Multiscale and Multiphysics Modelling of an Adaptive Material for Sound Absorption

Tomasz G. Zielinski, Kamil C. Opiela

Institute of Fundamental Technological Research of the Polish Academy of Sciences, Warsaw, Poland

I. INTRODUCTION:

A periodic microstructure of adaptive porous material is constructed in **COMSOL Multiphysics®** as a periodic representative cell of pores and linking channels with a valve ball inside the large pore (Fig.1). The ball can block some channels to change the transport parameters which are strongly related to the sound absorption of such porous medium.

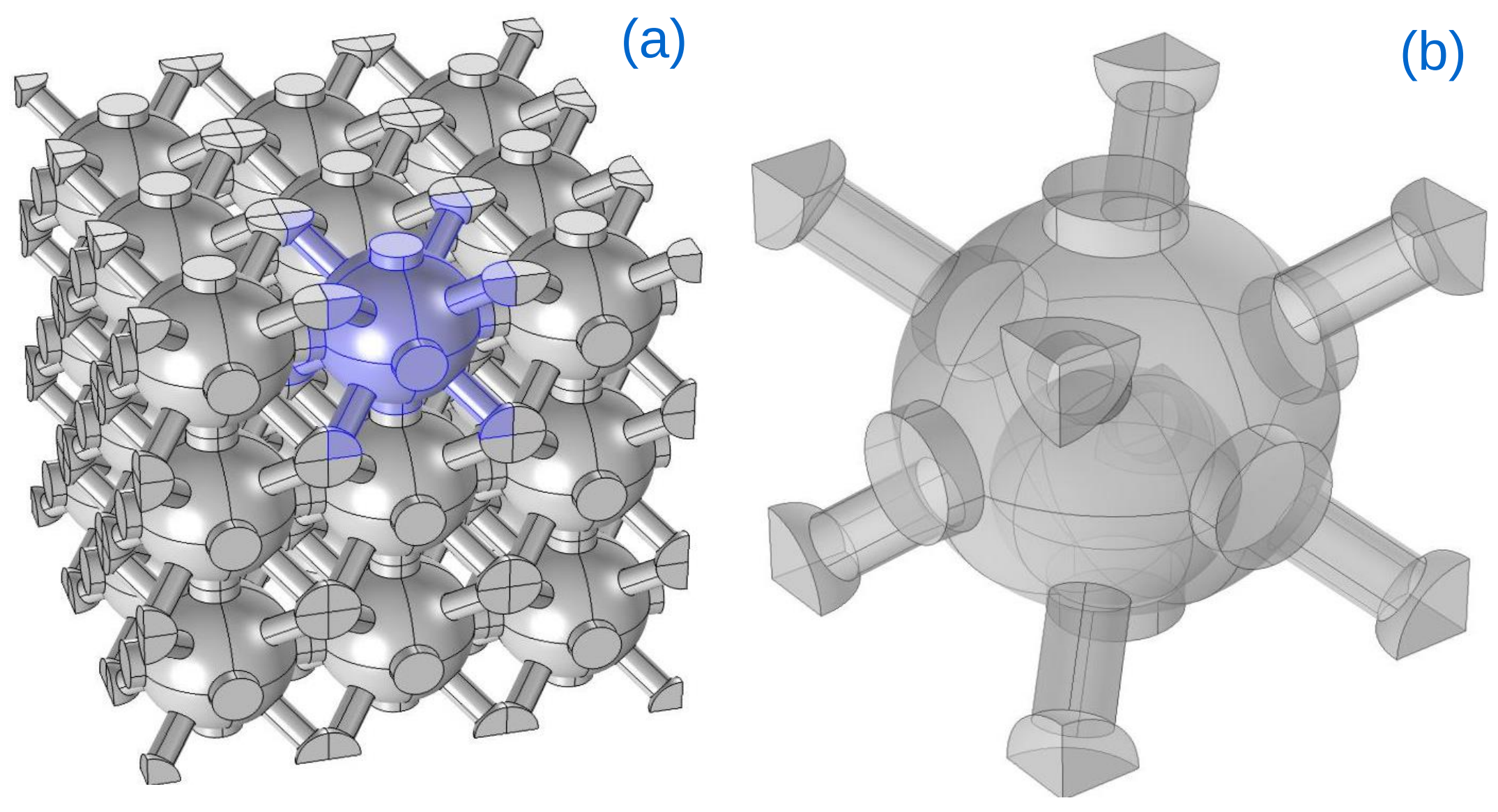


Figure 1: The porous geometry: (a) a periodic domain of pores filled with air, and (b) a single periodic cell with a steel ball inside the large pore

II. COMPUTATIONAL METHODS:

Dual-scale modelling is applied. At the macroscopic scale, the porous material is modelled as an equivalent fluid using the so-called Johnson-Champoux-Allard-Pride-Lafarge (JCAPL) model available from the **Acoustics Module** of COMSOL Multiphysics®. This model requires transport parameters of porous medium, which can be determined from its micro-geometry and by solving **three BV-Problems** on the periodic fluid domain inside pores (Fig.2), namely:

1. the re-scaled **Stokes (viscous, incompressible) flow** through the porous cell,
2. the **Laplace problem** which simulates the electric conduction of a porous material with dielectric skeleton a conductive pore-fluid, and
3. the **Poisson problem** which, in a re-scaled way, simulates the thermal transport inside the pores.

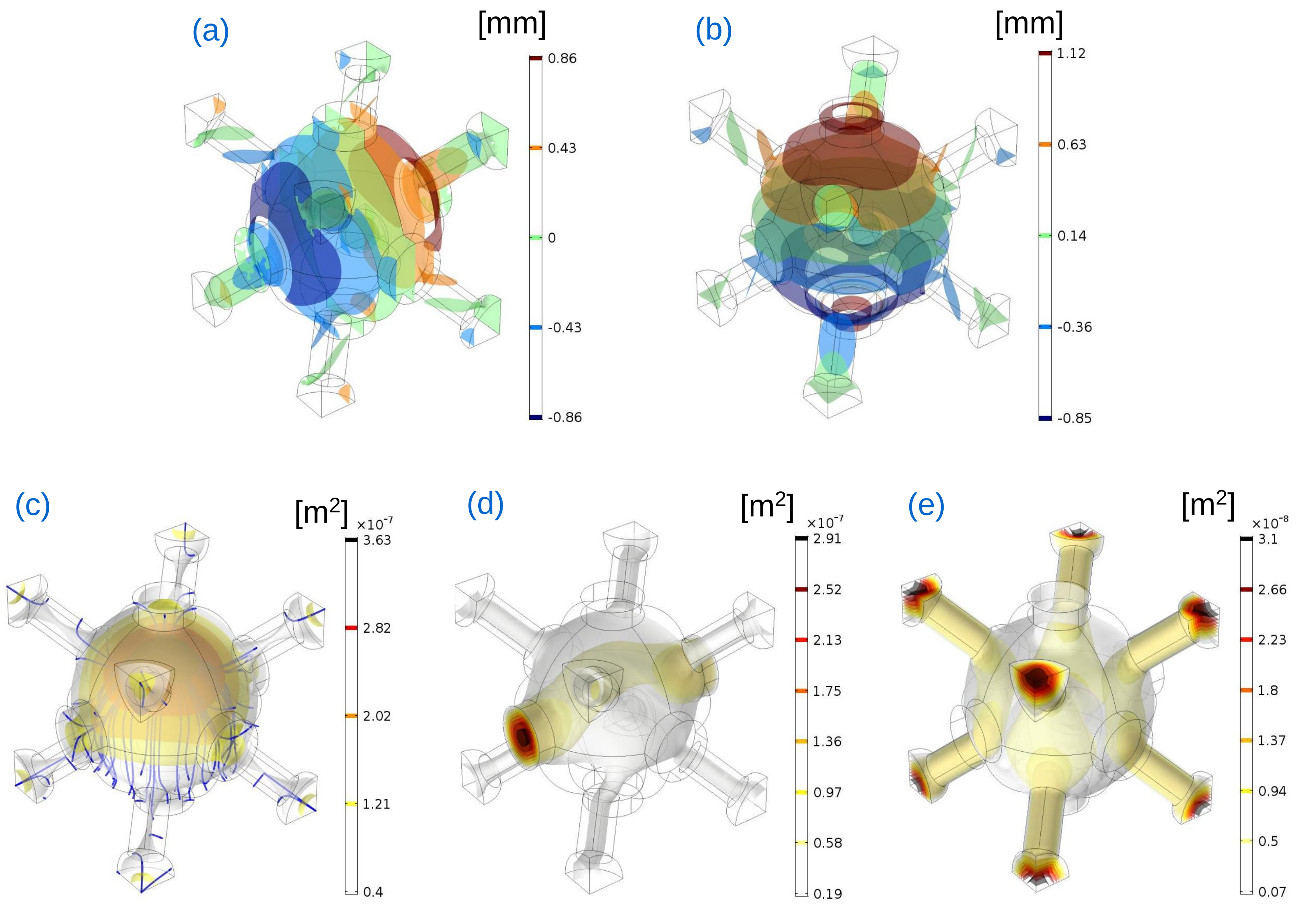


Figure 2: Solutions on the micro-scale level: (a,b) Laplace problem, (c) Poisson problem, (d,e) re-scaled Stokes flow through the periodic cell. The driving vector direction is horizontal (a,d) or vertical (b,e)

III. RESULTS:

A cuboid sample of the adaptive sound-absorbing porous material was 3D-printed (Fig.3) and tested in a special set-up of impedance tube with square-to-circular-shape adapter (Fig.5). A quarter of porous cuboid with an adjacent layer of air is modelled in **COMSOL Multiphysics** using the **Helmholtz equation** of linear acoustics and the **JCAPL model** (Fig.4) in order to predict the sound absorption of such sample. The predictions show desired differences between the two cases and are confirmed by the measurements (Fig.6).

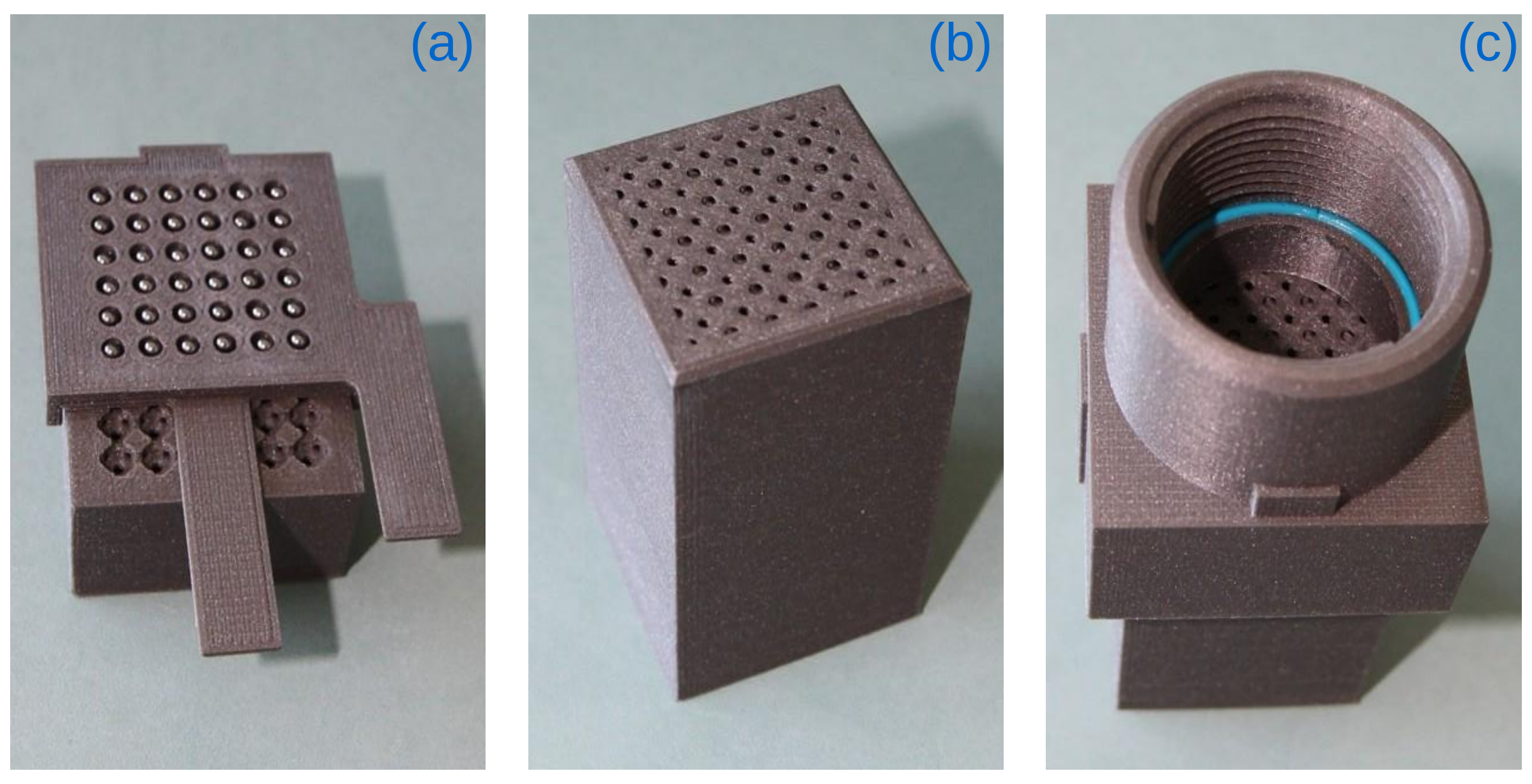


Figure 3: 3D-printing: (a) an original technique for the placement of steel balls inside pores, (b) a porous cuboid, and (c) the cuboid sample inside the adapter

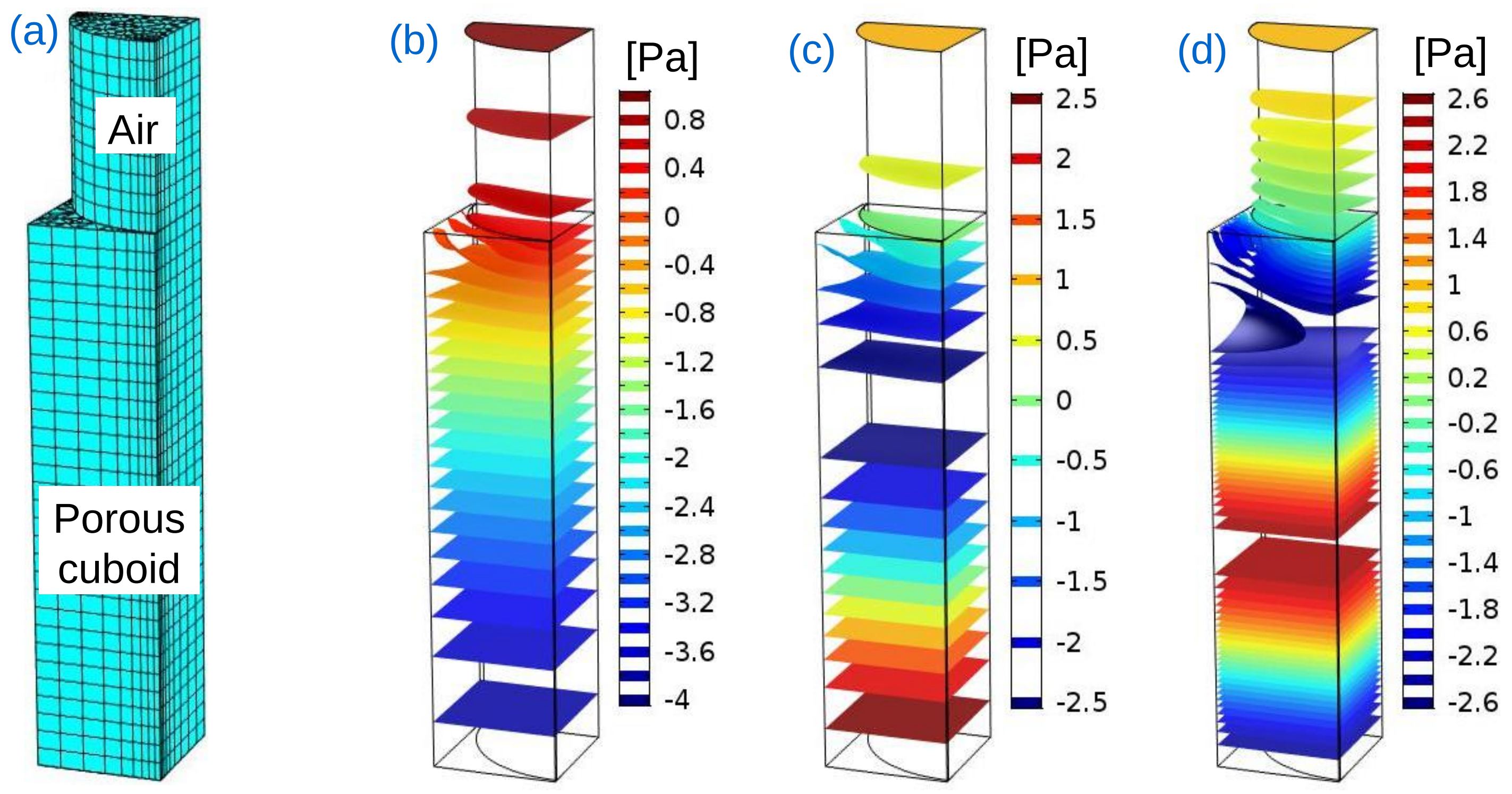
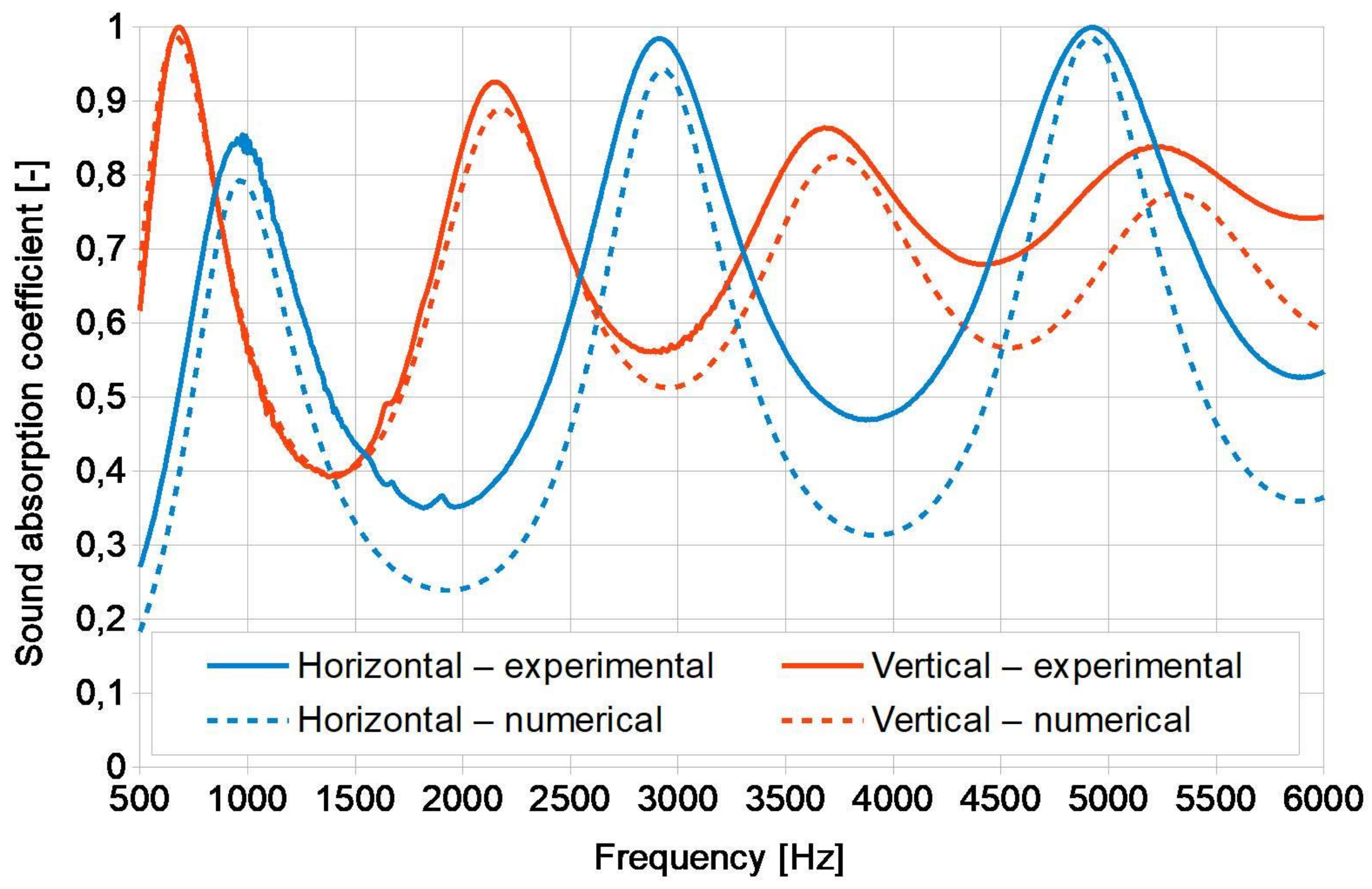


Figure 4: (a) FE mesh to model a cuboidal sample with an adjacent layer of air and the pressure distributions at 1 kHz (b), 3 kHz (c), and 5 kHz (d)



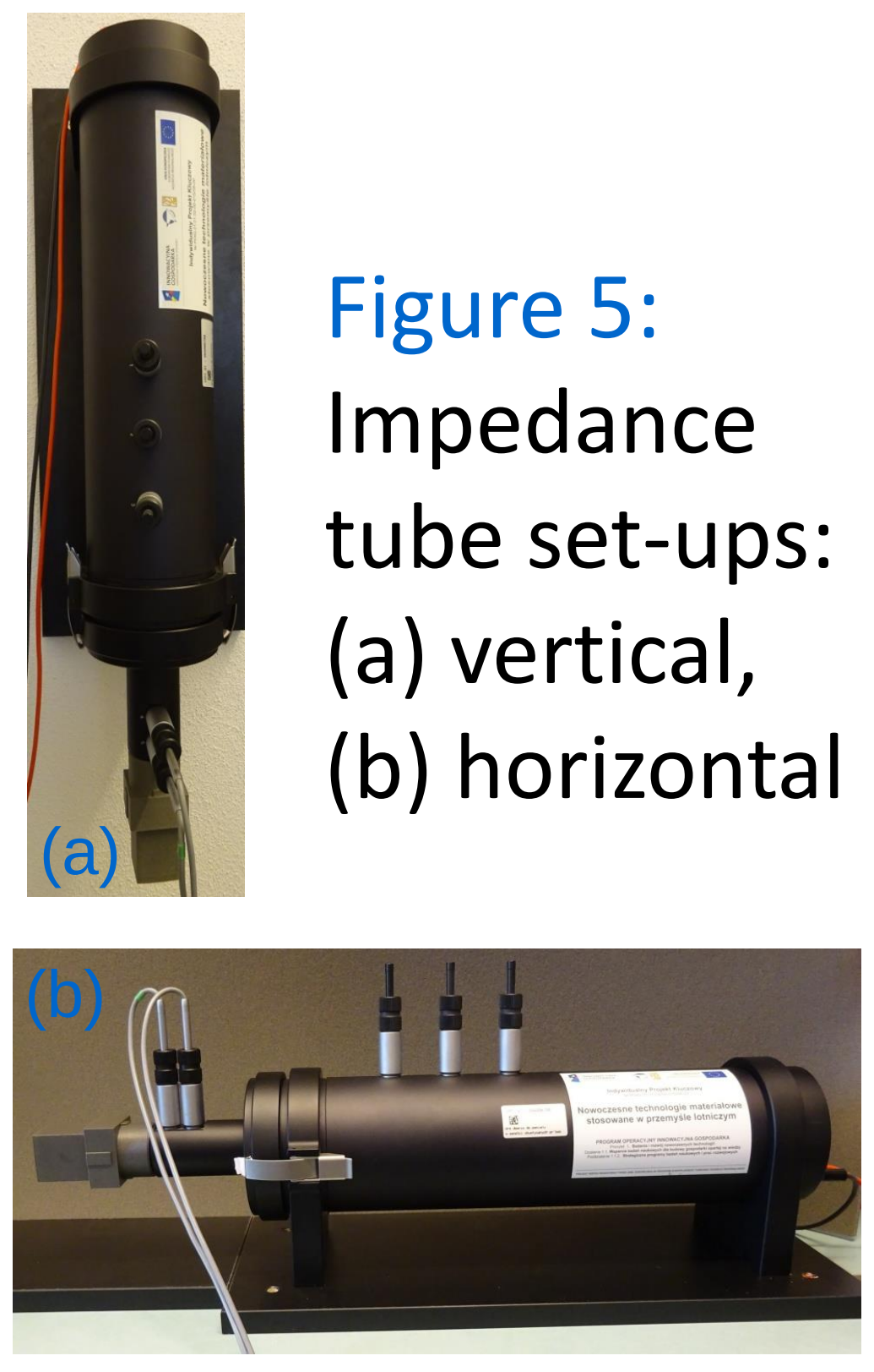


Figure 5: Impedance tube set-ups: (a) vertical, (b) horizontal

Figure 6: Numerical calculations and experimental results for the cuboid sample of adaptive sound absorbing material

CONCLUSIONS:

- Dual-scale modelling in COMSOL Multiphysics® allows for **a complex design process** and correct predictions.
- **A poor quality of 3D-printing** is the main source of discrepancies between predictions and measurements

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