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NOISE CONTROL FOR A BETTER ENVIRONMENT

Sound absorption of Multilayer Micro perforated Panel with Helmholtz Resonator Mount

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ABSTRACT

Micro Perforated panel (MPP) for noise control application is the promising alternative to the conventional porous material. However, the absorption frequency range of this MPP alone is not sufficient to contest with the porous material. In order to enhance the sound absorption of single leaf MPP, Helmholtz Resonator (HR) is introduced. In addition to that polyurethane foam is kept as another layer to ensure the one-stop solution for low, mid, and high frequency problem. The acoustic impedance of this configuration evaluated by transfer function method. The theoretical results compared with experimental one and the obtained result shown that it has two resonant frequencies and it is separated by one anti-resonant frequency as well. Later on, there is a shift in the frequency peak obtained due to effect of various neck lengths and diameter of Helmholtz resonator. Further the introduction of multiple parallel resonators results better sound absorption than the single Helmholtz resonator

Keywords: Micro-Perforated Panel, Helmholtz Resonator, Sound absorption, Polyurethane Foam

1. INTRODUCTION

Recent days, the increasing interest of improving living environment seeks more attention towards noise control application. Many materials have been used to control noise such as porous material, fiber materials and Micro-Perforated Panel (MPP).

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Among those materials, MPP carries its own advantages like environment-friendly, easy to manufacture and inexpensive .The theoretical formulation and design of Micro-Perforated Panel was first proposed by Maa [1-3]. The sub-millimeter size perforation provides more sound attenuation due to acoustic resistance offered by narrow region friction [4]. Zhoa et al. [5] practiced multilayer MPP leaf for sound absorption by optimizing design parameters, but the performance of sound absorption in lower frequency is inadequate it requires more depth of air cavity which is practically not possible. The primary mechanism behind the MPP absorber backed by air gap than the rigid wall which Helmholtz resonance absorption [6].Park [7] introduced Helmholtz resonator at the back of MPP to enhance the sound absorption at a lower frequency by means the Helmholtz shallow cavity reduces the low-frequency noise which is limited. Gai et al. [8] have investigated Helmholtz resonator mounted with MPP studied the influence of various neck length, neck diameter, and cavity size.In this study, we will investigate the acoustic properties of Helmholtz resonator mounted with MPP ,MPPHR parallelly coupled with Polyurethane foam and also multiple resonator with MPP .

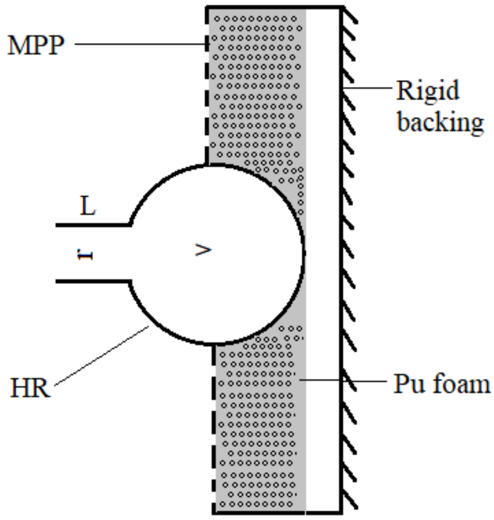


Figure 1: A schematic diagram of Helmholtz resonator mounted in MPP backed by Pu foam and Air gap

2. MATERIALS AND EXPERIMENTS

2.1. Theory

The acoustic impedance of MPPHR can be obtained using Equation 1 and Figure 1 shows the schematic representation of Helmholtz resonator mounted with MPP panel also coupled with Pu foam and 15*mm* air gap before rigid backing

$$Z = \frac{Z_{MMP} Z_{HR}}{Z_{MMP} + Z_{HR}}, \tag{1}$$

2.1.1 For MPP

$$Z_{MMP} = R + j\omega M - j\, cot\Big(\frac{\omega D}{c}\Big), \tag{2}$$

$$R = \frac{32\eta t}{\sigma\, \rho\, c\, d^2}\, k_r, \tag{3}$$

$$k_r = \sqrt{1 + \frac{K^2}{32}} + \frac{\sqrt{2}K}{8}\, \frac{d}{t} \tag{4}$$

$$M = \frac{t}{\sigma\, c} k_m, \tag{5}$$

$$k_m = 1 + \left[9 + \frac{K^2}{2}\right]^{\left(-\frac{1}{2}\right)} + 0.85\, \frac{d}{t} \tag{6}$$

$$K = d\sqrt{\frac{f}{10}} \tag{7}$$

Where R is acoustic resistance, M is the acoustic reactance, Normalized by dividing ρc, r is the normalized specific acoustic resistance, m is the normalized specific acoustic reactance, $\omega = 2\pi$ f is the angular frequency, ρ density of air, c is the speed of sound in air, t, d, σ, and K are the thickness, perforation diameter, perforation ratio and perforates constant.

2.1.2 For Helmholtz Resonator

The acoustic impedance Z_{HR} is calculated using Equation 8

$$Z_{HR} = R_a + j\omega M_a - \frac{j}{\omega C_a} \tag{8}$$

Acoustic resistance R_a

$$R_a = \rho c\left[16\; kx^2\left(1 + \frac{1}{8x(1 + 4x^2)}\right)\frac{1}{s}\, \frac{k^2}{2\pi}\right] \tag{9}$$

Acoustic reactance M_a

$$M_a = \rho\left(\left[\frac{4}{3} - \frac{10}{3(10 + x)}\right]\frac{1}{S}\right), \tag{10}$$

Acoustic compilance c_a

$$C_a = \frac{V}{\rho c^2}, \tag{11}$$

$$S = \frac{\pi d_h^2}{4}, \tag{12}$$

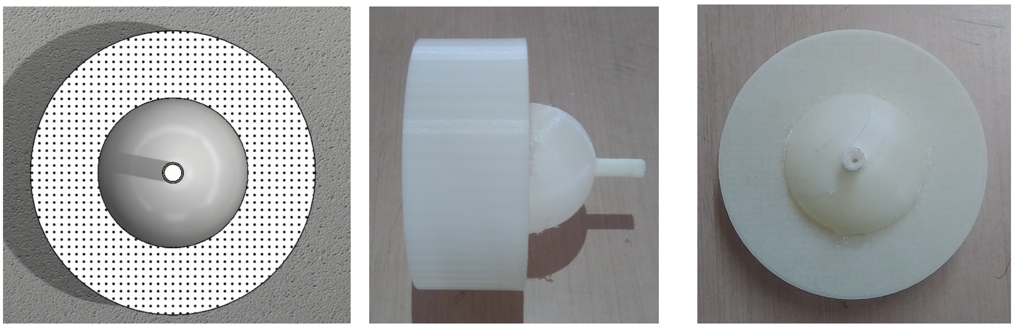
$$x = \sqrt{\frac{2\eta}{\rho\omega d_h^2}} \tag{13}$$

where V is volume of the sphere, S is the surface area of the neck diameter, d_h is neck diameter, η viscosity of air and l is the length of the neck.The sound absorption coefficient obtained by using Equation 14

$$\alpha = \frac{4R_e(Z)}{[1 + R_e(Z)]^2 + [I_m(Z)]^2} \tag{14}$$

2.2. Materials

MPPHR layer was printed using a standard 3D printing machine (uPrint SE Plus) with additive manufacturing process. The sample is printed layer by layer with the resolution of 0.254 mm. The polymer material named Acrylonitrile Butadiene Styrene (ABS) was used as base material.The sample images shown in Figure 2 and the geometric dimension and other properties listed in Table 1.



(a) CAD model *(b) 3D printed sample* *(c) Top view*

Figure 2: MPPHR sample images

Properties	MPP	Properties	Pu Foam
Hole geometry		Thickness (mm)	25
Hole spacing, b (mm)	10	Density, (kg/m3)	30
Hole diameter, d (mm)	1	Airflow resistivity, (N.s/m4)	22000
Perforation ratio, p (%)	0.0074	Porosity,	0.95
MPP specimen geometry		Tortuosity,	1.38
Panel diameter (mm)	96	Viscous characteristic length, (m)	0.000017
Thickness, t (mm)	1.02	Thermal characteristic length, (m)	0.000040

Table 1: Properties of MPP and Polyurethane foam

3. RESULTS

3.1. MPP mount with HR

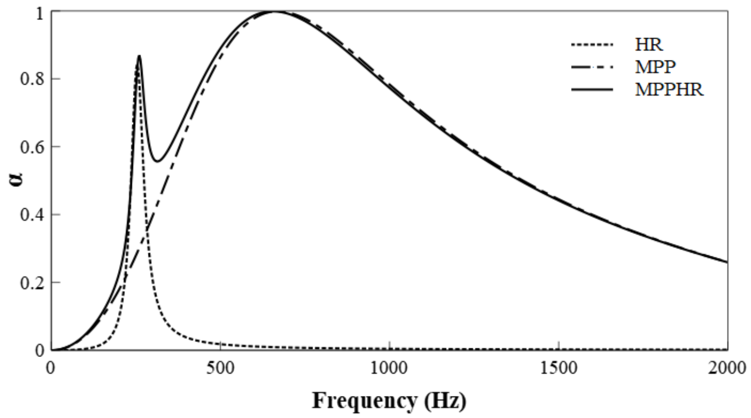


Figure 3: Sound absorption of HR,MPP and MPPHR

Figure 3 shows the predicted example of sound absorption of MPPHR having thickness of 0.5 mm, 0.3mm perforation diameter, perforation rate of 1%, cavity depth of 60mm.The neck length of resonators l=20mm,neck diameter d=6mm, Helmholtz sphere radius r=25 mm. One can easily observe that two peak frequencies separated by antinode, the first peak is at lower frequency region caused by Helmholtz resonator and the other one is at higher frequency region which is very close to the peak of MPP.

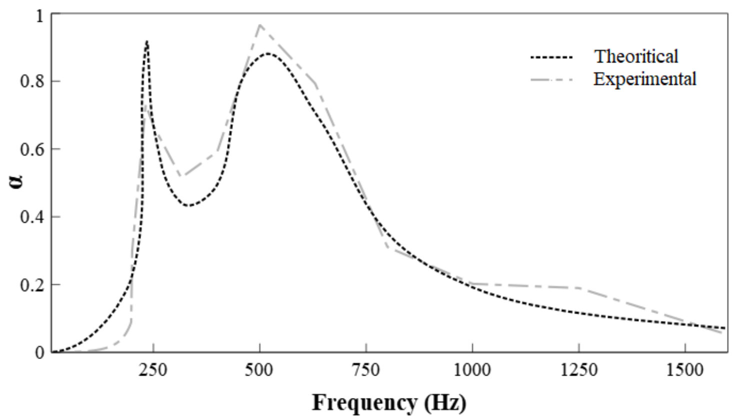


Figure 4: Comparison of Theoretical and Experimental sound absorption of MPPHR

Figure 4 shows the experimental sound absorption of 3D printed sample tested in two microphone impedance tube using transfer function method.The experimental results shows good agreement with theoretical one expect few region, this main due surface roughness in other words machining error.The geometric properties of MPP mention in Table 1 neck length of 20 mm, neck diameter of 6 mm, radius of sphere is 25 mm and Air gap of thickness 38 mm is maintained.

3.2. MPPHR coupled Polyurethane foam

MPPHR is performing well at lower frequency and mid frequency region however for higher region sound absorption performance is not sufficient.The main aim of this study is to proposed material that can give better acoustic properties in wide range of frequency. To accomplish that Pu foam is coupled around the Helmholtz sphere which also reduces the air gap from 38 to 13 mm.Figure 5 shows the comparison of experimental and theoretical sound absorption of MPPHR coupled Polyurethane foam. The acoustic impedance of MPP,Pu foam and Air layer calculated using Transfer Matrix Method. The porous material properties mentioned in Table 1.

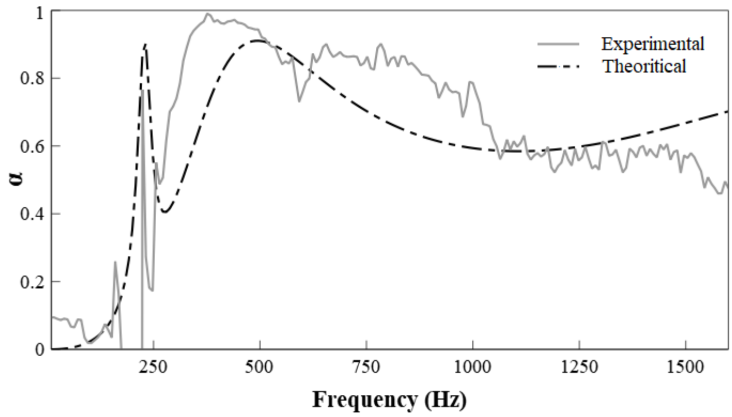


Figure 5: Sound absorption of MPPHR coupled with Pu foam

3.3. Effect of neck length and diameter

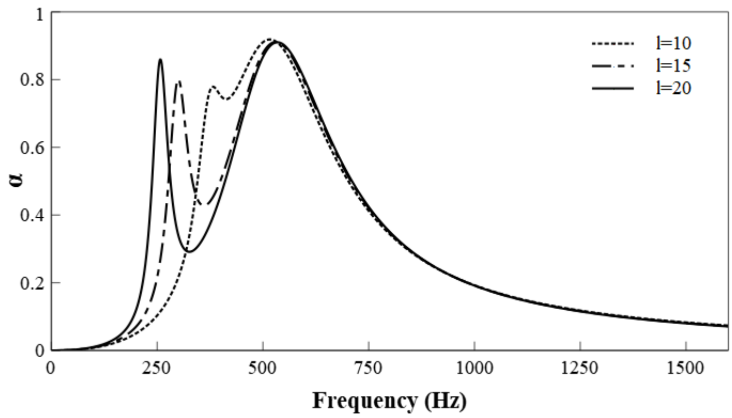


Figure 6: Sound absorption of various neck length l=10, 15, 20 mm

Figure 6 compares the effect of changing various neck length by keeping all other parameter constant.It clearly denotes that increasing of neck length shifting the sound absorption peaks towards lower frequency region and MPP peaks remains same for various neck length because we altering only in the Helmholtz part.Whereas for the effect of various neck diameter is entirely different. The increase of neck diameter leads to the shift of peak frequencies towards higher frequency region.the simulated result shown in Figure 7.

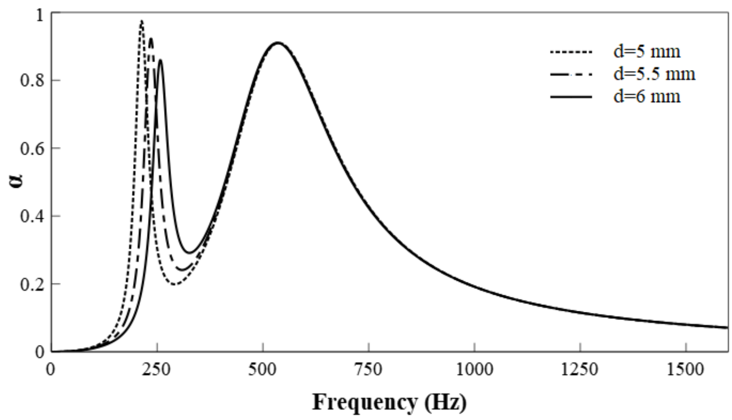


Figure 7: Sound absorption of various neck diameter d=5, 5.5, 6 mm

3.4. Effect of Multiple Resonator

In order to improve sound absorption at lower frequency region multiple Helmholtz resonator is introduced.This multiple resonator results multiple peaks near the lower frequency zone.The simulated results shown in Figure 8 which has two peaks near lower frequency region because of two Helmholtz resonator coupled in parallel and simulated.

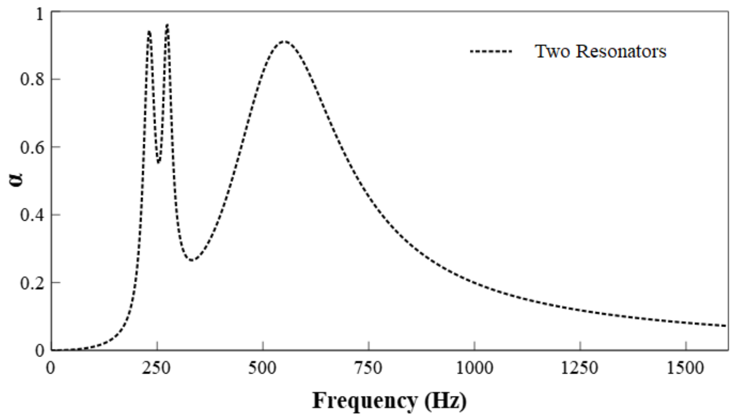


Figure 8: Sound absorption of two resonator coupled in parallel

4. CONCLUSIONS

In this study,we investigated the acoustic performance of the MPP mounted with Helmholtz resonator and also coupled with Pu foam.Sound absorption of MPPHR show that two peak frequencies separated by anti-node, the first peak is at lower frequency region caused by Helmholtz resonator and the other one is at higher frequency region which is very close to the peak of MPP.To enhance the performance of sound absorption over the wide range pf frequency Pu foam is coupled and significant results noticed in higher frequency region. The low-frequency peak shift towards to low frequency when the neck length increased and the when other parameters remain same.But, the increase of neck diameter leads to the shift of peak frequencies towards higher frequency region. Multiple resonator results multiple peaks near the lower frequency zone,by optimizing the number and other parameters of HR one can develop a good sound absorber which can be used for low-mid-high frequency noise control application.

5. ACKNOWLEDGEMENTS

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6. REFERENCES

1.Maa DY. Theory and design of microperforated panel sound-absorbing constructions. Sci Sin 1975;18:55–71.
2.Maa DY. Microperforated-panel wideband absorbers. Noise Contr Eng1987;29:77–84.
3.Maa DY. Potential of microperforated panel absorber. J Acoust Soc Am1998;104:2861–4.
4.Liu J, Herrin DW. Enhancing micro-perforated panel attenuation by partitioning the adjoining cavity. Appl Acoust 2010;71(2):120–7.
5.Zhao X-D, Zhang X-J, Jiang Z. Three layer micro-perforated panel optimal design and analysis of its characteristics. Acta Acust 2008;33(1):84–7.
6.Sakagami K, Morimoto M, Yairi M. Double-leaf micro-perforated panel space absorbers: a revised theory and detailed analysis. Apll Acoust 2009;70:703–9.
7.Park SH. Acoustic properties of micro-perforated panel absorbers backed by Helmholtz resonators for the improvement of low-frequency sound absorption. Journal of Sound and Vibration. 2013 Sep 30;332(20):4895-911.
8.Gai XL, Xing T, Li XH, Zhang B, Wang WJ. Sound absorption of micro-perforated panel mounted with helmholtz resonators. Applied Acoustics. 2016 Dec 15;114:260-5.