A pilot study on improving the absorptivity of a thick microperforated panel absorber

Sakagami, Kimihiro
Morimoto, Masayuki
Yairi, Motoki
Minemura, Atsuo

(Citation)
Applied Acoustics,69(2):179-182

(Issue Date)
2008-02

(Resource Type)
journal article

(Version)
Accepted Manuscript

(URL)
https://hdl.handle.net/20.500.14094/90000849

A pilot study on improving the absorptivity of a thick microperforated panel absorber

Kimihiro SAKAGAMI*, Masayuki MORIMOTO

Environmental Acoustics Laboratory, Faculty of Engineering, Kobe University

Rokko, Nada, 657-8501 Kobe, Japan

E-mail: saka@kobe-u.ac.jp

Motoki YAIRI, Atsuo MINEMURA

Kajima Technical Research Inst., Kajima Corporation

Tobitakyu, Chofu, 182-0036 Tokyo, Japan

E-mail: yairi@kajima.com

*Corresponding author

Fax: +81 78 803 6043, Email: saka@kobe-u.ac.jp

Abstract

Microperforated panel (MPP) absorbers are promising as a basis for the next-generation of sound absorbing materials. MPPs are typically made of a thin metal or plastic panel. However, thin limp panels are generally not suitable as an interior finish of room walls because they do not have sufficient strength, which prevents practical application of MPPs as an interior finish of room walls. In order to overcome the lack of appropriate strength required for room walls, it is possible to make an MPP out of a thick panel. However, thick MPPs are usually not efficient because the resistance and/or reactance become too high. In this study, trial production of thick MPPs and measurement of their normal absorption coefficients were carried out. Results show that efficient absorption can be given with a thick MPP by using a tapered perforation.

Keywords: Microperforated panel (MPP), Sound absorption, Thick panel

Introduction

A microperforated panel (MPP) is promising as a basis for the next-generation of sound absorbing materials and is now being widely used. Since the pioneering works by Maa [1-3], many studies have been made on the application of MPPs for various purposes such as attenuating noise in small rooms and for duct silencing [4-6]. An MPP is typically made of a thin metal panel, although making MPPs out of a range of different materials such as a thin plastic film or a thicker acrylic panel has been investigated. In many cases, an MPP is not suitable for an interior finish, particularly for finishing room walls, because thin limp panels do not have enough strength. The use of a thin panel to make an MPP is not only to facilitate the manufacturing process, but is important to give an appropriate range of its acoustic resistance. However, for finishing room walls, the panel should be thicker than at least 10 mm to make the panel stiff enough. If MPPs can be made stiffer, they would be more widely used as a sound absorbing material in a building.

This work investigates the application of MPPs to use as a room interior finish. The main problem is how to make MPPs stiff enough without deteriorating its acoustical performance. Some means can be considered for this purpose, but the simplest idea is to make an MPP out of a thick panel. In this note, firstly problems of thick MPPs are pointed out by some calculated results with Maa’s theory, then the measured results of trial products of thick MPPs are reported.

Problems with thick MPPs

MPPs are usually made of thin panels. This is mainly for manufacture ease since making submillimetre perforations in thick panels is quite difficult. In addition, small perforations in a thick panel tend to result in an extremely large acoustic resistance, which leads to low acoustical performance. In order to demonstrate the difficulties with thick MPPs, some numerical examples calculated by Maa's theory are presented in Figure 1. For the calculations, the formulae proposed by Maa [3] were used: The MPP's specific acoustic resistance *r* and reactance ωm are:

$$r = \frac{32\eta t}{p\rho c d^2}\left(\sqrt{1+\frac{k^2}{32}}+\frac{\sqrt{2}}{32}k\frac{d}{t}\right) \tag{1}$$

and

$$\omega m = \frac{\omega t}{pc}\left(1+\frac{1}{\sqrt{9+\frac{k^2}{2}}}+0.85\frac{d}{t}\right), \tag{2}$$

where

$$k = d\sqrt{\frac{\omega\rho}{4\eta}}, \tag{3}$$

d, *p* and *t* are hole diameter, perforation ratio and thickness (throat length), respectively, and ω is the radian frequency ($\omega=2\pi f$), η the coefficient of viscosity of the air (η=17.9 μPa s). ρ and *c* are air density and sound speed, respectively.

In the calculation, the hole diameter and thickness of an MPP are changed, but the perforation ratio and cavity depth are kept constant at 1.0 % and 50 mm, respectively.

The absorption characteristics of a typical thin MPP (hole diameter 0.4 mm and thickness 0.4 mm) are significantly changed if the thickness is increased to 10 mm: the peak shifts to much lower frequencies and the value is greatly reduced. This is because the acoustic resistance of the panel becomes too high due to its increased thickness. If the hole diameter is enlarged to 4 mm when the thickness is 10 mm, the peak value becomes higher, however, the frequency range of the effective absorption becomes very narrow. This is because of the large reactance produced by the long throat due to the large thickness of the panel. These examples show the difficulty in making effective wide frequency bandwidth absorbers using thick MPPs, which is mainly caused by the excess acoustic resistance or reactance of their holes. Therefore, it is necessary to adjust the acoustic resistance and/or reactance of the holes in optimal range by some means.

Experimental study

In order to improve the absorption characteristics of a thick MPP, an experimental study of a trial production of thick MPPs was made. Since the sound absorption performance of thick MPPs deteriorate due to their high acoustic resistance and/or reactance, it is difficult to improve their performance by simply adjusting the hole diameter or perforation ratio. However, there is the possibility to improve their acoustic performance by adjusting the hole shape or profile. Randeberg [7] examined MPPs with horn-shaped orifices (micro-horn panels), and suggests its possibility to improve the acoustical performance. The numerical results of Randeberg suggest that micro-horn perforation could offer fairly good performance despite its longer throat than ordinary MPPs. Therefore, there can be possibility to adjust the acoustic resistance and/or reactance with orifice design in the case of a thicker panel as well.

Thus, in the trial production, two specimens were made with a normal straight hole profile, and a third was made with a tapered hole profile. The parameters of these three specimens are given in Table 1. The three MPPs were made of acrylic plastics 10 mm thick, and the perforation was made by using a laser beam machine. Note that the specimen D in Table 1 is the same as the reverse of specimen C. All specimens were set in a impedance tube with an air-back cavity. The cavity depths were determined so that the resonance frequencies became around 250 Hz. The normal absorption coefficients of the specimens were measured in an impedance tube using the transfer function method (in accordance with ISO 10354-2).

The measured results of the normal absorption coefficient are shown in Fig. 4. Specimen A with 0.5 mm perforation shows quite low absorptivity. This is because of the very high acoustic resistance due to the long throat, resulting from a large thickness. Specimen B with 0.8 mm perforation shows much higher peak absorptivity, but with a narrower absorption region. This is due to the fact that large perforations result in large acoustic reactance, which makes the absorption peak sharper. Specimen C with a tapered perforation (where the hole diameter is varied from 0.8 mm on the exposed side surface to 0.5 mm on the back side surface) shows a reasonably high absorption peak and wide frequency absorptive range. This suggests that even a thick MPP can offer reasonably high absorption performance with tapered perforations. Randeberg [7] discussed the effects of orifice parameters (the diameters of the inner and outer part, the length, the profile of an orifice, etc.), with numerical simulation by integration method, finite element and finite difference methods. The effects do not cause a monotonic change in its absorption performance: this seems to suggest that an optimal value exists for each parameter. However, it is also pointed out that there is no simulation method to give sufficient accuracy for optimal design of micro-horn orifices, though the numerical simulations can give qualitatively correct insight. Quantitative prediction is still an open question.

Interestingly, specimen D gave exactly the same result as the specimen C. It was expected that their absorption characteristics would be different because their hole diameters on the exposed side are different. Also, an effect similar to 'impedance matching' was expected due to varying hole diameter [7]. However, from these results it is inferred that only the resistance and reactance affect the characteristics. Further investigation is also needed to clarify this effect.

Concluding remark

In this paper, as an attempt to apply an MPP for a room interior finish, a trial production of thick MPPs and the measurement of their normal absorption coefficients were made. Results show that thick MPPs are normally not efficient, but there is a possibility to improve the performance by employing a tapered hole profile.

Acknowledgements

The work was supported in part by a Kajima Foundation Scientific Research Grant.

References

[1] Maa D-Y. Theory and design of microperforated panel sound-absorbing constructions. Scientia Sinica 1975; 17: 55-71.

[2] Maa D-Y. Microperforated-panel wideband absorber. Noise Control Eng. J. 1987; 29: 77-84.

[3] Maa D-Y. Potential of microperforated panel absorber. J. Acoust. Soc. Am. 1998; 104: 2861-2866.

[4] Fuchs HV, Zha X, Drotleff HD. Creating low-noise environments in communication rooms. Applied

Acoustics 2001; 62: 1375-1396.

[5] Zha X, Fuchs HV, Drotleff HD. Improving the acoustic working conditions for musicians in small spaces. Applied Acoustics 2002; 63: 203-221.

[6] Wu MQ. Micro-perforated panels for duct silencing. Noise Control Eng. J. 1997; 45: 69-77.

[7] Randeberg RT. Perforated panel absorbers with viscous energy dissipation enhanced by orifice design. PhD thesis, NTNU (Trondheim, Norway), 2000.

Table 1. Parameters of the specimens used in the experiment. All specimens are 10 mm thick.

Specimen	Thickness [mm]	Hole profile	Hole diameter mm	Perforation ratio* [%]	Cavity depth [mm]
A		Straight	0.5	0.79	36
B		Straight	0.8	2.00	42
C	10.0	Tapered	0.8 (exposed side) 0.5 (back side)	2.00 (exposed side)	56
D		Tapered	0.5 (exposed side) 0.8 (back side)	0.79 (exposed side)	56

*Hole separation is kept constant to 5 mm in all specimens.

Note 1: Cavity depths are determined so that the resonance frequency should be around 250 Hz.

Note 2: Specimen D is the same as the reverse of Specimen C.

Captions of figures

Figure 1. Calculated example of the absorption characteristics of a thick MPP. Hole diameter 0.4mm, thickness 0.4mm (solid line); hole diameter 0.4mm, thickness 10mm (dotted line); hole diameter 4mm, thickness 10 mm (dashed line). Other parameters: perforation ratio 1.0%, cavity depth 0.05m.

Figure 2. Photographs of the specimens. Top: Specimen A, Middle: Specimen B, and Bottom: Specimen C. Specimen D is the same as the reverse of Specimen C.

Figure 3. Results of the measured normal absorption coefficients of thick MPP specimens. All specimens are 10mm thick, and hole diameters are: 0.5mm (Specimen A: dashed line), 0.8mm (Specimen B: dotted line) and tapered hole with diameter 0.8-0.5mm (Specimen C and D: solid line. Note that the results for Specimens C and D are overlapped.).

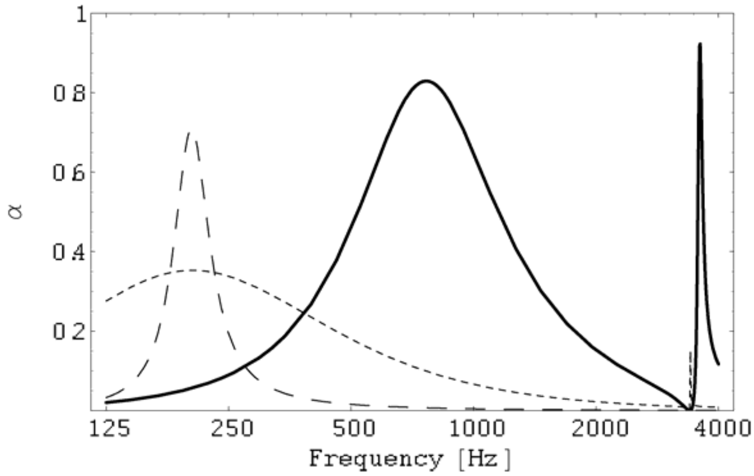

Figure 1. Numerical example of the absorption characteristics of a thick MPP calculated by Maa's theory. Hole diameter 0.4mm, thickness 0.4mm (solid line); hole diameter 0.4mm, thickness 10mm (dotted line); hole diameter 4mm, thickness 10 mm (dashed line). Other parameters: perforation ratio 1.0%, cavity depth 0.05m.

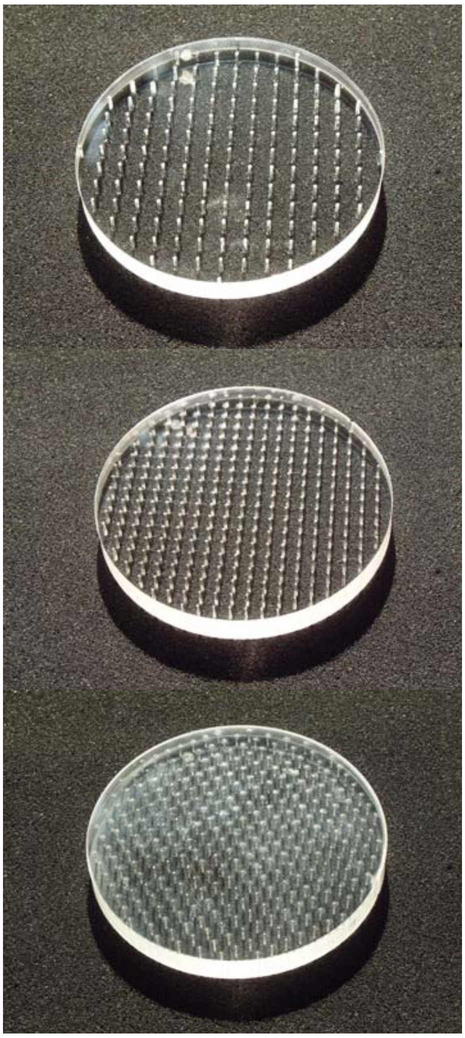

Figure 2. Photographs of the specimens. Top: Specimen A, Middle: Specimen B, and Bottom: Specimen C. Specimen D is the same as the reverse of Specimen C.

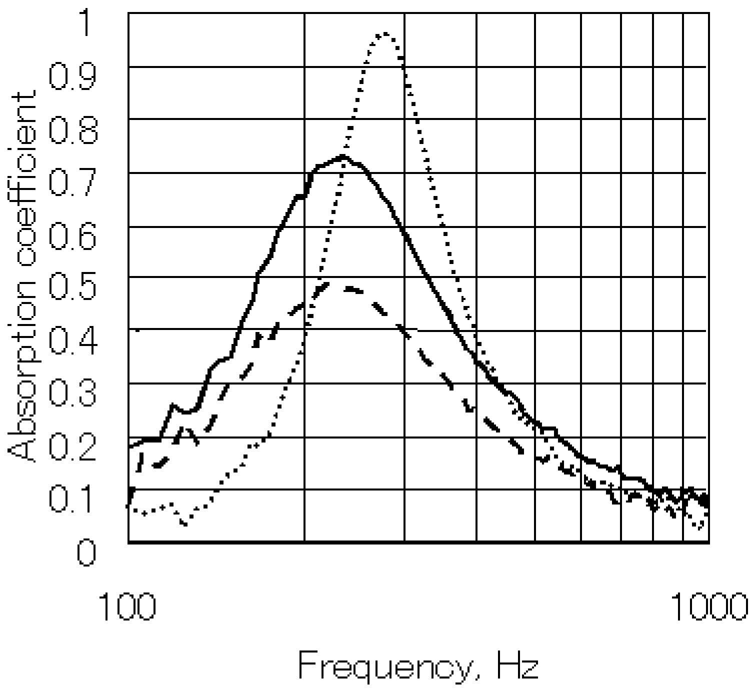

Figure 3. Results of the measured normal absorption coefficients of thick MPP specimens. All specimens are 10mm thick, and hole diameters are: 0.5mm (Specimen A: dashed line), 0.8mm (Specimen B: dotted line) and tapered hole with diameter 0.8-0.5mm (Specimen C and D: solid line. Note that the results for Specimens C and D are overlapped.).