Faster Thermoviscous Acoustic Simulations For Micro-Acoustics

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Abstract

Micro-acoustic simulations are used to simulate acoustic waves in narrow geometries, where viscous- and thermal relaxation dissipation (together: thermoviscous dissipation) are of importance. Examples of systems were micro-acoustics simulations are required are hearing protection, hearing aids and wireless in-ears. The latter also involves electro-acoustics. The standard `Pressure Acoustics' interface in COMSOL® is unable to model thermoviscous dissipation. Fortunately, COMSOL Multiphysics® is well-equiped for solving these micro-acoustic problems. For regularly shaped pores (i.e. prismatic ducts), the Narrow Region Acoustics physics from the Pressure Acoustics interface can be used. For wide pores w.r.t. the viscous and thermal penetration depths, boundary-boundary interaction is negligible. In this case the `Boundary Layer Impedance' boundary condition is able to efficiently model the thermoviscous dissipation at the walls.

For arbitrary geometries, the linearized Navier Stokes equations can be solved using the `Thermoviscous Acoustics' physics interface. The disadvantage of the
linearized Navier Stokes equations is that instead of for one (pressure in the Pressure Acoustics), 5 dependent variables need to be solved. These are the acoustic pressure, temperature and 3 velocity components. Moreover, the generally small thermoviscous boundary layer needs to be resolved in the mesh. Combined the `Thermoviscous Acoustics' interface has a large simulation cost.

In response to this problem, research has been done to find mathematical models that are capable of solving micro-acoustics problems in arbitrary geometries, without the simulation cost overhead of the Linearized Navier Stokes equations. One valueable research output is the so-called Sequentially Linearized Navier Stokes (SLNS) model, as developed by Kampinga et al. The SLNS model requires a sequential solution (uncoupled system of equations) for three complex Helmholtz-like partial differential equations. It is still required to resolve the thermoviscous boundary layer in the mesh. Nonetheless, w.r.t to the linearized Navier Stokes model, still a significant decrease in computational cost is obtained. In some of our practical `benchmarks', we find speedups of approximately a factor of 100. In this paper, we will quickly glance the derivation of the SLNS model, show the implementation of the SLNS model in COMSOL® and compare results for some geometries. Besides that, we will elaborate on some of its limitations.

Figures used in the abstract

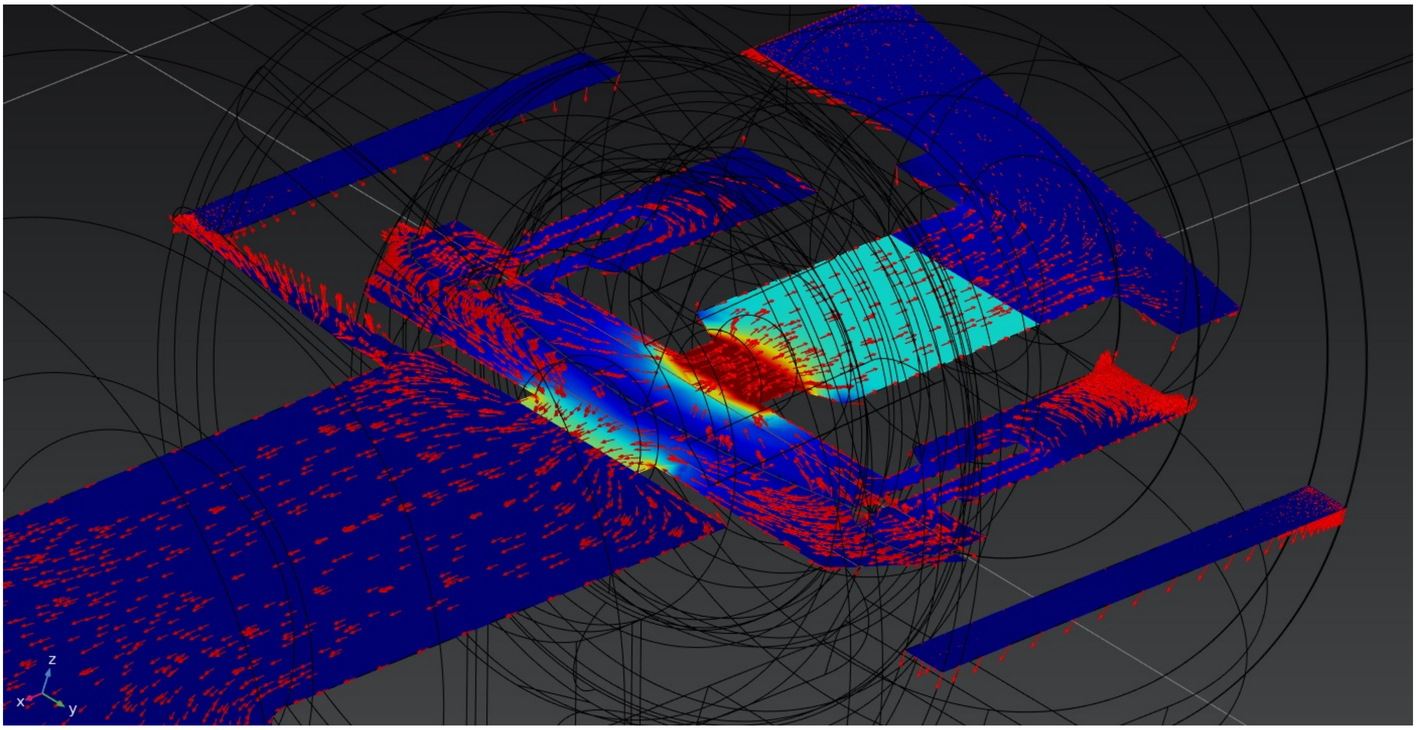

Figure 1 : SLNS Thermoviscous acoustics simulation in a small in-ear device.