A LOW FREQUENCY HONEYCOMB SOUND ABSORBER

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The thickness of the micro-perforated plate (MPP) used in sound absorption usually does not exceed 1.5mm due to the difficulty of punching. A dense honeycomb core is presented to replace the micro-perforated plate to improve the sound absorbing performance in low frequency. The perforation ratio is controlled by punching large holes in a thin face plate which is fixed to the honeycomb core. This structure is named low frequency honeycomb sound absorber (LFHSA) in this article. The sound absorbing performance of LFHSA is measured in an impedance tube. The LFHSA and back space in a limited 100mm depth show a good sound absorbing performance in frequency range 100-300Hz.

Keywords: low frequency honeycomb sound absorber, micro-perforated plate

1. Introduction

Micro-perforated plates (MPP) are widely used for engineering noise control in vehicles, buildings and ventilation facilities due to their good sound absorption and environmental friendliness, durability and hygienic properties. Maa [1-2] firstly proposed the idea that panels with sub-millimeter perforations could provide sufficient acoustic resistance to achieve high absorption coefficients. Later many researchers [3-12] have tried best to improve the sound absorbing performance of MPP and its derivative structure. Some of these studies [10-12] attempt to improve low-frequency sound absorption by using a method equivalent to increasing the thickness of the perforated plate. A bundle of long flexible tubes or short straight tubes were connected to the perforations of MPP to increase the oscillating air mass which could greatly decrease the sound absorption peak frequency without increasing the depth of the back cavity. In this paper a dense honeycomb core was presented to replace the bundle tubes. Another thin plate punched with large holes could tune the effective perforation ratio. First the sound absorbing performance of the LFHSA was predicted based a theoretical model. Second the sound absorption coefficient was measured in an impedance tube. Finally the discussions and conclusions were made in the following section.
2. Theoretical analysis

Fig. 1 shows the sketch of LFHSA which consists of a thin face plate, a dense honeycomb and a back cavity. The face plate is punched with large holes to tune the perforation ratio. The air in the honeycomb core behind the large holes acts as the oscillating mass. The thickness of the honeycomb is much larger than that of the MPP, so the resonant frequency of the LFHSA can be much lower than that of the MPP of the same size. The specific acoustic impedance of one of the honeycomb core could be approximately expressed as

\[ z_c = j\omega \rho_0 t_c \left[ 1 - \frac{2}{x} \frac{J_1(x\sqrt{-j})}{x\sqrt{-j}J_0(x\sqrt{-j})} \right]^{-1} \]

where \( x = (d/2)\sqrt{\omega \mu / \eta} \), \( t_c = t + 0.85d \), \( t \) is the thickness of the honeycomb, \( d \) is the equivalent aperture of the honeycomb core, \( \omega \) is the angular frequency, \( \rho_0 \) is the density of the air, \( c_0 \) is the speed of the sound in the air, \( \eta \) is the viscous coefficient of air and \( \mu \) is the kinematic viscosity.

The specific acoustic impedance of the face plate and honeycomb core can be written as

\[ z = \frac{z_c}{\phi_f \phi_c} \]

where \( \phi_f, \phi_c \) are the perforation ratios of the face plate and the honeycomb core respectively. Then the specific acoustic impedance of the LFHSA can be written as

\[ z_L = z + z_{\text{cavity}} \]

where \( z_{\text{cavity}} = -j\rho_0 c_0 \cot \left( \frac{\omega D}{c_0} \right) \).

The sound absorption coefficient can be written as

\[ \alpha = \frac{4\rho_0 c_0 \text{Real} (z_L)}{(\rho_0 c_0 + \text{Real} (z_L))^2 + (\text{Imag} (z_L))^2}. \]

3. Measurement of the sound absorption coefficient

The sound absorption performance of LFHSA is tested in an impedance tube with a diameter of 100mm. Fig. 2 shows the tested sample which consists of a face plate with large holes and a honeycomb with a thickness of 5mm. Fig. 3 shows the comparison of measured and calculated sound absorption coefficient of LFHSA. The tested sample in Fig. 3 has a 100mm thick cavity and a 5mm thick honeycomb. When the face plate has four, three, two and one 4mm-diameter holes, the sound absorption coefficients are shown in Figures 3(a), (b), (c) and (d), respectively. The LFHSA has very good sound absorption performance in low frequency. The sound absorption frequency bandwidth can cover 2~3 octaves. The sound absorption peak moves to low frequency decreasing the effective perforation ratio. When the number of perforations in face plate is small, the test and calculation results are greatly deviated as shown in Fig. 3(c) and (d) due to the estimation error of the perforation ratio. The interaction
effect between honeycomb cores in a large hole on the sound absorption is neglected in the theoretical model. That also leads to the theoretical and experimental deviation.

![Image](image)

Figure 2: The pictures of the tested sample.

![Graphs](graphs)

Figure 3: The measured (solid red line) and calculated (dashed blue line) sound absorption coefficient of LFHSA: (a) Four 4mm-diameter holes; (b) Three 4mm-diameter holes; (c) Two 4mm-diameter holes; (d) One 4mm-diameter hole.
4. Conclusions

A dense honeycomb core is presented to replace the MPP or the flexible bundle tubes in order to improve the sound absorbing performance in low frequency. The effective aperture of the dense honeycomb core must be far smaller than that of ordinary honeycomb core. The measured and calculated results show that LFHSA is a very good sound absorbing structure of which frequency bandwidth can cover 2~3 octaves. However the theoretical model based on the MPP has some deviation in predicting the sound absorption coefficient of LFHSA because the effective perforation ratio and the additional mass are not accurately estimated in the model.

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REFERENCES