Improvement of the Sound Absorption Performance of Sandwich Panel Using Inhomogeneous Micro Perforations

Zacharie Laly [*1, 2], **Christopher Mechefske** [†2], **Sebastian Ghinet** [‡3], **and Charly T. Kone** [♦3], **N. Atalla** [#1], **and B. Ashrafi** [♠4]
[1]CRASH, Centre de Recherche Acoustique-Signal-Humain, Université de Sherbrooke, Québec, Canada.
[2]Department of Mechanical and Materials Engineering, Queen's University, Kingston, Ontario Canada.
[3]Aerospace Research Center, National Research Council Canada, Ottawa, Ontario, Canada.

1 Introduction

Micro-perforated panel (MPP) absorbers are widely used for noise reduction in several engineering applications. They are non-combustible, high temperature and wear resistant and can be used in environments where fibrous or porous materials can deteriorate. MPP absorbers have been studied in linear and nonlinear regimes [1-4] and their sound absorption coefficients generally present only one resonant frequency that depends of the geometrical parameters of the MPP and the cavity depth.

In this paper, an MPP absorber is studied using finite element method (FEM) and inhomogeneous micro-perforations are considered to enlarge the sound absorption frequency band. With uniform micro-perforations, the sound absorption presents only one resonant peak and when the number of different sets of MPP diameters increases, the number of the sound absorption resonant peaks increases.

2 Finite element modelling of sandwich panel with inhomogeneous micro perforations

In the following, an MPP absorber design with inhomogeneous micro perforations is proposed and studied numerically to broaden the attenuation frequency band. Figure 1 shows an MPP absorber whose cavity is made of a honeycomb structure with 33 hexagonal cells. The micro-perforated panel is shown in Fig. 1 (a) Each micro-perforation is positioned in the center of each hexagonal cell as shown in Fig. 1 (c) and the backing plate is rigid. The material used for the MPP absorber in Fig. 1 is aluminum. The thickness of the MPP and the backing panel is set to 1 mm and the thickness of the honeycomb core is 15 mm with a cell size of 3/8 inch (9.525 mm). The thickness of the cell wall is 0.5 mm and the lateral dimensions of the structure are 48 mm x 53 mm. Figure 2 shows the numerical models based on the two microphones transfer function method to calculate the sound absorption coefficient and the surface impedance of the MPP absorber. The two microphones are denoted by M_1 and M_2 and the acoustic pressures at M_1 and M_2 positions are calculated numerically. The air within each micro-perforation is modeled using the thermo-viscous acoustic module of COMSOL Multiphysics to account for the viscous and thermal losses and the honeycomb structure comprising the honeycomb core, the MPP and the backing panel is characterized using the solid mechanics module while the rest of the domains are modeled using the pressure acoustics module. A normal incidence plane wave with pressure amplitude of 1 Pa is applied on the inlet plane with plane wave radiation condition.

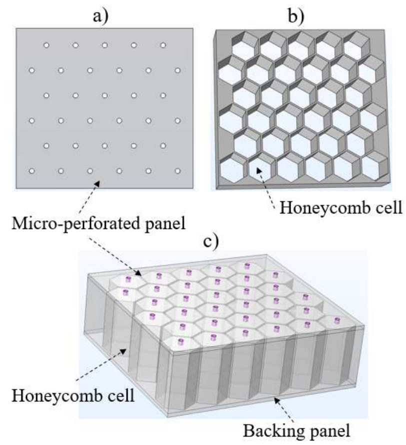

Figure 1: Numerical models of sound absorber (a) micro-perforated panel (b) honeycomb cell (c) micro-perforated panel absorber.

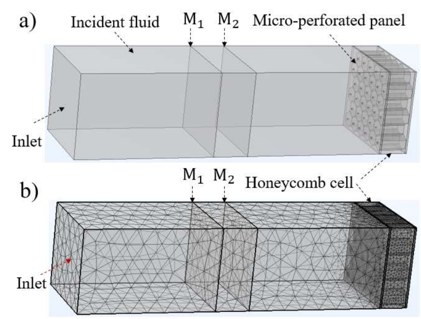

Figure 2: Numerical models (a) geometry (b) mesh.

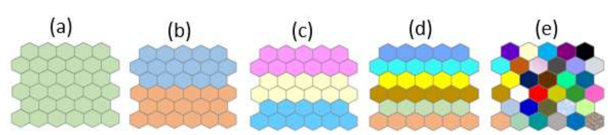

Figure 3: Different configurations of MPP.

The different configurations that are studied are shown in Fig. 3 where each color represents an MPP diameter. In Fig. 3 (a), identical MPP diameters are considered and in Fig. 3 (b), two sets of different MPP diameters are used. The

* zacharie.laly@usherbrooke.ca
† chris.mechefske@queensu.ca
‡ sebastian.ghinet@nrc-cnrc.gc.ca
♦ tenoncharly.kone@nrc-cnrc.gc.net
noureddine.atalla@usherbrooke.ca
♠ behnam.ashrafi@nrc-cnrc.gc.ca

configuration D is made of six sets of different MPP diameters while in Fig. 3 (e), each MPP diameter is different in every cell.

Figure 4 shows the sound absorption coefficient of configuration A using same MPP diameter d that is varied from 0.5 mm to 1.5 mm. For d=0.5 mm, the mesh in Fig. 2 (b) consists of 315750 domain elements and 43860 boundary elements where the number of degrees of freedom is 1096469. In Fig. 5, the sound absorption coefficients of the configurations B to E are presented. For case B, the two sets of MPP diameters (Fig. 3 (b)) are 0.8 mm and 1 mm and for case C (Fig. 3 (c)), the diameters are 0.7 mm, 1 mm, and 1.2 mm. The six sets of diameters used for case D in Fig. 5 (b) are 0.7 mm, 1 mm, 0.8 mm, 1.5 mm, 1.1 mm, and 1.3 mm while for case E (Fig. 3 (e)), 33 different diameters between 0.7 mm and 1.34 mm are used with a step of 0.02 mm. The corresponding surface impedance is illustrated in Fig. 6.

In Fig. 4, the sound absorption coefficient of the sandwich panel without micro-perforations is zero over the entire frequency range. For the MPP diameters of 0.5 mm, 0.8 mm, 1.2 mm and 1.5 mm, the absorption peak values in Fig. 4 are 0.8, 0.96, 0.6 and 0.34 at frequencies of 610 Hz, 956 Hz, 1348 Hz and 1624 Hz respectively. The normalized resistance for configuration A with d=0.5 mm is around 3 in Fig. 6 and for d=0.8 mm, it is close to 1 and for d=1.5 mm, it is 0.1 over the entire frequency range. The sound absorption resonant frequency in Fig. 5 increases as the diameter increases and the absorption peak value decreases because the resistance becomes low. At each resonant frequency, the reactance in Fig. 6 is zero. For case B in Fig. 5 (a) where two sets of different MPP diameters are used, there are two resonance frequencies of 956 Hz and 1124 Hz with absorption peak value of 0.95. With three sets of different diameters, three absorption peak values of 0.7, 0.99, and 0.92 are observed at respective frequencies of 836 Hz, 1168 Hz and 1296 Hz. In Figure 5 (b), the absorption coefficient presents six resonance peaks when six sets of different diameters are considered and with 33 different diameters, one observes that the absorption frequency band has been widened.

3 Conclusion

MPP absorbers with inhomogeneous micro-perforations were studied numerically. With uniform micro-perforations, the sound absorption presents only one resonant frequency, which increases as the MPP diameter increases while the peak value decreases. When 2, 3 and 6 different sets of micro-perforation diameters are used, the sound absorption shows respectively 2, 3 and 6 resonance peaks and with 33 different MPP diameters, the absorption frequency band is widened.

Acknowledgments

The authors acknowledge the National Research Council Integrated Aerial Mobility Program for the financial support.

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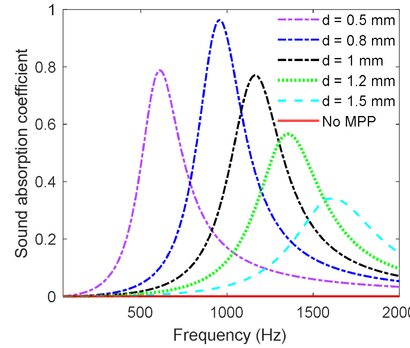

Figure 4: Sound absorption coefficient of configuration A.

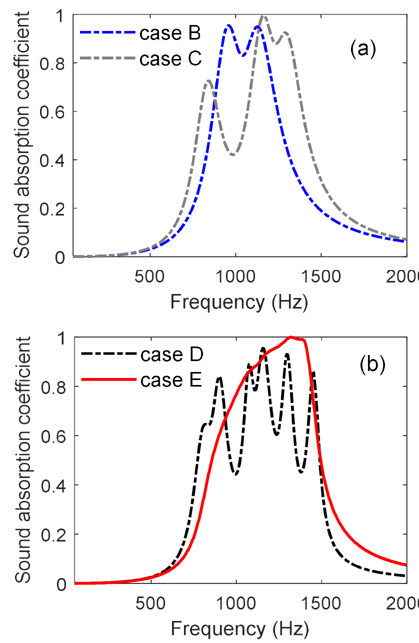

Figure 5: Sound absorption coefficient (a) configurations A and B (b) configurations C and D.

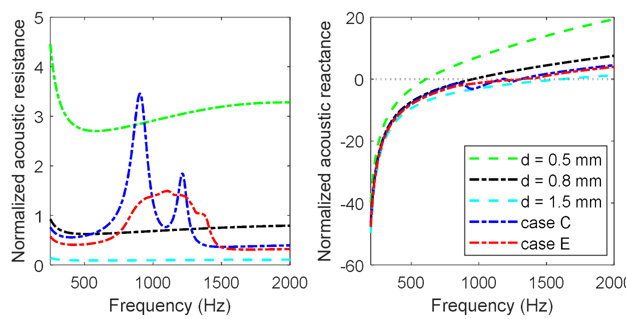

Figure 6: Normalized surface impedance (a) acoustic resistance (b) acoustic reactance.

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