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FUNDAMENTAL INVESTIGATION ON THERMOACOUSTIC PHENOMENA INSIDE NARROW TUBE BY CFD

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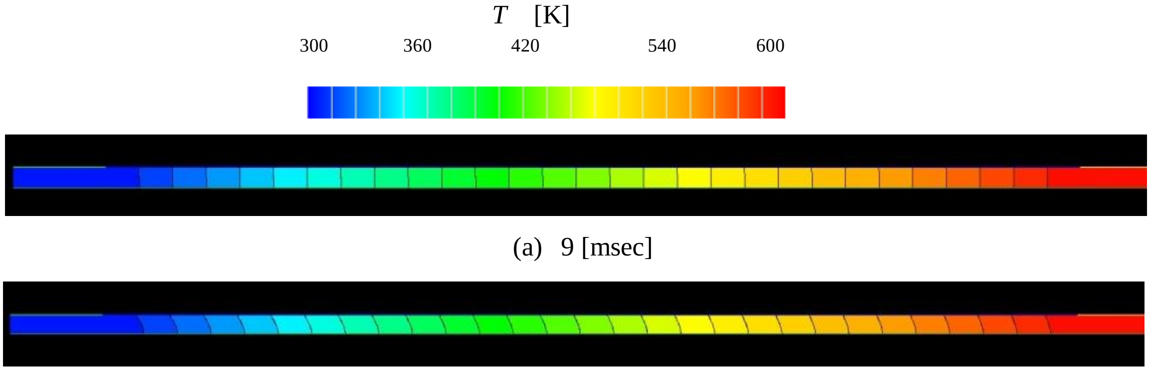
In recent years, issues on energy resource have become more important because of population explosion and resources depletion. In 2011, the accident of Fukushima-No.1 nuclear power plant in Japan was caused by a big earthquake, so that the situation has became more serious. From these backgrounds, the Japanese government has focused on varieties of renewable energy, such as solar power and wind power generation.

As one of alternative energy resources, a thermoacoustic engine has the potential to take work out of multiple heat sources such as a combination of industrial waste heat and solar energy. This type of engine also has the advantage of low cost and low maintenance as it has no moving parts. In the device, narrow tubes are installed to generate or amplify acoustic power. When the temperature at one side of the narrow tube is increased and the one at another side is reduced, the gas in the tube starts oscillation and acoustics wave is generated. In the thermo acoustic engine, thermal energy is transformed to the amplification of the acoustic oscillations and the acoustic power is converted to electric power using a linear alternators. However, the term *acoustic streaming* refers to the second-order steady velocity that is induced by and superimposed on the dominating first-order acoustic velocity. Streaming leads to nonzero time-averaged mass flows so that it is for convective heat transfer that can reduce the efficiency of thermoacoustic devices [1]. The effect of the acoustic streaming cannot be examined by linear theory, because these phenomena are caused from nonlinear effects. Consequently, the effect of the acoustic streaming is not well understood.

As for the geometrical effect of a thermoacoustic engine, Reyke reported the Reyke pipe made of very narrow cylindrical pipes of 20 mm diameter in 18 century. In this paper, it was observed that a vertical cylindrical tube can generate sound and vibration when it is heated with hot wire meshes at one quarter from the bottom of the cylindrical tube. In constant, many thermo-acoustic heat engines are being developed using a looped-tube with a resonator which is called as a stack [2], [3] . The stack,installed to achieve desired temperature gradient by external heating [4] . When the external thermal input to the system exceeds certain critical condition through cycles of expansion,cooling and heating, the fluid in the tube can become unstable and show oscillation.

In this study, numerical flow simulation called as CFD is employed to investigate some nonlinear problems as written above. Firstly, a narrow tube inside a stack involving large temperature gradient was solved as fundamental analysis of acoustic streaming. Figure1 shows temperature distribution in the tube. From the result, it can be confirmed that the temperature fluctuation was started. Further examination of the nonlinear phenomena will be carried out and presented at the conference.



(a) 9 [msec]

(b) 10 [msec]

REFERENCES

[1] Said Boluriaan and Philip J. Morris, Acoustic streaming : from Rayleigh to today, International Journal of Aeroacoustics, Volume 2, Number3&4, pp.255-292, 2003.

[2] Tetsushi Biwa, Measurements of acoustic streaming in a looped-tube thermoaxoustic engine with a jet pump, Journal of applied physics, Volume 101, Issue 6, 064914, 2007.

[3] S. Backhaus and G. W. Swift, An acoustic streaming instability in thermoacoustic devices utilizing jet pumps, Journal of Acoustical Society of America, 113(3), pp.1317-1324, 2013.

[4] Vitalyi Gusev, Ste´phane Job, He´ le`ne Bailliet, Pierrick Lotton, and Michel Bruneau, Acoustic streaming in annular thermoacoustic prime-movers, Journal of Acoustical Society of America, 108(3), pp.934-945, 2000.