Absorption coefficient of perforated plates backed by a porous material under high sound excitation: The holes interaction effect

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Objectives

Originally used to protect sound absorbing materials, perforated plates are often used as a complementary solution to the classical porous materials. Such assemblies are known to enhance the acoustic absorption near the resonance frequency. In most practical applications, the incident sound pressure are relatively high and the plates holes are very closed to each other such that these effects may alter the acoustic response of the system.

Prior work

Very few works deal with the holes interaction effects induced by a perforated plate. The classical models make use of Fok's function to account for the interaction effect. Meanwhile, under high sound regimes, this latter function is no longer valid to account for this effect. The modeling of porous materials submitted to high sound regimes is relatively mastered. The classical method consists of the use of Forchheimer law.

Theoretical development

Each layer is modeled as an equivalent fluid following the Johnson-Champoux-Allard approach.

The surface impedance is given by:

$$Z_S = \frac{1}{\phi} j\omega\rho_e h + Z_B$$

Z_B is the impedance of the medium behind the plate, ω is the pulsation, Φ is the plate porosity and ρ_e is its effective density. σ_0 and σ are the linear and high sound resistivities. ξ_1 and ξ_2 are the Forchheimer coefficients.

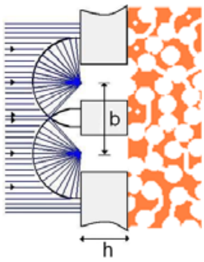

Fig 1: Schematic of the assembly and nomenclature used.

Corrections of the tortuosity (interaction effect) and the resistivity (high sound effect) for each layer are proposed in this work.

$$\alpha_\infty = f(b,h)$$ NEW

$$\sigma = \xi_1\sigma_0 v + \xi_2\sigma_0$$ (Forchheimer law)

Reflection and absorption coefficients are given by :

$$R = \frac{Z_S - Z_0}{Z_S + Z_0}$$ and $$\alpha = 1 - |R|^2$$

Samples tested

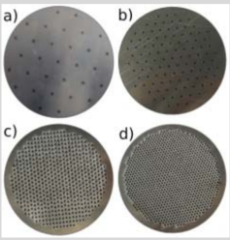

Fig 2: Perforated plates specimens of 1.5 mm thickness and 1.6 mm holes diameter are tested. Perforation distances of 12 mm, 8 mm, 3.5 mm and 2.6 mm.

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Fig 3: Polymeric foam

Harmonic Excitation

Experimental rig

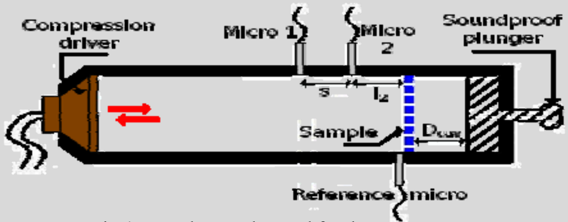

Fig 4: Impedance tube used for the measurements

Forchheimer coefficients (high sound level coefficients) are obtained after each sample resistivity measurements.

Important results

Holes interaction effect combined to the porosity effect

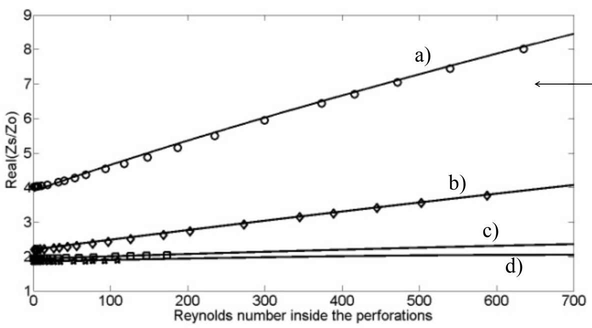

Fig 5: Surface resistance as a function of Reynolds number inside the perforations (454 Hz)

Resistance vs Reynolds number slope decreases with the distance between the perforation

Maximum of absorption coefficient solely decreases with an increase of Reynolds number

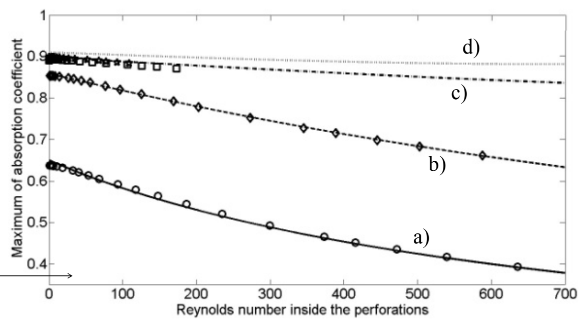

Fig 6: Maximum of absorption coefficient as a function of Reynolds number inside the perforations (454 Hz)

Conclusion

➢A modification of the resistivity and the tortuosity can be used to model a perforated plate backed by a porous material accounting for the high sound and holes interaction effects.

➢Fairly good agreement is obtained between the model and the measurements for the frequency studied.

References

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[2] Umnova et al. *J. Acoust. Soc. Am., Vol.114(3), pp.1346-1356, 2003.*

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