NUMERICAL INVESTIGATION OF HEAT EXCHANGE BETWEEN FLUID AND SOLID WALL OF OSCILLATORY FLOW

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Introduction

With respect to the estimation of heat transfer of oscillatory flow inside the engine, some numerical approaches combined with the classical linear thermoacoustic theory are suggested [1][2]. In their studies, the heat transfer of oscillatory flow considering heat exchange between wall and fluid is discussed, and phase dependent heat transfer rates and Nusselt numbers are investigated. However, for the oscillatory flow with larger displacement amplitude, which can be occurred in the actual engine, we have to consider the interaction of heat transfers among the heat exchangers, the stack and the resonator, and the conventional approach cannot reproduce those interactions.

Numerical Simulation

The present numerical simulation is based on three-dimensional unsteady compressible Navier-Stokes equation. Figure 1 shows the computational domain and the boundary conditions of the present simulation. Here, the thermoacoustic device is composed of two resonance tubes, two heat exchangers and a stack, and the engine core has six flat plates. The wall temperature is given as shown in Fig.1.

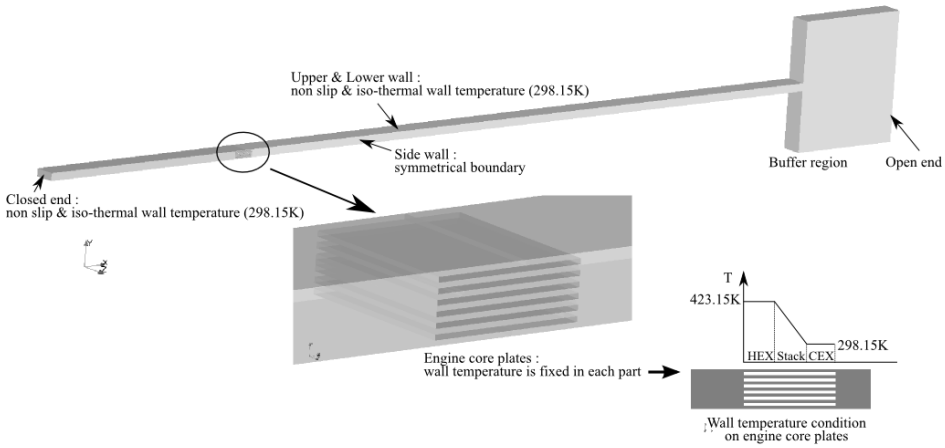
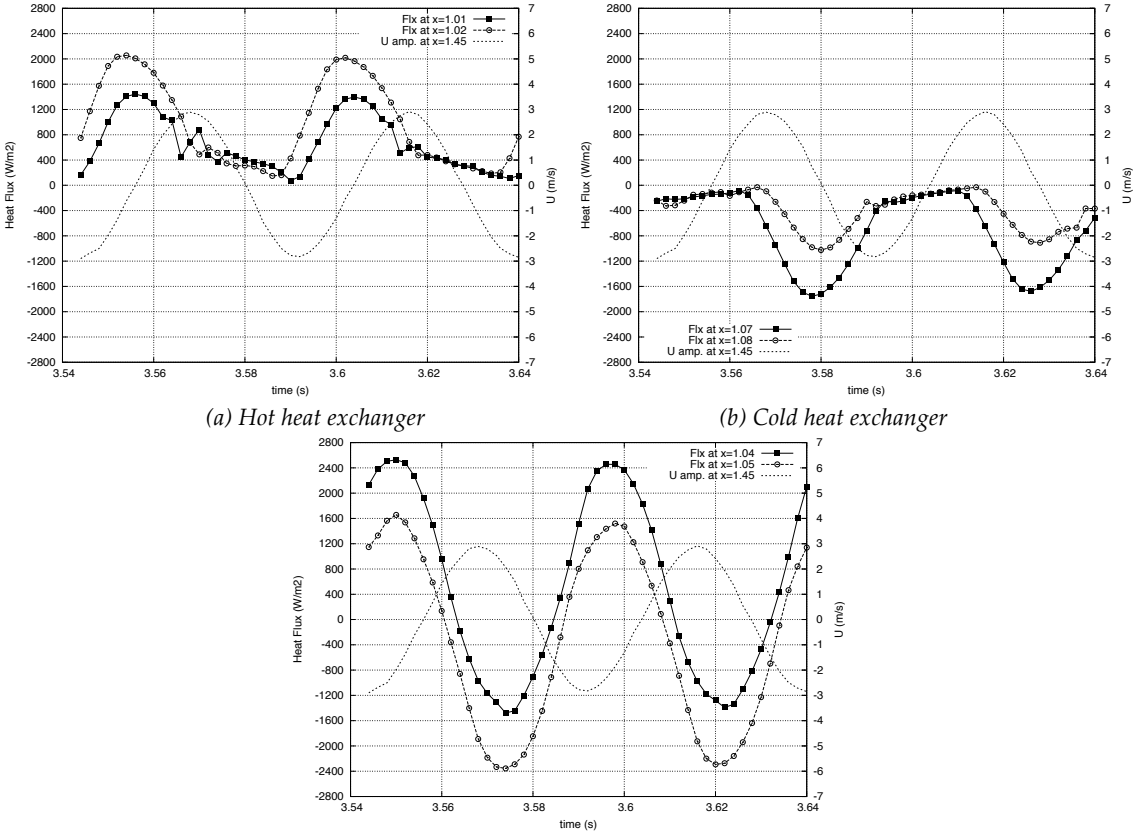


Figure 1: *Configuration of the computational domain and the boundary conditions.*

Results

The present simulation reproduces the self-oscillatory flow. To generate the self-oscillation, we execute the following procedures in the simulation. First, after the start of the simulation, we continue supplying the acoustic wave from the open end of the resonance tube for a

while. After 2.5 seconds, which corresponds to 1250000 time steps of the simulation, the supply of the acoustic wave is stopped. After that, we judge whether the self-oscillation is reached or not by monitoring the variation of the pressure and velocity amplitudes. The obtained self-oscillatory flow has large displacement amplitude in this condition. The amplitude is about 30 mm, the length of each engine core component (heat exchanger and stack).



(a) Hot heat exchanger *(b) Cold heat exchanger*

(c) Stack

Figure 2: *Time variation of heat flux on the wall of each component of the engine core (from wall to fluid : positive).*

From the CFD results, we investigate the heat flux of each engine core component. Figure 2 shows the heat flux on the wall of the hot and cold heat exchangers and the stack. As shown in the figures, with respect to the heat flux of the heat exchangers, the symmetry of the harmonic oscillatory flow collapses while the velocity amplitude keeps the sinusoidal curve. On the other hand, the symmetry is kept in the region of the stack. These results might be due to the fact that the convective heat transfer in the axis direction is affected by the large displacement of fluid element. Furthermore, it is clear that this behavior can be regarded as nonlinear effect, and we have to consider this effect for estimating the performance of the thermoacoustic engine. In the present study, we have a plan to investigate these mechanisms more in detail.

Acknowledgements

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References

[1] Piccolo, A. and Pistone, G., *Int. J. Heat Mass Tran*, 49, 1631-1642 (2006).

[2] Jaworski , A. J. and Piccolo , A., *Applied Thermal Engineering* 42, 145–153 (2012).