NUMERICAL SIMULATION OF THERMOACOUSTIC HEAT PUMPING

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In this study thermoacoustic heat pumping is simulated numerically. The device consists of a straight wave guide closed at the left end whereas an acoustic wave is generated at the right end of the tube usinga loudspeaker. A stack of parallel plates is placed near the left end of the tube. As a result of proper coupling between the acoustic wave and the solid stack plates, heat is pumped from the right to the left of the stack.

It is assumed here that thermal and viscous effects are localized near the stack plates, a domain therefore called the "active cell", considered short with respect to resonator's length. The flow inside the active cell is nonlinear and modeled with a low Mach number approximation [1-2]. The flow is assumed to be inviscid, isentropic and unidirectional in the remainder of the resonator. Therefore, the effect of the loudspeaker is straightforwardly used as prescribed velocity and acoustic pressure conditions on the right part of the active cell. The part of resonator left of the active cell is short, and therefore the temperature is assumed to be homogeneous, and the related speed of sound will vary slowly in time as a result of heat pumping. Proper matching between both parts of the device results in specific velocities at the left end of the active cell which are calculated using linear acoustic equations in the resonator. The periodicity of the stack plate arrangement results in reducing the active cell to a slice between two half-plates of the stack, extending into the resonator on both sides, with a total domain length of twice the stack length. The compressible Navier-Stokes equations in the low Mach number approximation are solved in this computational active cell domain. The solution is obtained using a finite volume code, second order accurate in time and space [3].

The simulation gives time dependent temperature, velocity and density fields inside the active cell until the establishment of a mean temperature gradient along the stack as a result of heat pumping. The mean velocity flow in also analyzed and the results are compared with the literature.

References

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