CFD STUDY OF OSCILLATORY FLOW AROUND PARALLEL PLATES IN A TRAVELING-WAVE THERMOACOUSTIC ENGINE

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Introduction

The stack/regenerator and heat exchangers are the core components whereby the thermoacoustic effect and energy conversion take place [1]. The flow field near the edges of the plates is crucial due to nonlinear behavior which affects the performance of the device significantly [2]. Therefore, there is a need to understand the oscillatory flow processes in the vicinity of such internal structures [3]. In this work, CFD simulation was performed and the oscillatory flow in the vicinity of a parallel plates placed in a traveling-wave thermoacoustic resonator was studied.

Methodology

The finite volume method was used to discretize the Navier–Stokes equations on equally spaced Cartesian grids with a cell-centered arrangement. The wall boundaries of objects were represented by the immersed boundary method using ghost cells of the level-set method [4]. The no-slip boundary condition was used for the velocity and the Neumann boundary condition was imposed on the walls for the pressure. On the other hand, the impedance matching boundary (IMB) condition was used on the both sides of the computational domain, which was developed by Hasegawa and Takahashi [5-6]. Parallel plates were assumed to be periodic in the y direction. The air at atmospheric pressure was used as a working fluid. The temperature gradient as a linear function was added to the plates as isothermal walls of 300 K at left side and 600K at right side of regenerator. Meanwhile, isothermal boundary condition was applied for the temperature.

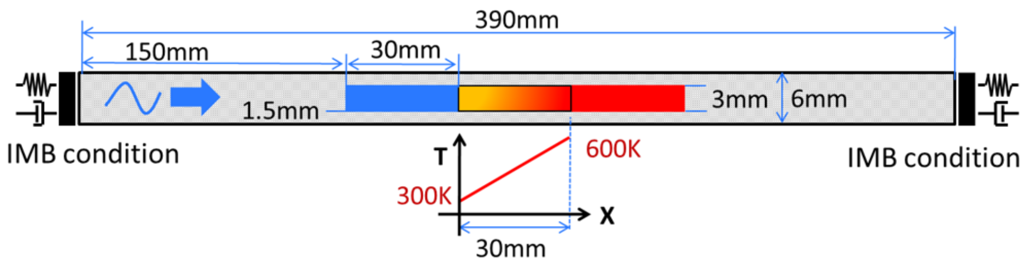

Figure 1: *Schematic of the computation domain.*

Discussions

In this work, the oscillatory flow structures around the parallel plates in a traveling wave thermoacoustic engine were studied. The flow structures formed around the plates and the heat transfer over a range of oscillation amplitudes and frequencies were discussed. The oscillation amplitudes were approximately 25%, 50%, 75%, 100%, 125%, and 150% of the regenerator length (30mm). Meanwhile, applied frequencies were 10Hz to 70 Hz. Using the CFD simulation, nonlinear vortex generation around the plates were studied. It was found that at small amplitudes the shear layers in the wake remain symmetric and produced attached symmetrical vortex structures. However, for larger oscillation amplitudes the flow lost its symmetry and stability, resulting unstable vorticity field behind the plates.

It was observed that the temperature oscillations at the edges of the plates were nonlinear. Moreover, the temperature oscillations near the plates had impact on heat transport processes and effected the enthalpy flux carried along the plates. The interaction of the acoustic wave with the regenerator plates having a temperature gradient, leaded to a significant enthalpy flux changes along the regenerator plates. The change in enthalpy flux significantly increased as the oscillation amplitude became larger. Acoustic power gain as a function of oscillation amplitude and frequency was investigated and it was noticed that the acoustic power gain were influenced significantly by oscillation amplitude.

Conclusions

CFD simulations with IMB condition were performed. The oscillating flow fields in the vicinity of a thermoacoustic couple over a range of particle oscillations amplitudes and frequencies were investigated. It was confirmed that the temperature oscillations at the edges of the plates were nonlinear and the change in enthalpy flux significantly increased as the oscillation amplitude became larger. Furthermore, the acoustic power gain as a function of oscillation amplitude and frequency was investigated and it was obtained that the acoustic power gain influenced significantly by oscillation amplitude. However, the results will be presented in detail at the workshop.

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