A finite element for viscothermal acoustics

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Introduction

The goal of this research project is to develop accurate models for hearing aid loudspeakers. A representative loudspeaker measures 3x4x8 mm; see figure 1. Because of the small size, a viscothermal acoustic model, or full linear Navier stokes model, is needed to describe the air inside such devices.

Figure 1: A hearing aid loudspeaker

Existing models

Many existing viscothermal acoustic models require simple domain geometries or smooth boundaries. Unfortunately, these requirements are not met in hearing aid loudspeakers. An interesting model without such limitations is Malinen's FEM model [1]. We present a similar model on this poster and in several conference proceedings [2,3]. This finite element accounts for:

- compressibility and inertia
- viscous forces and heat conduction
- arbitrary domains and boundaries

Theory

The starting equations are the Navier Stokes equations. This set consist of the (vector) momentum equation, the enthalpy equation and the continuity equation. Next, the following assumptions have been made:

- Newtonian viscous fluid
- Fourier heat conduction
- ideal gas
- small perturbations
- no mean flow

Finally, Fourier transformation yields an harmonic formulation. A weak form is created by using Galerkin's method. The finite element that results after discretization has the velocity components, the temperature perturbation and the pressure perturbation as degrees of freedom. The boundary force components and the heat flux can be applied as natural boundary conditions. 2D, 3D and axial symmetric elements have been developed.

Experimental validation

The finite element is validated with an impedance tube measurement. The used sample is a cylindrical layer resonator; see figure 2. The measured absorption coefficient is compared to the absorption coefficient calculated with an axial symmetric FEM model; see figure 3.

Figure 2: Sample

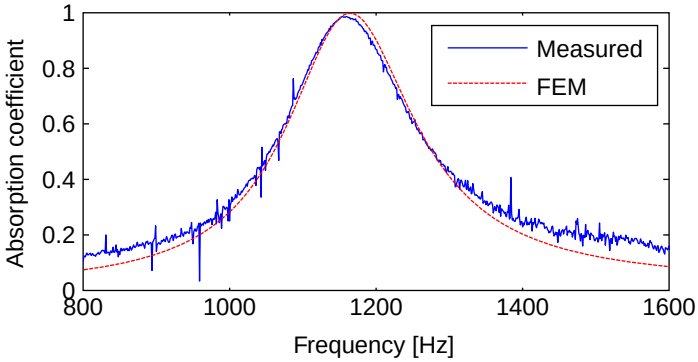

Figure 3: Validation results

Future work

The element has been validated on a 3D geometry, see [3]. It is intended to validate it on a more complicated axial symmetric geometry as well. Another research priority is fluid structure interaction and its validation. Finally, a model of a hearing aid loudspeaker will be made.

Acknowledgements

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References

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