How to compute the reflection and transmission coefficients of a plane acoustic wave by a low-porosity perforated plate ?

Sophie LAURENS, CERFACS, quipe ALGO-EMA

Estelle Piot, ONERA, dpartement DMAE

Abderrahmane Bendali, INSA, dpartement GMM

Sbastien Tordeux, INRIA, quipe MAGIQUE-3D

MBarek Fares, CERFACS, quipe ALGO-EMA

Perforated plates and screens are widely used in engineering systems due to their ability to absorb sound or to reduce sound transmission, in a variety of applications including room acoustics and aeroacoustics. They can be used as protective layers of porous materials, to form sandwich structures in aircraft fuselages or as facing layers of liners. In this case, the perforated plates are either backed by honeycomb cells which are mounted on a rigid backplate or by a plenum acting as a resonant cavity in gas turbine combustion chambers.

In this work, we investigate the acoustic properties of a low-porosity perforated plate in a compressible ideal inviscid fluid in the absence of mean flow. Because the acoustic wavelength is large as compared with the aperture size, each aperture can be considered as acoustically compact. This means that the local motion through an aperture is assumed to be incompressible. At a large enough distance from the perforated plate, the scattered pressure field can be decomposed into a reflected and a transmitted wave where the reflection and transmission coefficients are complex constants, depending on the acoustic properties of the plate. In particular, we show that they can be expressed in terms of the Rayleigh conductivity of an isolated perforation by extending the approach introduced for the case of thick plates by [1]. The Rayleigh conductivity depends on the ratio of the volume flux through the aperture by the difference in unsteady pressure between each sides of the plate. Using the linearized momentum equation, it can be expressed as a function of pressure only, but it still require the computation of the solution to obtain its value. For thin plates with a circular aperture, [2] gives an analytical expression of this quantity. For untilted cylindrical or conical apertures, one only have the Howe'estimates [3], established empirically by assuming that the flow is potential and governed by the linearized Helmholtz equation in the aperture if the characteristic size of the hole is small in comparison with the acoustic wavelength.

Lower and upper bounds for the Rayleigh conductivity of a perforation in a thick plate are usually derived from intuitive approximations and by reasoning based on physical observation like Howe's. This work addresses a mathematical justification of these approaches, yielding accurate bounds for various geometries, untilted or tilted, with a conical shape or an elliptical section. Accurate estimates of the Rayleigh conductivity for a single perforation have a direct impact on the precision of models used for predicting the acoustic behavior of a perforated plate mainly on the basis of its reflection and transmission coefficients. It'll be shown in this work how asymptotic expansions can be used to derive first and second-order accurate, albeit approximate expressions of these coefficients, as well as of the effective compliance of the perforated plate.

Références

[1] F. G. Leppington and H. Levine. Reflexion and transmission at a plane screen with periodically arranged circular or elliptical apertures, *J. Fluid Mech.*, 61:109–127, 1973.

[2] Lord Rayleigh. *The Theory of Sound*, volume 2, Dover publications, New York, 1945.

[3] M. S. Howe. *Acoustics of fluid-structure interaction*, 1998.

[4] S. Laurens, E. Piot, A. Bendali, M. Fares, and S. Tordeux. Effective conditions for the reflection of an acoustic wave by low-porosity perforated plates , *to appear in J. Fluid Mech.*, 2014.

Sophie LAURENS, 42 avenue Gaspard Coriolis, 31 100 Toulouse
`sophie.laurens@cerfacs.fr`