Testing and Analysis of the Sound Absorption Characteristics of Perforated Plates

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Abstract. Perforated plates are studied in terms of the influence of different parameters on the sound absorption characteristics using reverberation chamber test methods, it draws a conclusion: fixing aperture、perforation rate thickness of perforated plate and changing arrangement (triangle and square), the absorption peak of square arrangement (resonant frequency) is the same with triangle, it means that they have nearly identical the sound absorption characteristics; fixing the arrangement(triangle and square)、aperture、thickness of perforated plate and changing perforation rate, with the increasing of perforation rate, the absorption peak(resonant frequency) moves to higher frequency; fixing the arrangement(triangle and square)、perforation rate, thickness of perforated plate and changing aperture, with the decreasing of aperture, the absorption peak(resonant frequency) moves to higher frequency. The result has some reference value to researching the sound absorption characteristics of perforated plates.

Introduction

1 Structure

The sound absorption structure of perforated plates is composed by kinds of sheets with holes and air space behind it. Since each opening is corresponding to the cavity behind it, it's called Helmholtz Resonator in parallel. The panel material is hardboard, veneer board, plaster cast, fiber cement board, steel plate and aluminium plate in general.

2 Sound Absorption Principles

Since it is the combination of Helmholtz Resonator, there could be seen a resonance system which consist with quality and spring. When the incident wave frequency is consistent with the system's resonant frequency, the perforated plate neck air produce intense vibration friction, so it enhances the absorption effect so that forming the absorption peak and making sound energy attenuation significantly, when stay away from the resonance frequency, it reverses. If we place porous materials after perforated plates to increase the acoustic resistance, it can make the structure's the absorption band widened.

1）The influence factors of sound absorption performance

The main influence factors of the sound absorption characteristics of perforated plate structure are:

a)   Thickness of perforated plate、aperture、hole pitch (or perforation rate) and air layer depth after the plate, mainly affect the acoustic frequency range;

b)   Type and location of sound absorbing material set in the cavity, mainly affects the absorption coefficient and acoustic band width;

c)   When the perforation rate is more than 20%, the sound quality of perforated plates is small so that its acoustic effect is reduced, at this time the acoustic characteristics of the sound absorbing structure is mainly decided by the board after the sound-absorbing material and perforated plate as sound-absorbing material of cover panels.

2）The calculation of resonance frequency

The resonance frequency of the perforated plate (Hz) can press type calculation:

$$f_0 = \frac{c}{2\pi}\sqrt{\frac{P}{(t+0.8d)L}} \tag{1}$$

In the formula, L is the thickness of air layer after the plate; t is the thickness of perforated plate, d is aperture, c is sound velocity and P is perforation rate.

3）The calculation of perforation rate

Square arrangement: $P = \frac{\pi}{4}\frac{d^2}{B^2}$ $\tag{2}$

Triangle arrangement: $P = \frac{\pi}{2\sqrt{3}}\frac{d^2}{B^2}$ $\tag{3}$

In the formula, d is aperture, B is hole pitch.

Test equipment and methods

1 Equipment
1)   German lande HEAD company : The front-end, sensors and microphones;
2)   The calibrator in accordance with JJG699, JJG176, JJG778 verification rules;
3)   JTS01 noise signal generator (filters);
4)   JTS022 power amplifier;
5)   JTSY omni-directional source;
6)   Artemis analysis software.

2 Methods

Based on the national standard of reverberation chamber, the size of the rectangle is 12 square metre, aspect ratio is 0.75, any boundary is greater than or equal to 1 m from the room, sealing side with borders that reflection coefficient is high.

Testing result analysis

The calculation of quantity of sound absorption coefficient and sound absorption

1) The absorption quantity of empty reverberation chamber:

$$A_1 = \frac{55.3V}{c_1 T_1} - 4Vm_1 \tag{4}$$

In the formula, V is the volume of reverberation chamber（m^2）; c_1 is the sound velocity in the solution of empty（m/s）; T_1 is the reverberation time of that (s); m_1 is the decay factor of sound intensity of that (m^{-1}), including c=331.45+0.6t and $m_1 = \frac{\alpha}{10\lg(e)}$

2) The absorption quantity of having sample:

$$A_2 = \frac{55.3V}{c_2 T_2} - 4Vm_2 \tag{5}$$

In the formula, c_2 is the sound velocity in the solution of having sample（m/s）; T_2 is the

reverberation time of that (s); m_2 is the decay factor of sound intensity of that (m^{-1}), including c=331.45+0.6t and $m_2 = \dfrac{\alpha}{10\lg(e)}$

3) The absorption quantity of the sample:

$$A_T = A_2 - A_1 = 55.3V\left(\frac{1}{c_2 T_2} - \frac{1}{c_1 T_1}\right) - 4V(m_2 - m_1)\tag{6}$$

4) The sound absorption coefficient α_s :

$$\alpha_s = \frac{A_T}{S}\tag{7}$$

In the formula, S is the area.

Test results

The sound absorption coefficient of the perforated plates that is measured under the different parameters is shown in table 1. The size of sample 1 is that d=4mm, B= 12.3mm, P=9.6%, t=1.5mm, the arrangement is square. The sample 2 is d=4mm, B= 12.3mm, P=9.6%, t=1.5mm, the arrangement is triangle. The sample 3 is d=2mm, B= 8.9mm, P=4.6%, t=1.5mm, the arrangement is square. The sample 4 is d=4mm, B= 17.8mm, P=4.6%, t=1.5mm, the arrangement is square.

Table 1 the sound absorption coefficient of the perforated plates under the different parameters

Frequency (Hz)	The sound absorption coefficient α_s			
	Sample 1	Sample 2	Sample 3	Sample 4
100	0.021	0.023	0.031	0.024
125	0.018	0.023	0.028	0.021
160	0.017	0.020	0.019	0.019
200	0.017	0.021	0.021	0.020
250	0.014	0.020	0.017	0.020
315	0.017	0.021	0.018	0.019
400	0.025	0.022	0.034	0.034
500	0.030	0.036	0.065	0.060
630	0.056	0.056	0.095	0.090
800	0.081	0.072	0.145	0.123
1000	0.094	0.097	0.152	0.119
1250	0.093	0.092	0.137	0.105
1600	0.085	0.082	0.121	0.077
2000	0.067	0.071	0.083	0.063
2500	0.052	0.060	0.070	0.038
3150	0.050	0.058	0.075	0.041
4000	0.040	0.046	0.063	0.038
5000	0.017	0.032	0.045	0.020

As shown as table 1, the sound absorption coefficient of the perforated plate is so small and the frequency-selecting is so quite that the absorption broadband is narrow. So in a engineering practice, it often using acoustic system of perforated plates that fill the sound-absorbing material inside the cavity behind it. This structure can not only make up for the shortage of sound absorption of the porous sound absorbing material on low frequency, but also can give full play to the advantages of decorative strong and enough strength.

The influence of different parameters on the sound absorption characteristics of the perforated plates

1 The comparison of the different arrangements

When the aperture、hole spacing、perforation rate and thickness is the same（d=4mm，B=12.3，P=9.6%，t=1.5mm）,comparing arrangement of square (sample 1) and triangle (sample 2), as shown in Figure 1.
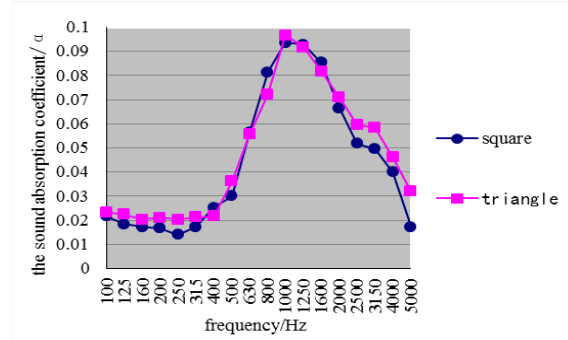

Figure 1: The compare of square arrangement and triangle arrangement

As shown as Figure 1, when the aperture、hole spacing、perforation rate and thickness is the same, they have nearly identical the sound absorption characteristics.

2 The compare of the different perforation rates

When the arrangement 、 aperture and thickness is the same(triangle arrangement, d=4mm,t=1.5mm）, comparing the perforation rate of the triangle arrangement 1(sample 2, P=9.6%) and the triangle arrangement 3(sample 4, P=4.6%), as shown in Figure 2.
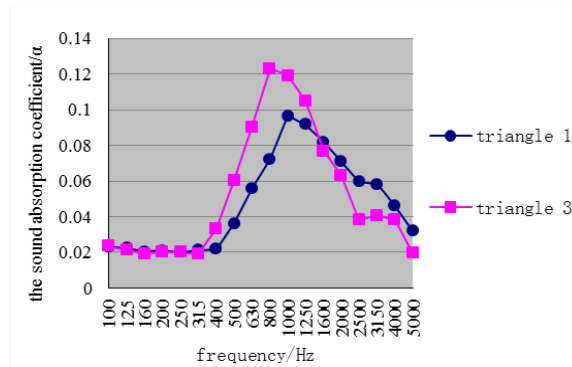

Figure 2: The compare of the triangle arrangement 1 and the triangle arrangement 3

As shown as Figure 2, when the arrangement、 aperture and thickness is the same, with the increasing of perforation rate, the absorption peak(resonant frequency) moves to higher frequency.

3 The compare of the different apertures

When the arrangement、perforation rate and thickness is the same(triangle arrangement, P=4.6%，t=1.5mm）,comparing the aperture of the triangle arrangement 2(sample 3, d=2mm) and the triangle arrangement 3(sample 4,d=4mm), as shown in Figure 3.
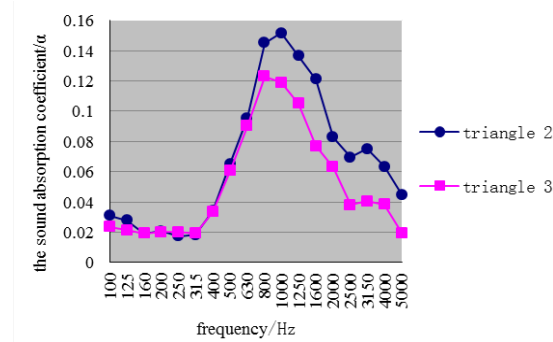
Figure 3: The compare of the triangle arrangement 2 and the triangle arrangement 3

As shown as Figure 3, when the arrangement、perforation rate and thickness is the same, with the decreasing of aperture, the absorption peak(resonant frequency) moves to higher frequency.

Conclusion

(1)　Fixing aperture、perforation rate thickness of perforated plate and changing arrangement (triangle and square), the absorption peak of square arrangement (resonant frequency) is the same with triangle, it means that they have nearly identical the sound absorption characteristics;

(2)　Fixing the arrangement(triangle and square)、aperture、thickness of perforated plate and changing perforation rate, with the increasing of perforation rate, the absorption peak(resonant frequency) moves to higher frequency;

(3)　Fixing the arrangement(triangle and square)、perforation rate, thickness of perforated plate and changing aperture, with the decreasing of aperture, the absorption peak(resonant frequency) moves to higher frequency.

References

[1] Maa Dahyou. Noise and Vibration Control Engineering [M]. China Machine Press, 2002.427-431.

[2] Zhiyong Wei. Industrial Noise and Vibration Control Technology [M], China Labour & Social Security Publishing House, 2010.52-54.

[3] Jinhua Zhou, Yanyan Zuo, Zhancheng Li, Wenxian Shi. The acoustic characteristics of the composite perforation plate acoustical structure analysis and application [J], Journal of Agricultural Machinery, 2007,12.

[4] Yanyan Zuo, Jinhua Zhou, Haibo Liu, Jianhai Hong. Sound Absorption Performance and Application of Sound Absorption Structure of Perforated Plate [J]. The Chinese Mechanical Engineering, 2007, 4.

[5] Zonghui Hong, Zhonglin Pan. Environmental Noise Control Engineering [M]. Higher Education Press, 2002, 8.