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Orifice Impedance under Grazing Flow
Measured with a Single Microphone Method

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The effect of one-sided grazing mean flow on the acoustical impedance of rectangular orifices is measured at low Mach number and low Helmholtz number by means of a single microphone method. The results are fairly consistent with previous experimental results obtained by means of a two-microphone impedance tube. Furthermore no significant influence of the aperture aspect ratio and aperture wall thickness on the non-dimensional scaled impedance is found, at least for the qualitative trend. Comparison with an existing theoretical model shows reasonable agreement for the resistance, provided that the experimental results are tentatively corrected for boundary layer- and induced flow effects. For the reactance no agreement is found.

I. Introduction

In order to suppress noise in ducts, such as combustion engine exhausts and in- and outlets of jet engines, acoustic damping material, protected by perforated plates, can be placed at the walls. Often the damping material itself is omitted, and the space between the perforate plates and the backing wall is filled with honeycomb structure. The so obtained acoustic liner is then basically an array of Helmholtz resonators, cf. figure 1. Sometimes one or two additional layers of resonators are used to obtain a double Degree of Freedom (DOF) respectively triple DOF liner.1,2 The acoustic properties of a Helmholtz resonator are partly determined by the impedance of its orifice. Due to the specific application in liners, especially the effect of grazing flow on the orifice impedance is of interest. This has been investigated experimentally by several authors, e.g. Ronneberger,3 Goldman and Panton,4 Kirby and Cummings,5 and Cummings.6 These studies concern the impedance of circular apertures or perforated plates3,5,6 in duct flow3,5,6 for very low Strouhal numbers Sr and thin3,5,6 or thick4 boundary layers. Generally, it is concluded that above a certain velocity limit the effect of the flow is to increase the resistance (absorption) and to decrease the reactance (added mass). Ronneberger3 proposed a simple model, which predicts the experimental results well, but is argued to be only valid for thin boundary layers and low Strouhal number. Goldman and Panton4 and Cummings5,6 give empirical formulas which solely predict absorption and no sound production by the orifices. Sound production was measured,6 but was assumed to be due to experimental error. Howe7,8 proposed a theoretical model for linear perturbations. For the specific case of a rectangular aperture with large aspect ratio an exact analytical expression was given for the orifice impedance. Strouhal number ranges for sound absorption as well as production are predicted. The theoretical model of Howe will be summarized in section II. Golliard11 experimentally investigated the impedance of a rectangular orifice with large aspect ratio. A two-microphone impedance tube was used. He compared his results with the theoretical model of Howe.7,8