Multiphysics Modelling of Sound Absorption in Rigid Porous Media Based on Periodic Representations of Their Microstructural Geometry

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Abstract

Introduction
Sound absorption in porous materials with rigid frame and open porosity can be very effectively estimated by applying the Johnson-Allard model [1] in order to substitute a porous medium with an equivalent effective fluid and then utilise the Helmholtz equation for time-harmonic acoustics.The model uses several parameters which characterize the micro-geometry of porous material from the macroscopic perspective; they are: the total porosity, the viscous permeability and its thermal analogue, the tortuosity, and two characteristic lengths -- one specific for viscous forces, the other for thermal effects. These parameters can be measured experimentally, however, recent computational powers allow to calculate them from the microstructure of porous medium [2,3,4] provided that a good representation of usually very complex micro-geometry can be found. Inverse identification of these parameters is also possible [5].

The microstructural approach is based on the Multiscale Asymptotic Method and leads to two uncoupled micro-scale Boundary-Value Problems (BVPs) [3,4]. The first one is a harmonic, viscous, incompressible flow, with no-slip boundary conditions on the skeleton walls, driven in the specified direction by the pressure gradient of unit amplitude, uniform in the whole fluid domain. The second one is a harmonic thermal flow with isothermal boundary conditions on the skeleton walls and the uniform source of unit amplitude in the whole fluid domain. A scaled Laplace problem should also be solved in order to calculate some of the parameters. All BVPs must be solved using the same periodic cell representative for the microstructure.

Use of COMSOL Multiphysics®
COMSOL Multiphysics® offers two extremely useful features which makes this numerical environment very suitable for such microstructure-based modelling of periodic media representative for porous materials; they are: the periodic boundary conditions and a very convenient possibility of implementation of new mathematical models, or modification of the implemented ones, using symbolic expressions. To illustrate this the acoustic absorption for a layer of freely packed assemblies of small rigid spheres was measured and compared with the result calculated from the microsctructural analyses using COMSOL Multiphysics® (see Figure 3). The FE analyses (see Figure 2) were carried out using periodic representative volume

elements (RVEs) of regular sphere packings [2,4], for example, the so-called body-centered cubic (BCC) adjusted to match the actual porosity of 42\% (see Figure 1). The discrepancies between the numerical and experimental results - although not very big (see Figure 3) - suggest that better microstructural representations are necessary. Such RVEs may be constructed, for example, by using techniques for random generation of periodic representative volume elements which have been recently advocated by Zielinski [6].

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Figures used in the abstract

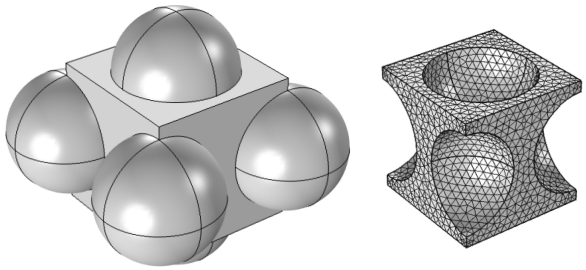

Figure 1: Regular sphere packing of the BCC type and the corresponding FE mesh on the adjusted RVE

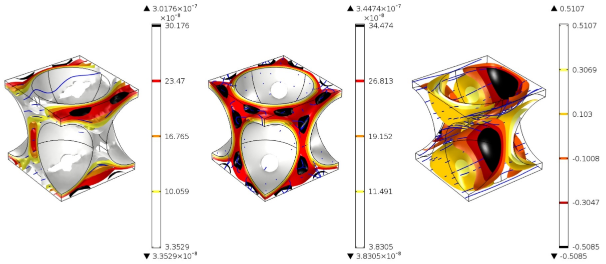

Figure 2: Results of FE analyses for BCC representation of porous microstructure

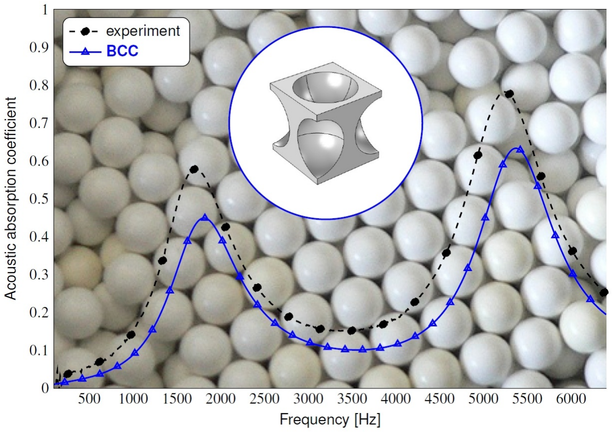

Figure 3: Sound absorption of 41mm-thick layer of rigid spheres: experimental and numerical results