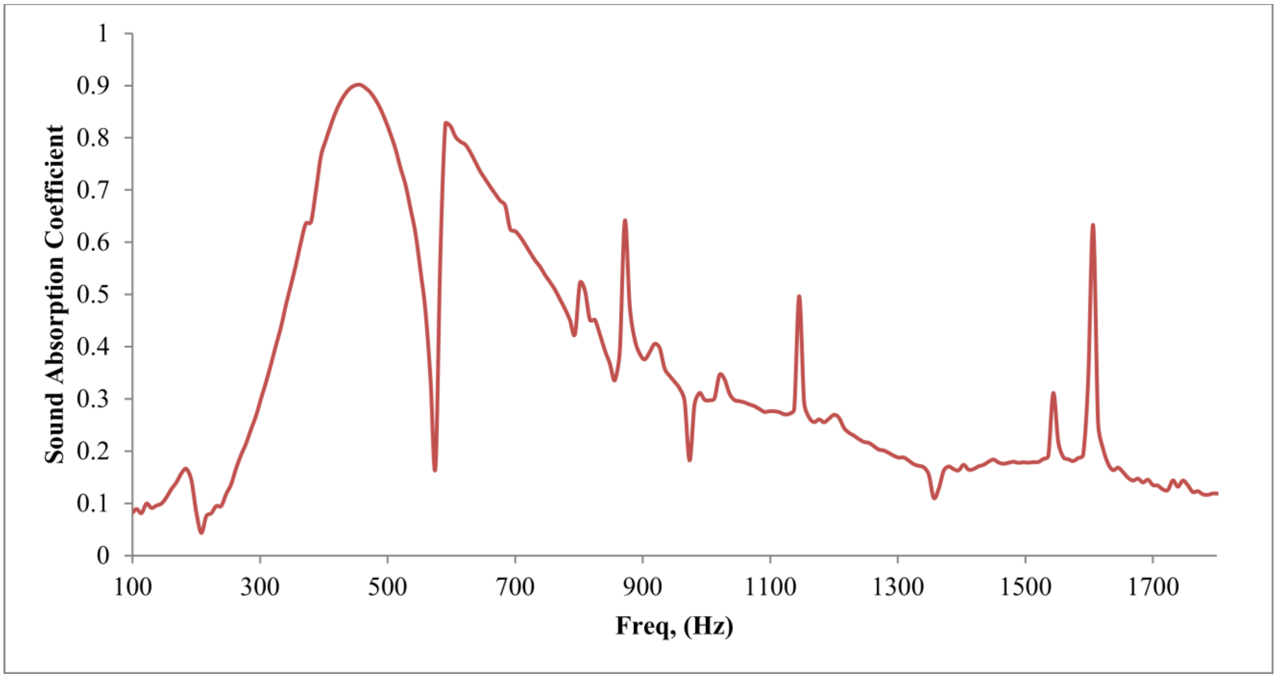

Fig. 4. Sound absorption coefficient of MPP sound absorber for multiple size air cavity – D_2 = 30 mm

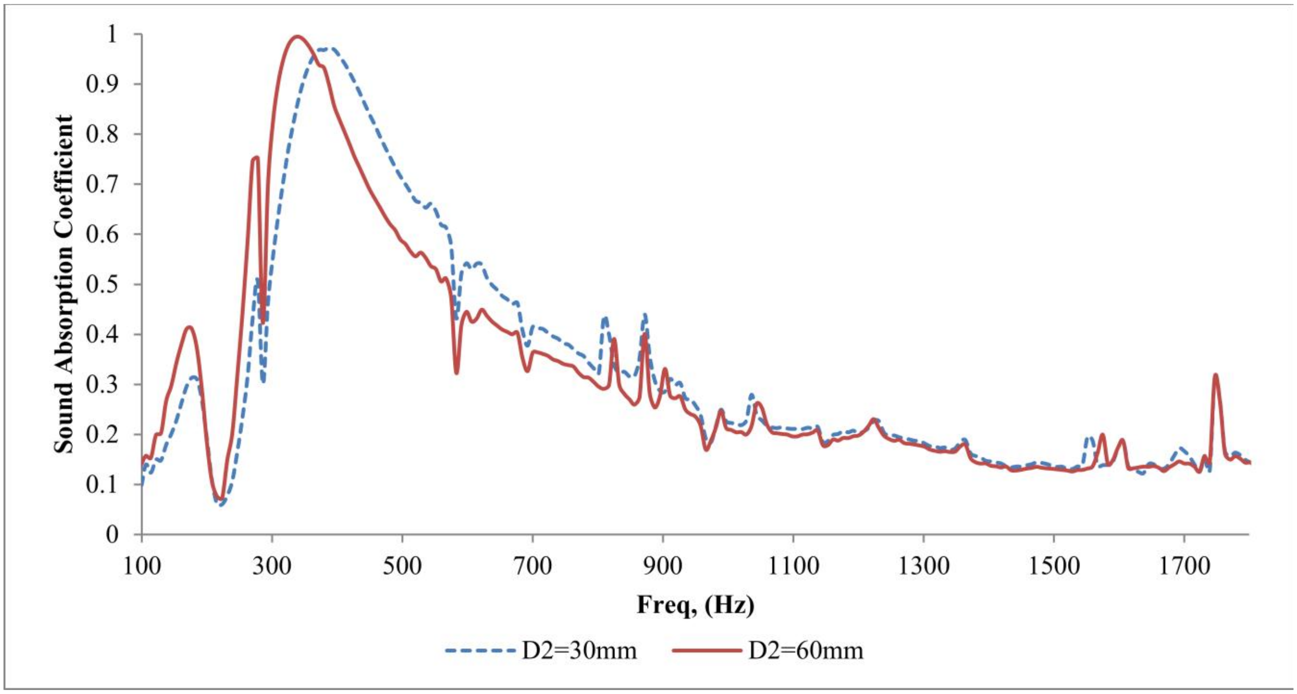

Fig. 5. Sound absorption coefficient of MPP sound absorber for multiple size air cavity – D_2 = 30mm, 60mm

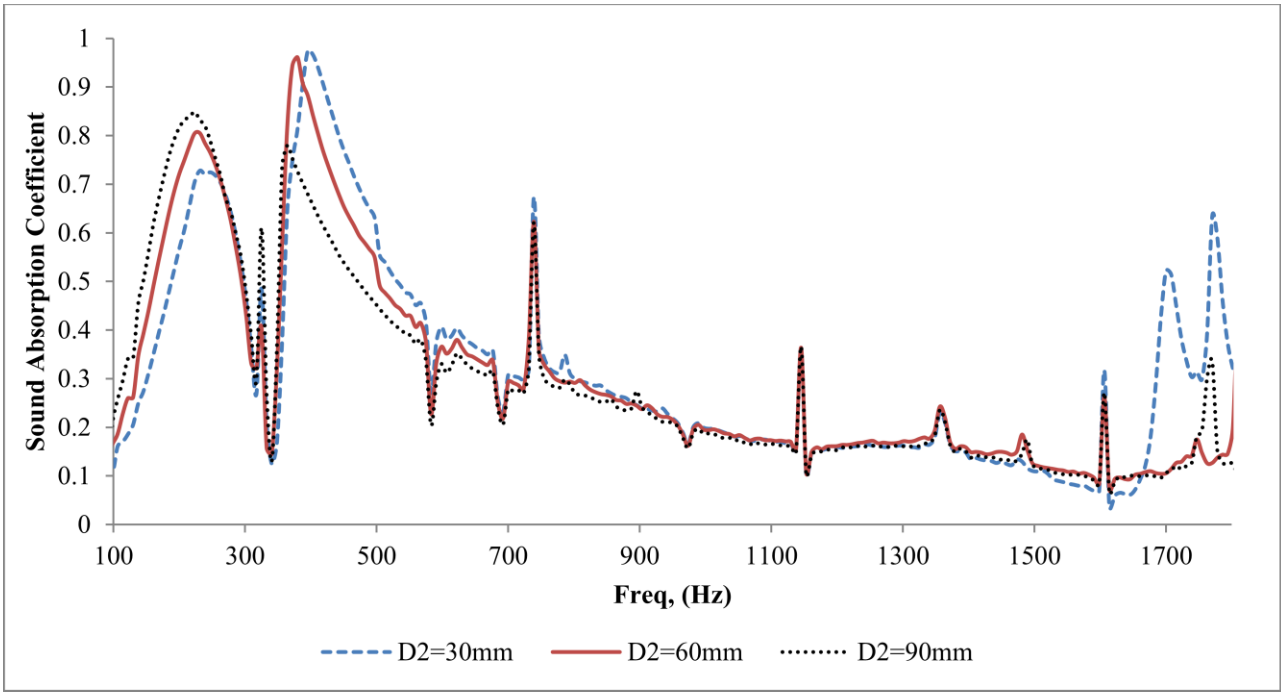

Fig. 6. Sound absorption coefficient of MPP sound absorber for multiple size air cavity – D_2 = 30mm, 60mm, 90mm

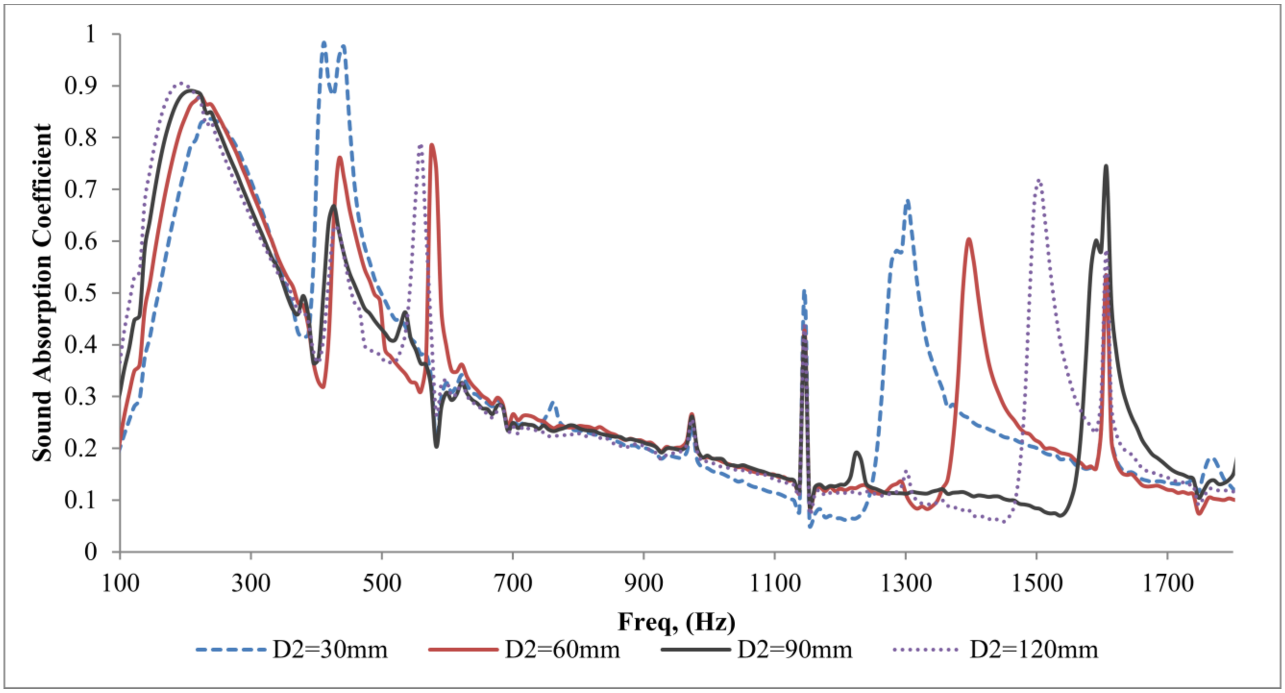

Fig. 7. Sound absorption coefficient of MPP sound absorber for multiple size air cavity – D_2 = 30 mm, 60 mm, 90 mm, 120 mm

Group 3 (D_1 = 90 mm) – Sound absorption coefficient Measurement

The sound absorption coefficient of MPP sound absorber with D_2 = 30 mm, 60 mm, and 90 mm is shown in Figure 6. Based on the graph, it is found that the trend of curves for different depth of D_2 is similar to each others obviously. For the combination of multiple air cavity depth, there are 2 major peaks occurring at about 240 Hz and 370 Hz respectively. Besides that, it is also found that the first peak and second peak value changing inversely as the D_2 changing from 30 mm to 90 mm. For example, the first peak and second peak value for D2 = 90 mm are 0.8 and 0.7 respectively; however the first peak is 0.7 and second peak is 0.9 when D_2 become 30 mm. It is also showed that the first peak value is getting higher and shifted to lower frequency band as D_2 increasing. On the other hand, second peak value become higher and shifted to higher frequency as D_2 decreasing. It is considered the trend is reasonable as the peak value will be affected and shifted for frequency range when changing the air cavity depth.

Group 4 (D_1 = 120 mm) – Sound absorption coefficient Measurement

For D_1 = 120 mm and the D_2 changing from 30 mm to 120 mm, it is found that there are 3 major sound absorption coefficient peaks for frequency range less than 700 Hz, which are shown in Figure 7. The first 3 major peaks occur at the lower frequency band, which are about 200 Hz, 430 Hz, and 600 Hz. However, there also consist of few major peak drops at higher frequency band, which is 1150 Hz and above. Obviously, it is shown that the phenomenon of first 3 major peaks is similar with group 3 (D_1 = 90mm). The peak values and its frequency band are changing inversely. When D_2 getting increasing, the peak values become increasing and shifted to lower frequency band. At the same time, second peak values getting decrease as D_2 increasing. Besides, the third peak phenomenon is not follow the sequential as mentioned above. It is changing without following the order of D_2 air cavity depth. This is an interesting observation to be obtained as 2 different size air cavity depths applying on the MPP sound absorber.

IV. CONCLUSION

The experimental study on the MPP sound absorber with multiple size air cavities was carried out successfully. There are 4 groups of different air cavity size by changing D_1 and D_2. For the study, different configuration of air cavities will give the different sound absorption characteristic of MPP sound absorber. Based on experimental measurement, it is found that air cavity with combination 2 different deep will give the sound absorption coefficient curve with 2 major peaks and shifted on the frequency band as D_2 changing for D_1 = 60 mm and D_1 = 90 mm. For D_1 = 120 mm, there are 3 major peaks are occurring. Another significant observation had been obtained is the first and second major peak values are changing inversely when D_2 is getting higher. At the same time, the frequency band of the peak value also shifting as changing the D_2. This kind of phenomenon also had been observed by others research as the air cavity become deeper, the peak value is getting higher and it will shift to the lower frequency band [10, 11].

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