Acoustic characterization of orifices and perforated liners with flow and high-level acoustic excitation

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Abstract

This thesis is motivated by the need for noise control in aircraft engine with orifices and perforated liners. The presence of high-level acoustic excitation, different flow situations either bias flow, grazing flow or any combination in the aircraft engine, makes the acoustic behavior complex due to the interaction between sound and flow over the lined wall. Both systematic acoustic prediction of aircraft engines and liner optimization necessitate progress in impedance measurement methods by including the effect of the complex flow situations. The aim of the present thesis is to experimentally study the change in acoustic properties of orifices and perforated liners under bias or grazing flow.

In order to study the effect of different combinations of bias flow and high-level acoustic excitation, an in-duct orifice has been investigated with finely controlled acoustic excitation levels and bias flow speeds. This provides a detailed study of the transition from cases when high-level acoustic excitation causes flow reversal in the orifice to cases when the bias flow maintains the flow direction. Nonlinear impedance is measured and compared, and a scattering matrix and its eigenvalues are investigated to study the potentiality of acoustic energy dissipation or production. A harmonic method is proposed for modelling the impedance, especially the resistance, which captures the change in impedance results at low frequencies compared with experimental results.

The presence of grazing flow can increase the resistance of acoustic liners and shift their resonator frequency. So-called impedance eduction technology has been widely studied during the past decades, but with a limited confidence due to the interaction of grazing flow and acoustic waves. A comparison has been performed with different test rigs and methods from the German Aerospace Center (DLR). Numerical work has been performed to investigate the effect of shear flow and viscosity. Our study indicates that the impedance eduction process should be consistent with that of the code of wave propagation computation, for example with the same assumption regarding shear flow and viscosity. A systematic analysis for measurement uncertainties is proposed in order to understand the essentials for data quality assessment and model validation. The idea of using different Mach numbers for wave dispersion and in the Ingard-Myers boundary condition has been tested regarding their effect on impedance eduction. In conclusion, a local Mach number based on friction velocity is introduced and validated using both our own experimental results and those of previous studies.

Keywords
Bias Flow, Grazing Flow, Nonlinear Acoustics, Acoustic Impedance, Impedance Eduction, Single Mode Straightforward Method, Uncertainty Analysis, LEE, LNSE