Predication of Acoustical Dissipation in Large Irregular Cavities By Helmholtz Solver

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Abstract

Acoustical dissipations are mainly due to viscous forces and heat transfer between fluid medium and solid one. This visco-thermal dissipation essentially takes place in small layers close to the boundary regions called viscous and thermal boundary layers. Viscothermal losses are important when sound propagates in geometries with small dimensions. In order to take them into account rigorously, the Full Linearized Navier-Stokes (FLNS) model is recommended. However for geometries such as tubes with simple transversal form (circular, rectangular or triangular) simplified analytical models (LRF, BLI, etc.) are developed. When geometries are more complexes, the FLNS model is mandatory through numerical calculations. Unfortunately this model solves for three variables (acoustical pressure, temperature and velocity field with its three components), requires boundary meshing and is therefore costly in terms of computing resources. In this present poster, we will present a lightweight approach based on perturbation theory to predict the energy damping rate of sound wave propagating in cavities having "large" transversal dimensions compared to boundary layers. Knowing that dissipation occurs in boundary layers, the perturbation theory states that the fluid viscosity and heat conductivity which act in this region will not affect the bulk velocity and temperature for relatively large geometries. In this case, velocity and temperature will remain the same than those happening for an inviscid fluid. With this consideration one can use Helmholtz equation solution to determine mean energy losses by viscous forces and heat transfer applying just fluid viscothermal properties (viscosity, heat conductivity, heat capacities…).

To validate this approach, two kinds of geometries (figures 1&2) are exploited using COMSOL software. All steps are defined in COMSOL except the post processing which is achieved by Matlab. The COMSOL module used is the Acoustics module. To implement our model we just used Acoustics pressure branch of the module. However, in order to prove its validity we compare the results with those calculated with the Thermoacoustics Branch which used the FLNS modeling. The sound absorption coefficients obtained with the two branches showed a quiet agreement in any case where the dimensions of the section are large compared with the thickness of the boundary layers (figure 3 and 4). One can notice that for small sectional dimensions, our approach tends to overestimate the sound dissipation.
One important thing is that the Thermoacoustics Branch confirms the fact that the sound losses mainly take place in the boundary layers. This supposes that a boundary layers mesh is necessary to compute losses, what COMSOL Multiphysics offers with much flexibility.

To conclude, for geometries having large sectional dimensions the lightweight we propose here is an efficient tool to compute acoustical losses. The model can be very useful for complex and large geometries in which computing Thermoacoutics will be time consuming.

Reference

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Figures used in the abstract

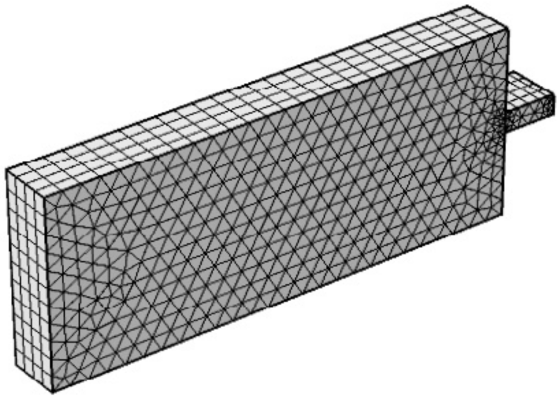

Figure 1: rectangular resonator

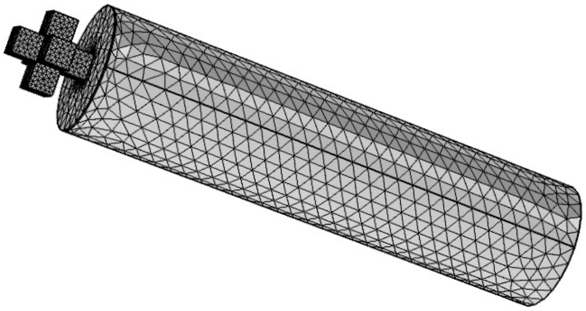

Figure 2: First order of Sierpinski sponge

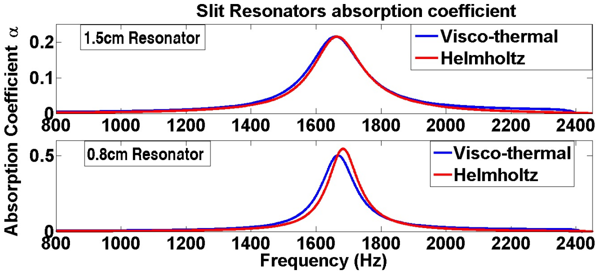

Figure 3: Absorption coefficient of rectangular resonators of two different widths

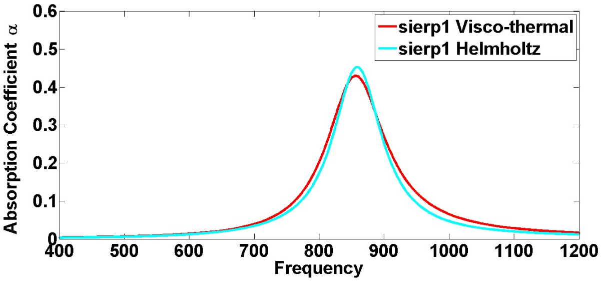

Figure 4: Absorption coefficient of first order Sierpinski sponge