Absorption and transmission of boundary layer noise through micro-perforated structures: measurements and modellings

Cédric Maury[1], Teresa Bravo[2] and Daniel Mazzoni[3]

[1]Aix Marseille Univ. CNRS Centrale Marseille, Laboratory of Mechanics and Acoustics (LMA UMR 7031)
38 rue Frédéric Joliot-Curie, 13013 Marseille, France
cedric.maury@centrale-marseille.fr

[2]Instituto de Tecnologías Físicas y de la Información (ITEFI) , Consejo Superior de Investigaciones Científicas (CSIC)
Serrano 144, 28006 Madrid, Spain
teresa.bravo@csic.es

[3] Aix Marseille Univ. CNRS Centrale Marseille, Institut de Recherche sur les Phénomènes Hors Equilibres (IRPHE UMR 7342)
38 rue Frédéric Joliot-Curie, 13013 Marseille, France
daniel.mazzoni@centrale-marseille.fr

Mitigating flow-induced noise is currently a major feature in the acoustic design of automotive and aircraft cabins. The problem of reducing the airframe noise under a low-speed flow is complex as it should comply with low drag and mass-saving constraints. Moreover, the current use of lighter and stiffer structures with a low critical frequency enables a more efficient transmission of the mid-frequency noise components towards the cabin, such as those induced by a turbulent boundary layer (TBL) of air. In order to avoid the introduction of active or massive components, structures made up of micro-perforated panels (MPP) are potential lightweight solutions that could be used to enhance the absorption and decrease the transmission of flow-induced noise. MPP resonance absorbers have been introduced [1] in the frame of building acoustics. They are composed of sub-millimetric holes backed by an air cavity. They showed to be efficient around their Helmholtz resonance under plane wave and diffuse field excitations. Unbacked MPPs still provide damping due to viscous dissipation of the acoustic pressure jump across their apertures or to its conversion into vorticity. The present work describes experimental and modelling studies that examine the effect of MPP partitions, either flush-mounted (I) or in a recessed configuration (II), on the wall-pressure fluctuations induced by a low-speed TBL.

In case I, an experimental methodology has been generalized from [2] to measure in a low-speed wind-tunnel the frequency-averaged power flow injected by TBL wall-pressures into MPP partitions, e.g. the absorption, as well as the transmission loss (TL). The measurements have been assessed against simulations of the power absorbed and transmitted by finite-sized and infinite-sized flexible MPP-Cavity-Panel (MPPCP) partitions forced by an aeroacoustic excitation. Both models compare satisfactorily against transmission and absorption measurements and a number of trends have been drawn [3]. At low frequencies, a large part of the power injected by the aerodynamic pressures into the partition is transmitted through the apertures with inefficient back-scattering properties. As frequency increases, the absorption steeply decays due to the MPP apertures that efficiently back-scatter small-scale turbulence into sound. Furthermore, two absorption peaks are observed and predicted at the MPP aerodynamic coincidence frequency and at the Helmholtz resonance frequency, the latter being significant if the acoustic component exceeds 20%. As for the TL, it decreases when increasing the acoustic component of the excitation due to a larger correlation area of the forcing pressures that better couple with the MPP resonant modes. In practice, a MPPCP partition under a low speed flow would achieve a tradeoff between absorption and transmission depending on the spectral content of the aeroacoustic excitation.

In case II, numerical and experimental studies have been carried out to evaluate the effect of microperforating the base wall of shallow cavities in transitional and closed flow regimes in order to reduce their tonal and broadband noise components under a low-speed TBL [4]. As shown in Figure 1, micro-perforating the base wall of a transitional cavity reduces by up to 8 dB the first peak levels that appear over one-third of the cavity floor towards the leading edge. They are identified as transverse tunnel-cavity resonances excited by the shear layer and coupled with the thin MPP flexural modes. This is confirmed by two-dimensional Lattice-Boltzmann simulations that predict an attenuation of the dominant peaks at the floor and at the mouth of the cavity, but with an overestimated amplitude. It was found that the dissipation of energy occurs at the regions of maximum velocity fluctuations induced by well-established outflow conditions within and at the inlet-outlet of the base wall apertures.

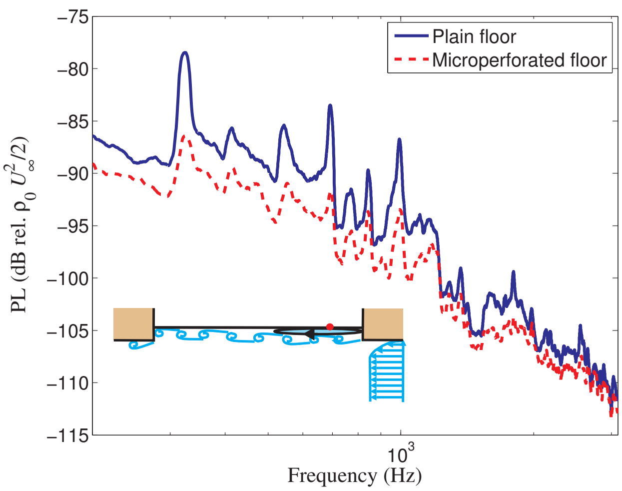

Figure 1: Effect of a microperforated floor on the pressure level (PL) spectra measured over the base wall of a transitional cavity of length-to-depth ratio 10.6 at $9.8\,\mathrm{cm}$ from the cavity upstream edge under a TBL ($U_\infty = 30.7\ \mathrm{m\,s^{-1}}$); the red dot in the sketch shows the measurement location.

References

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