EXPERIMENTAL AND NUMERICAL ANALYSIS OF PERFORATED SYSTEMS AT HIGH SOUND PRESSURE

F. Pompoli, P. Bonfiglio
MechLav, University of Ferrara

1. Introduction

The present paper shows an experimental and numerical study on perforated panels subjected to increasing levels of acoustical excitation. Experimentally it was observed that the behaviour of such systems is dependent on the particles velocity within the holes. This effect occurs even when the system is put in contact with a porous material. In the latter case it has also been shown experimentally that the contact between the systems leads to a further increase in fluid-dynamic losses in the holes. In this research, it is proposed a numerical method that allows to fully consider the nonlinear effects of the change in level of excitation and interaction between holes and porous media.

2. Experimental and numerical investigation

The experimental investigation has been carried out on different perforated systems consisting of a full disc having holes with a diameter of 5 mm and different values of perforation area (Fig. 1). Resonators were tested in a plane wave tube and values of the complex reflection coefficient have been measured by means of the well established transfer function method (ISO 10534-2 [1]). Tests have been also carried out partially filling the air gap with a layer of polyester fiber.

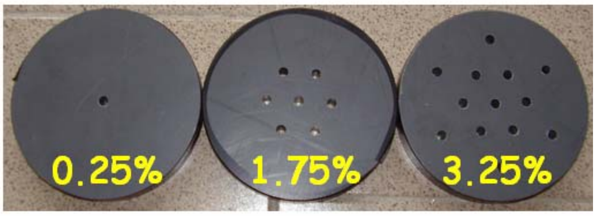

Fig. 1 – Perforated systems

In the present paper perforated systems have been modelled by using a finite element scheme (Comsol Multiphysics 3.5 a). In particular a rigid frame approach of the air within the holes has been utilized and complex density and sound speed of any single hole has been calculated by means of Johnson-Champoux-Allard model [2]. Regarding polyester fiber, complex quantities to be used in FEM simulations have been calculated by using Garai-Pompoli model [3].
Non linear effects due to high incident pressures and possible contact between resonators and polyester fiber layer has been introduced by modifying airflow resistivity as follows:

$$\sigma = \left(\frac{4t}{d} + 4\right) \cdot \frac{R_s}{\phi t} + \frac{R_{f\_NL}}{\phi t} + \frac{R_{contact}}{\phi t} \ \text{(N s/m}^4\text{)}$$

where $R_s = 0.5 \cdot \sqrt{2\eta\omega\rho_0}$ (ω [rad/s] being the angular frequency, η the dynamic viscosity of the fluid [Pa·s], ρ_0 the density of the fluid [kg/m^3]), t [m] is the thickness and d [m] diameter of the holes respectively. R_{f_NL} and $R_{\_contact}$ [N s/m^3] are additional terms describing non linear and contact effects and they were calculated by using a CFD approach (ANSYS CFX 12.0).

In the model of the hole open porosity and tortuosity are fixed to the unit and characteristic lengths are equal to the radius of the hole.

(a) (b) (c)

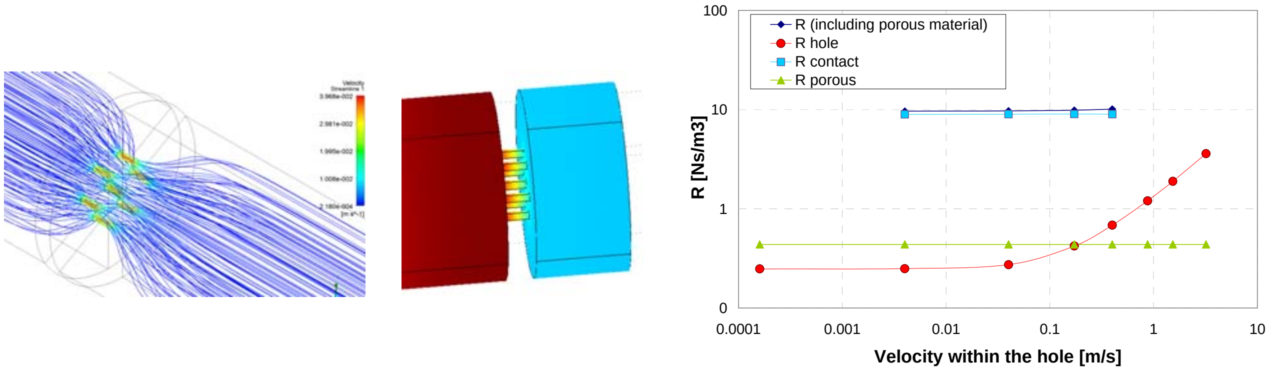

Fig. 2 – CFD and FEM numerical models and results. (a) CFD simulation - (b) FEM model - (c) values of specific resistance for each component (hole, material, contact, etc…) by using CFD computation

3. Results

Figure 3 shows experimental and numerical curves of sound absorption coefficient for a multilayer system made of (i) a perforated panel (7 holes) , (ii) polyester fiber (38 mm thick), and (iii) air gar (12mm thick). In the numerical comparison, the absorption coefficient curve obtained in linear regime by using standard Transfer Matrix approach is also depicted

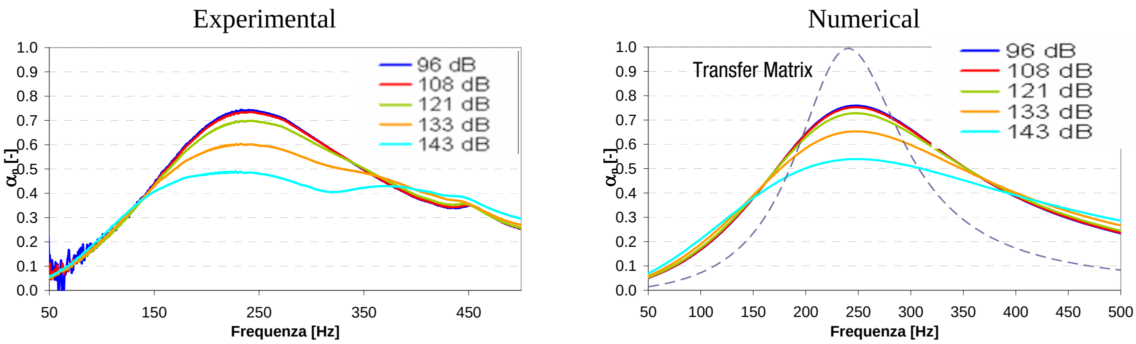

Fig. 3 – Comparison between experimental and numerical sound absorption coefficient curves as a function of excitation level

4. Bibliography

[1] SO 10534-2:1998 Acoustics -- Determination of sound absorption coefficient and impedance in impedance tubes -- Part 2: Transfer-function method

[2] Atalla N., Sgard F. (2007), Modelling of perforated plates and screens using frame porous models, J.Sound Vibr 303, 195-808.

[3] M.Garai, F.Pompoli (2005), A simple empirical model of polyester fibre materials for acoustical applications, App. Acoustics, 66 pp.1383-1398.

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