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Keywords: Boundary Element Method, Finite Element Method, Visco-thermal acoustic losses.

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Evaluation of a Hybrid FEM-BEM Implementation of Acoustics with Visco-Thermal Losses

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The modeling of acoustic setups including viscous and thermal losses is of particular relevance for devices where narrow features in the millimeter/micrometer range are present. Most of these losses take place in the so-called *viscous and thermal boundary layers*, which for the audible frequencies have thicknesses ranging from a few micrometers to a fraction of a millimeter. When these thicknesses are comparable to the dimensions of the acoustic domain, the effect of losses can be very relevant and should be accounted for. This is the case of many acoustic transducers, couplers, absorbing materials and acoustic metamaterials.

The available tools for acoustic modeling with losses include analytical models for simplified geometries, numerical models with simplifying assumptions and full numerical models. In the latter class, the linearized Navier-Stokes equations with no flow are discretized by means of the Finite Element Method (FEM) or the Boundary Element Method (BEM).

In BEM, the Kirchhoff decomposition is employed to split the sound field into three *modes*: acoustic, thermal and viscous, which are then discretized independently and coupled at the boundary. Recently, new implementations where FEM is employed for the acoustic mode and BEM for the viscous and thermal modes have been proposed [1,2]. In both cases, the FEM and BEM matrices are sparse: FEM already produces sparse matrices, while BEM is only used for the thermal and viscous modes, which die out at a short distance, making most BEM matrix coefficients negligible.

In this work, the hybrid FEM-BEM with losses is analyzed in terms of stability, convergence, and computational load. The goal is defining the class of problems where the new method can be advantageous in terms of size, geometrical complexity and frequency range.

References

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[2] Andersen, P. R., Cutanda Henriquez, V., Aage, N. & Marburg, S., *Numerical Acoustic Models Including Viscous and Thermal losses: Review of Existing and New Methods*, Proceedings of DAGA 2017. Deutsche Gesellschaft für Akustik e.V., Kiel, Germany, 2017.