Sound propagation in porous media : upscaling methods, optimization and validation

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Sound Propagation in Porous Media: Upscaling Methods, Optimization and Validation

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Introduction

Noise reduction is a key issue for High-tech and high precision instruments. To reduce the noise levels emitted by internal or external sources, porous materials can be used for acoustic shielding. The acoustic wave penetrates into the pore network, and part of its energy is dissipated as heat by viscous friction and thermal-elastic damping, material mechanical damping and Helmholtz type resonators [1]. Therefore acoustic properties of porous materials are highly sensitive to geometrical and mechanical properties of the microstructure.

Objective

The objective of this work is building relationships between microscopic and macroscopic acoustic properties of porous materials, based on physical models of geometrical features and material characterizations of the porous medium at micro-level. In this way, it will be feasible to optimize the local geometry of the medium for improving its sound absorption performance.

Preliminary Strategy

- **Acquisition and Modeling**

The acquisition of the 3D local geometry of the porous medium is obtained by X-ray computed tomography at micro-level. Once the 3D observation at the microscale is made, either the direct meshed model or simplified interpretation of the complicated microstructure can be produced.

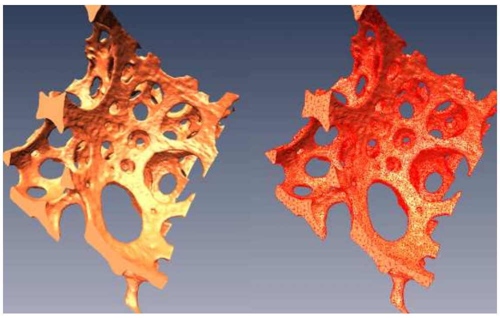

Fig. 1 *Local geometrical features acquisition based on X-ray computed tomography.*

- **Pore Scale Formulation**

A micro-structural model based on the material characteristics and the local geometrical features aims at describing the detailed sound propagation phenomena. This model incorporates fluid-structure infarction and the pertinent thermodynamics.

- **Scale Bridging**

A proper scale bridging method is needed to transfer the micro-scale response to macro-scale at the least computational cost. There are several upscaling methods utilized for poroelastic materials in the literature like: volume averaging and asymptotic homogenization [2]. Also there are some phenomenological approaches like Biot's theory [3]. Unaddressed in the literature so far are multilevel finite element (FE^2) scale bridging method and statistical multi-scale modeling for wave propagation in porous media.

- **Validation**

To validate the reliability of the multi-scale scheme, numerical simulation results will be compared with experimental data. To this end, the acoustic absorption coefficient of the sample is measured using an impedance tube (standing wave or Kundt's tube) [4].

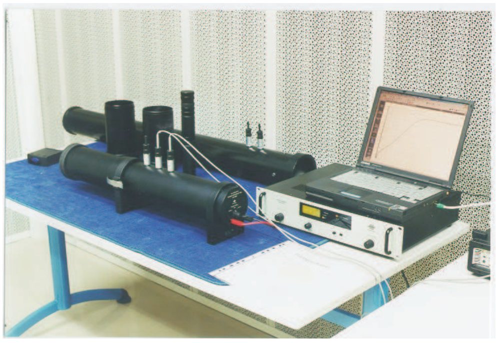

Fig. 2 *Sample placed in a standing wave tube, where sound absorption as a function of frequency is measured.*

- **Optimization**

The validated multi-scale scheme can be applied for microstructure optimization of highly porous materials.

Challenges

Computational Resource Extremely large number of elements, due to complex microstructure and considering air gaps as the second phase.

Multi-scale Scheme Resolving time-scale details (frequency dependency) and considering boundary effects on micro-macro bridging.

Macro-model Based Optimization Design variables determination, Design space reduction and Optimal sequencing of multilayered covers.

References:

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