Multiscale modeling of acoustic shielding materials

Technische Universiteit **Eindhoven** University of Technology

Multiscale modeling of acoustic shielding materials

K. Gao, J.A.W. van Dommelen, M.G.D. Geers

Background

It is very important to protect high-tech systems from acoustic excitation when operating in a noisy environment. Some passive absorbing materials such as acoustic foams can improve the performance which depends on the interaction of the acoustic wave and the microstructure of the foam.

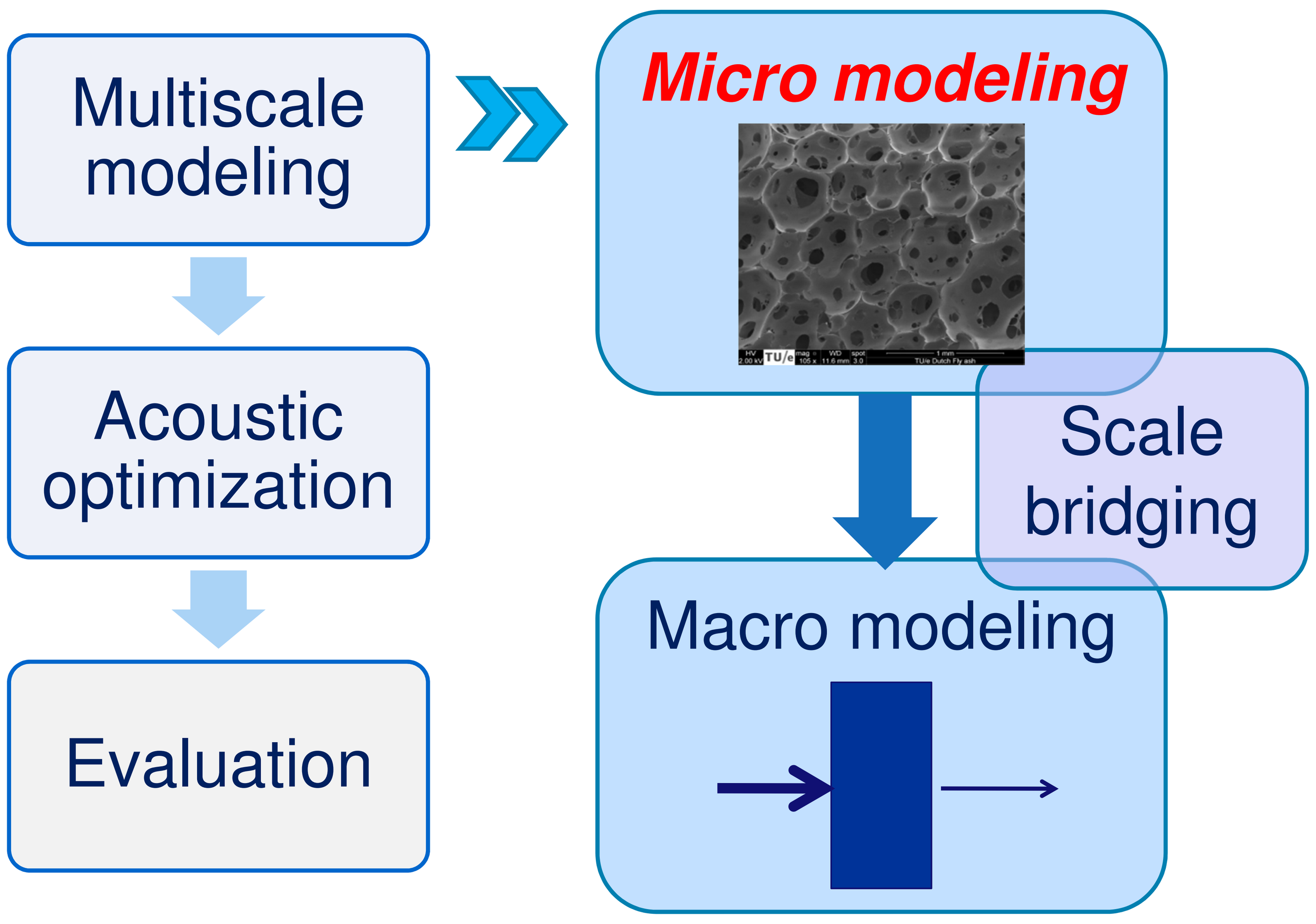

Figure 1. An illustration of this project. The current work is on the microscopic modeling.

Theory

Macroscopic displacements of porous materials can be described by Biot's theory [1], in which the coupling interaction is appeared as ρ_a an added mass and $\tilde{b}$ a complex viscous coefficient. The expressions of the parameters can be given by the JCAL model [1].

Starting from the microscopic governing equations of a representative volume, a micro-macro relation is found by applying Slattery's average theorem,

$$\omega^2\left(\rho_a+\frac{\tilde{b}}{j\omega}\right)\Delta\bar{\boldsymbol{u}}=\boldsymbol{d}\overset{\text{def}}{=}\frac{1}{V}\int_{S_i}\boldsymbol{n}\cdot\boldsymbol{\sigma}_f\,dA \qquad (1)$$

where $\Delta\bar{\boldsymbol{u}}=\overline{\boldsymbol{u}^f}-\overline{\boldsymbol{u}^s}$ is the difference of the phase-average displacements of the fluid and the solid. Here S_i is the fluid-solid interface.

Simulation

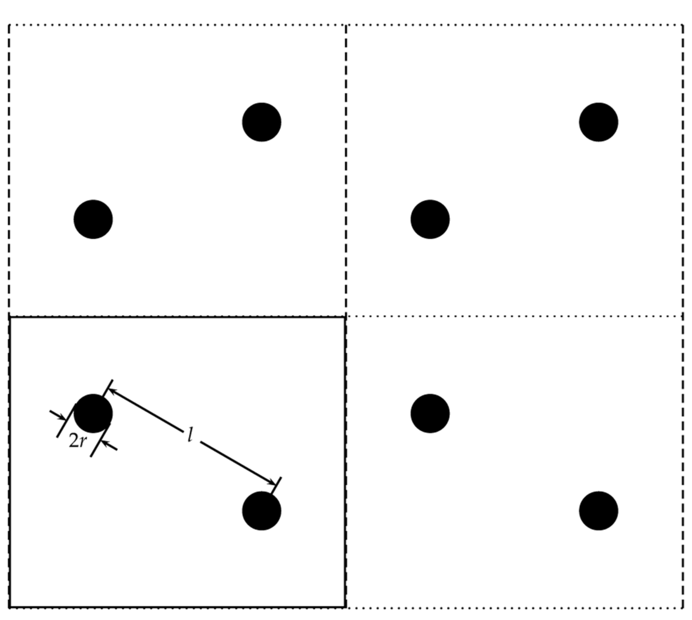

Figure 2. The periodic unit cell (enclosed by the black solid lines) in the simulation. The black solid circles are the motionless solid phase for simplicity. A macro-pressure drop is applied in the horizontal direction. $l = 884$ μm and $r = 161$ μm

A 2D counterpart of a Kelvin cell in figure 2 is simulated. The results are compared with the corresponding JCAL model with suitable parameters and are presented in figure 3. It shows that the numerical coupling mass agrees with the JCAL model quite well except for the real part at low frequencies, which actually disappears at zero frequency.

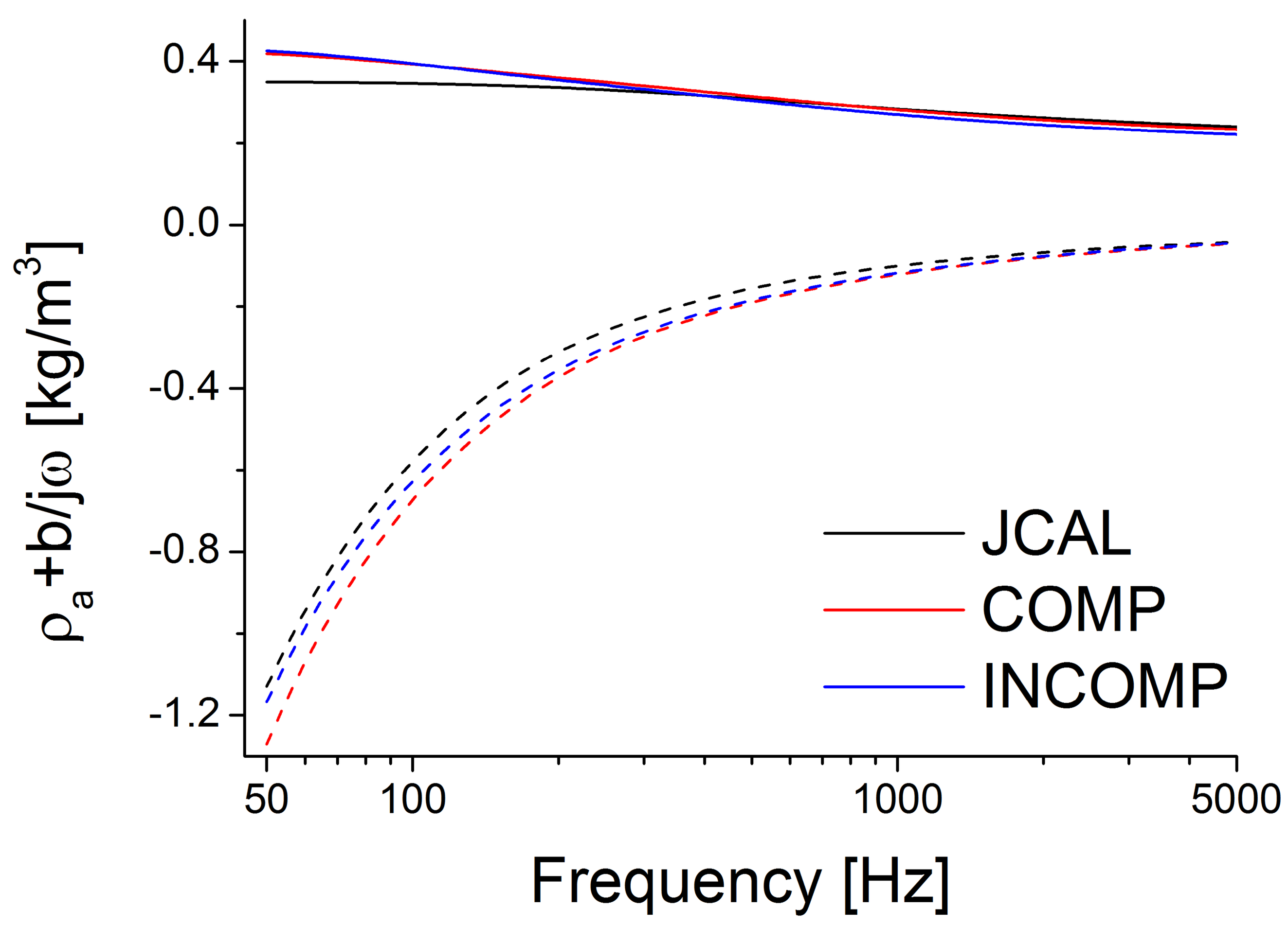

Figure 3. The coupling masses obtained from the JCAL model, the compressible flow model and the incompressible flow model. The solid curves are the real parts and the dashed curves are the imaginary parts.

Outlook

Equation (1) provides a new way to obtain the coupling mass required in Biot's theory. The next stage will be focused on the evaluation of this new approach by substituting the numerical results into Biot's theory such as figure 4.

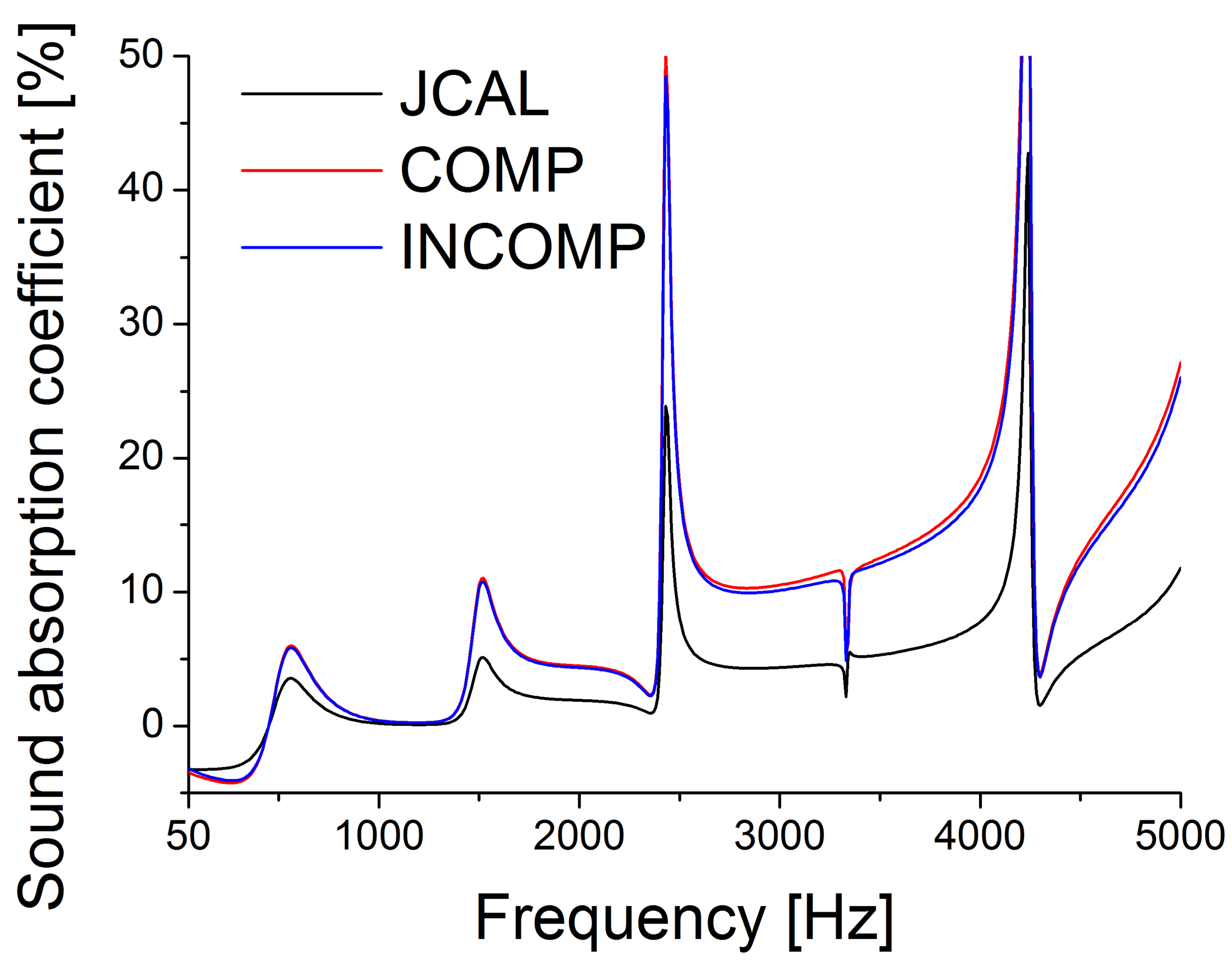

Figure 4. The normal sound absorption coefficient in simulations of a impedance tube by Biot's theory with the coupling masses shown in figure 3.

Reference

[1] J.F. Allard and N. Atalla, Propagation of Sound in Porous Media 2nd, John Wiley & Sons Ltd, 2009