DESIGN OF MICRO-PERFORATED ABSORBERS (MPA)

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ABSTRACT

MPA's are becoming popular for noise control in industrial application due to its lightweight and ease of mounting. The main idea behind MPA is to convert acoustical energy into heat. In a traditional absorber, the sound wave propagates into the absorber. Because of the proximity of the porous material, the oscillating air molecules inside the absorber lose their acoustical energy due to friction. A MPA works in almost the same way. MPA's are indispensible in building acoustics as well as in transport industry for noise control. MPA absorber has usually provided sound absorption at low frequency band of one to two octaves. MPA's are generally used with air gap and sometimes with other porous absorbers to enhance sound absorption characteristic of the porous materials. The sound absorption of MPA depends upon hole separation, hole diameter and thickness of the MPA. MPA can be tuned to desired frequency band using these design parameters. A theoretical model for a micro perforated absorber is presented and discussed in detail in this paper. The paper presents parametric study of hole separation, hole diameter and thickness of MPA. The paper presents effect of each these parameters on sound absorption. It also gives details about the optimum parameters required for good sound absorption. The paper also presents design charts for each of these parameters as a function of frequency and sound absorption coefficient. Finally simulation for normal incidence and random sound absorption of MPA is discussed in detail.

KEYWORDS: MPA, Sound absorption

1. INTRODUCTION

Micro perforated absorber (MPA) is used to absorb sound reducing its intensity. It consists of thin plate made of different materials with holes punched in it. Unlike ordinary perforated panels where the perforations are in millimeters or even centimeters, with scarcely little inherent acoustic resistance, the perforations in MPA are reduced to sub millimeter size ~diameter 0.5–1 mm, so they can provide, by themselves, enough acoustic resistance and low acoustic mass reactance necessary for wide-band sound absorber, without additional fibrous, porous materials. When the oscillating air molecules penetrate the MPA, the friction between the air in motion and the surface of the MPA dissipates the acoustical energy. The perforated portion of their surface only adds up to a few percent, and no additional frictional resistance is required. Absorption is entirely due to the viscous friction of the air in the holes. It originates in the respective acoustical boundary layer, which is in the area where the velocity profile changes. The holes of micro-perforated absorbers are so small that this boundary layer extends over the entire cross-section of the holes. The thermal conductivity of the plate material is important, because a significant part of the frictional heat generated in the air is carried off by the plate. Micro-perforated absorbers can be made from different materials, including transparent acrylic glass. An MPA offers an alternative to traditional sound absorbers made from porous materials.

Many researches have been worked on it [1-4]. The theory of the absorber has been quickly developed in the last 30 years, and by now, it is widely approbatory. But the theory shows the complexity between the absorption coefficient and the structure parameters. The design of the MPA becomes difficult and time-consuming. Then, it is very valuable to find a way to design the parameters of MPA quickly.

2. Theory

The MPP may be considered a lattice of short narrow tubes, separated by distances much larger then their diameters, but small compared to the wavelength of impinging sound wave. The propagation of a sound wave in a tube was treated by Lord Rayleigh [5] and the treatment was simplified by Crandall [6] for short tubes. The specific surface impedance of the short tube is given as

$$Z_1 = j\omega\rho_0 t\left[1-\frac{2}{k\sqrt{-j}}\frac{J_1 k\sqrt{-j}}{J_0 k\sqrt{-j}}\right]^{-1}$$

$$k = a\sqrt{\frac{\rho_0\omega}{\eta}}$$

where a is the radius of the holes, ρ_0 density of air, η viscisity of air and J_1 is the Bessel function of the first kind and first order.

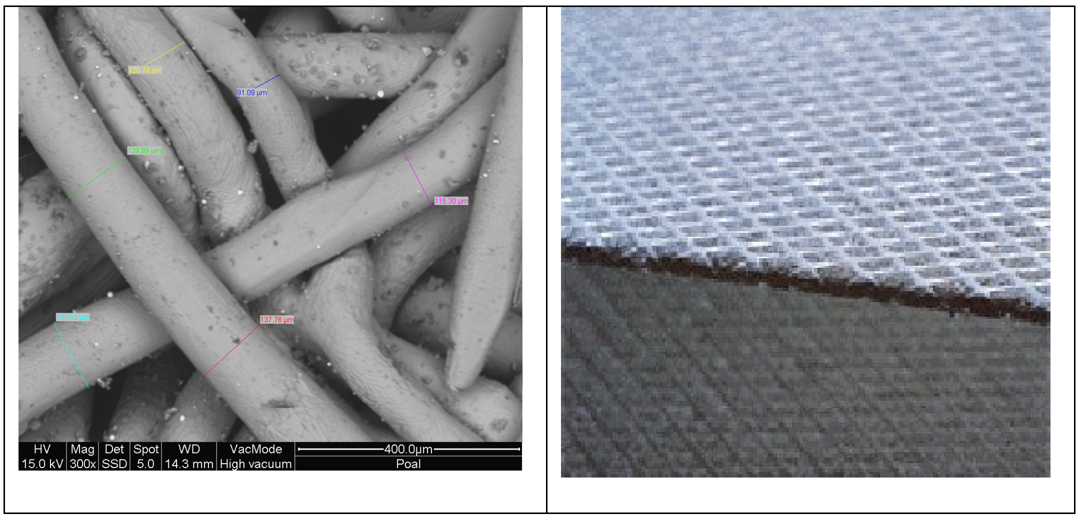

Figure 1: SEM Photograph of MPA and Micro perforated board

MPA is generally used with air cavities behind them, and then in this case the impedance of an air cavity is given as

$$Z = Z_1 + Z_2$$

with $Z_2 = -j\rho_0 c\cot(k.d)$ is the impedance of air cavity.

Once the total impedance of the MPA with air cavity is known the sound absorption coefficient at normal incidence is given as

$$\alpha(\theta) = 1-\left|\frac{Z\cos\theta-\rho_0 c}{Z\cos\theta+\rho_0 c}\right|^2$$

In a diffuse sound field, the statistical absorption is the average of all angles of incidence θ and equal to

$$\alpha_{Random} = \int_{0}^{82} \alpha(\theta) \sin 2\theta d\theta$$

This gives statistical sound absorption coefficient in reverberation room.

3. The Design of MPA

Just as shown in the theory, the absorption of the MPA only depends on the parameters mentioned. But the absorption coefficient is not a simple equation of these parameters. There are 4 parameters in the single layer structure, the membrane thickness (*t*), the hole orifice radius (*a*), hole separation (*D*) and the depth of the air cavity (*d*). In next section some of the design charts are presented with effect of hole separation shown in figure 2. From the figure it is clear that maximum sound absorption can be obtained when hole separation is around 5-7 mm. All these design charts for sound absorption coefficient are obtained with air cavity 60 mm and sheet thickness 0.2 mm.

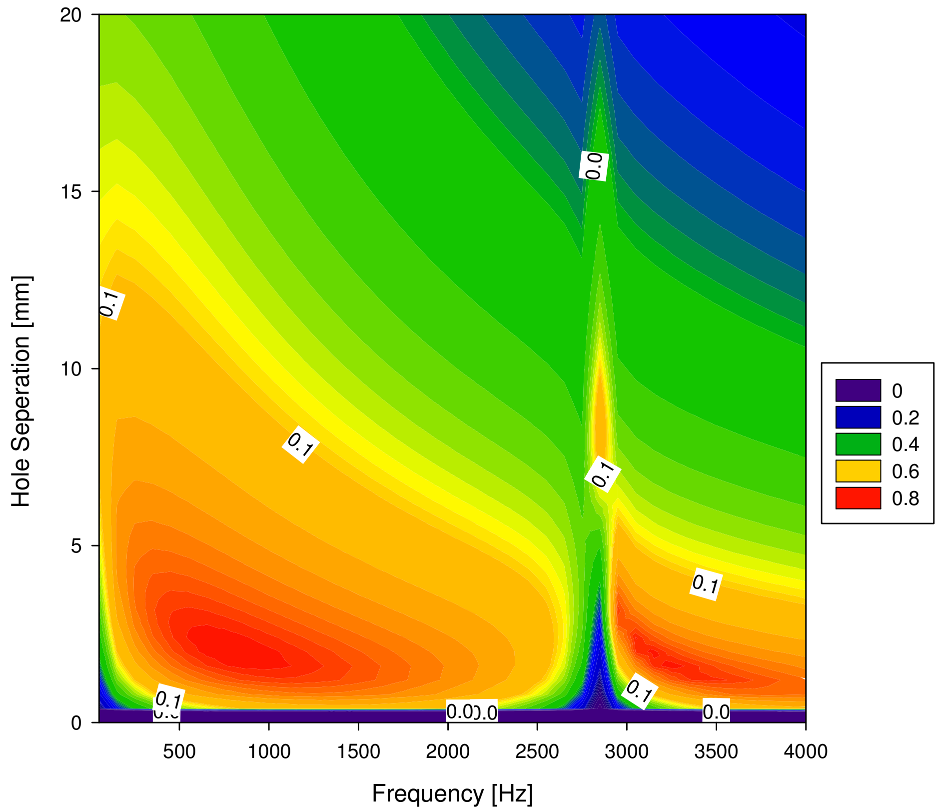

Figure 2: Effect of hole separation on Sound absorption coefficient

In figure 3, effect of hole diameter on sound absorption is shown. In this figure, it is observed that maximum sound absorption is obtained at lower value of hole radius (*a*) and it is maximum at hole radius 0.12 mm with panel thickness 0.2 mm and hole separation 0.25 mm.

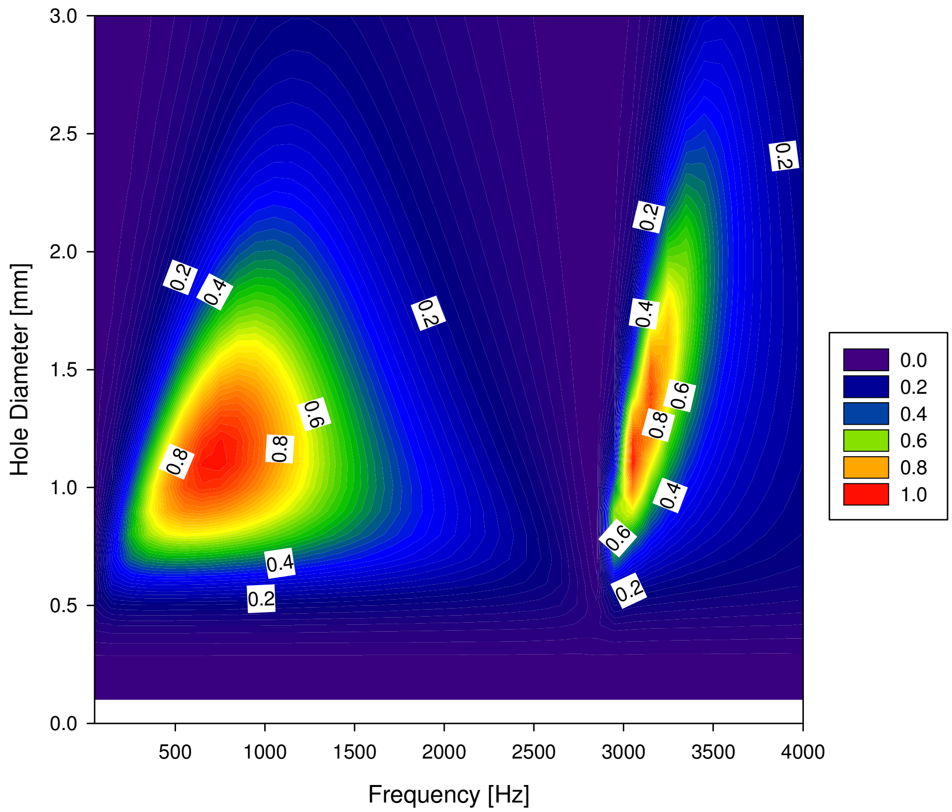

Figure 3: Effect of hole diameter on Sound absorption coefficient

Figure 4 gives effect of micro perforated panel thickness on normal incidence sound absorption coefficient. Maximum sound absorption can be obtained at panel thickness 1-2 mm. In this case, the hole diameter is considered around 0.2 mm and hole separation 0.25 mm. Also it is observed that the sound absorption coefficient decreases with increase in panel thickness. At last normal incidence sound absorption coefficient is simulated at normal as well as random incidence. At random incidence low frequency sound absorption is found to be increased.

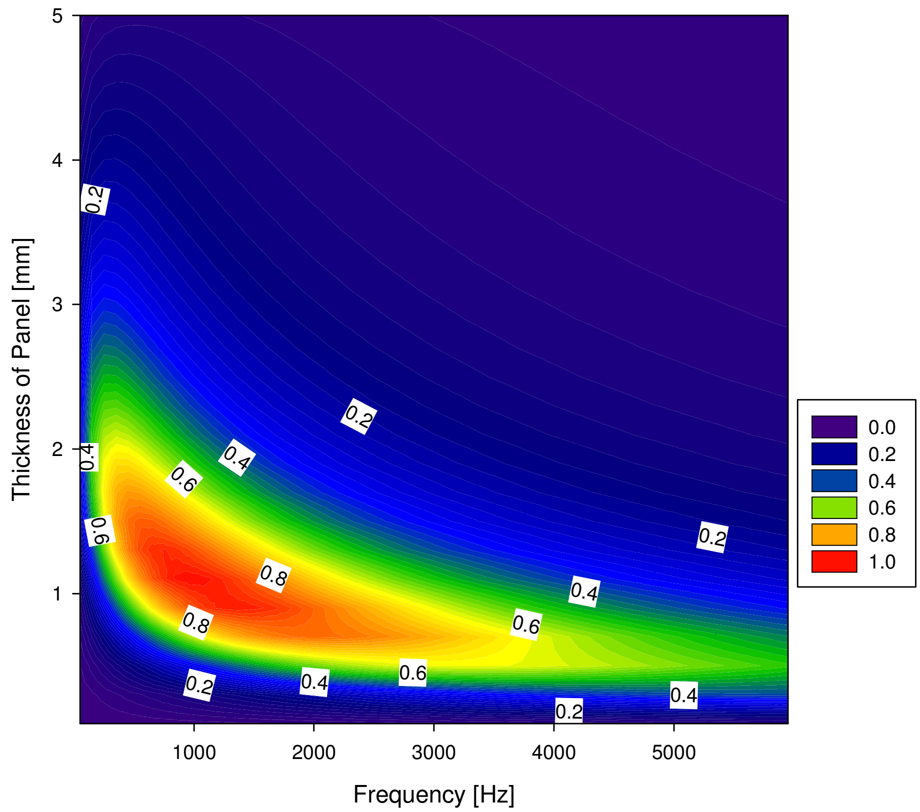

Figure 4: Effect of panel thickness on Sound absorption coefficient

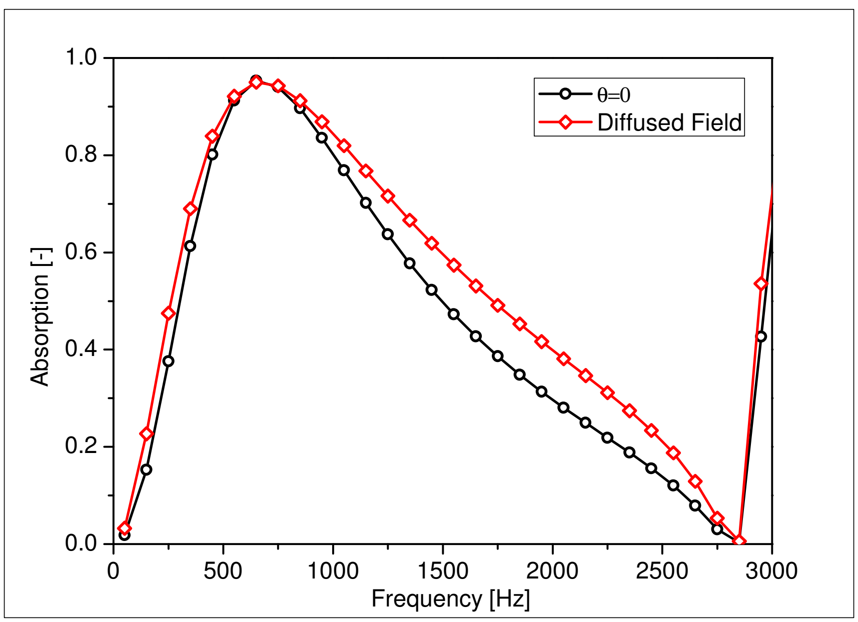

Figure 5: Predicted Sound absorption coefficient at Normal and Random Incidence

From these design charts, it is clear that sound absorption strongly depends not on single parameter but on combination of all these parameters. Optimization of all these parameters is a difficult task. To overcome this problem Genetic algorithm is implemented and results will be discussed during the conference.

4. Conclusions:

This paper presents effect of design parameters on sound absorption coefficient of MPA. Software based on GA for optimization of MPA is developed and results are discussed.

5. Acknowledgement:

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6. **References**:

[1] Maa Dah-You, Potential of micro-perforated panel absorber, Journal of the Acoustical Society of America, 104(5), 2861-2866, (1998).

[2] ZM. Zhang, X. T. Gu, The theoretical and application study on a double layer micro-perforated sound absorption structure, J. Sound & Vibration, 215 (3), 399-405, (1998) .

[3] J. KANG, H. V. Fuchs, Prediction the absorption of open weave textiles and micro-perforated membranes backed by an air space, J. Sound & Vibration, 220 (5), 905-920 (1999).

[4] Jian Zou, Yong Shen, A note on the prediction method of reverberation absorption coefficient of double layer micro-perforated membrane, Applied Acoustics, 67, 106-111, (2006).

[5] Rayleigh S., Theory of Sound, 2nd ed. Dover, New York, (1976).

[6] Lord Rayleigh, pp. 317–318, 487–491.