Numerical study of one directional flow caused by jet pump located in an acoustic resonator

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Abstract

When there is a flow path with a narrow diameter and temperature gradient in a gas-filled duct, acoustic vibration may occur thereby. This phenomenon is known as a thermoacoustic phenomenon, and the generated acoustic field may be accompanied by a unidirectional flow in the direction of the tube axis. While the magnitude of this flow is small compared to the vibration amplitude, it could give rise to a mass flow called acoustic mass streaming. Such acoustic mass flow influences the initially existing temperature distribution in the duct, causing convective heat transfer in addition to simple heat conduction and heat transport involved with acoustic vibrations. The heat transport phenomenon associated with this acoustic mass flow has a large effect on the heat transport characteristics of thermoacoustic devices, that is thermoacoustic prime mover, thermoacoustic refrigerator and so on. Therefore, in order to improve the performance of devices, it is inperative to clarify their characteristics. The goal of this study is to carry out numerical simulations using CFD to clarify the effects of thermoacoustic phenomena on acoustic mass flow and temperature distribution inside the duct, and ultimately on heat transport characteristics.

Reasons and benefits of using JAXA Supercomputer System

The numerical simulation in this study must be performed under an unsteady compressible flow environment, and especially the interaction between an unsteady acoustic field and heat transport is the key to this simulation. Therefore, although the mesh scale is relatively small, the simulation is necessarily highly accurate and long-time scale , minimum several seconds to tens of seconds on the heat transport time scale. In addition, building a database of analysis results requires a wide variety of calculation cases, resulting in a comprehensively large-scale and long-time simulation. In order to carry out simulations of this scale, it is essential to use a JAXA supercomputer that can run multiple simulations for long periods of time.

Achievements of the Year

A jet pump exists as a mechanism to suppress the acoustic mass flow (Gedeon flow) generated in a thermoacoustic engine, which is a mechanism that induces a one-way flow by using the asymmetry before and after the jet pump for sinusoidal acoustic oscillations that have an inherently symmetrical oscillation amplitude. However, the nonlinearity effect associated with the increase in oscillatory amplitude makes it difficult to properly control the unidirectional flow. In addition, understanding the relationship between the sound power loss caused by the jet pump and the acoustic flow suppression effect is also an important issue in the development of thermoacoustic engines. In order to solve these problems, a jet pump was inserted into the resonance tube and numerical simulation of the one-way flow generated in the acoustic oscillation flow was performed. Specifically, a jet pump was installed in a resonant tube with openings at both ends, and the generation of a one-way flow was reproduced by inserting sound waves from a branch tube connected in the middle of the resonance tube. The working fluid was air at room temperature (1 atm, 293.15 K), and the vibration amplitude varied from 200 Pa to 1000 Pa. Figure 1 shows the arrangement of a resonant tube having both opening ends and a jet pump and a branch tube for inserting sound waves. As a result of numerical simulation, a standing wave sound field was reproduced inside the resonant tube. Figure 2 shows the pressure amplitude distribution of the standing wave sound field associated with the input pressure amplitude and the sound power distribution. As shown in Fig. 2, it can be seen that a large sound power loss occurs in the jet pump section as the amplitude increases. Figure 3 shows the cross-sectional average distribution of time-averaged flow velocity. As shown in the figure, the direction of the unidirectional flow is reversed depending on the magnitude of the amplitude. Figure 4 shows the formation of vortices with respect to the time-averaged flow velocity before and after the change in the cross-section of the jet pump. Each of these shows a case where the direction of the one-way flow is reversed, but it is thought that the situation of vortex formation associated with the magnitude of the amplitude has an effect. These relationships need to be examined in more detail in the future, including quantitative analysis.

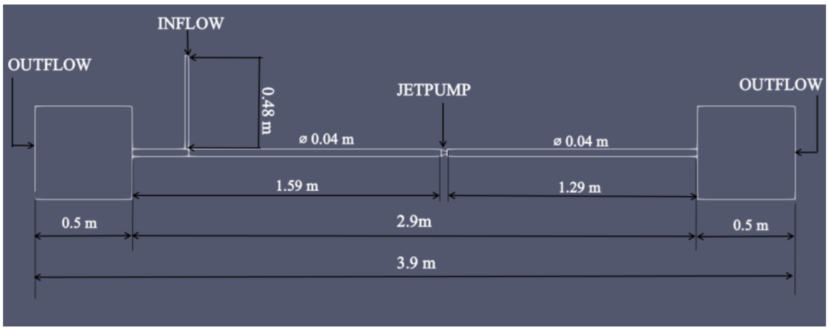

Fig. 1: Configuration of computational domain (resonator and branch ducts)

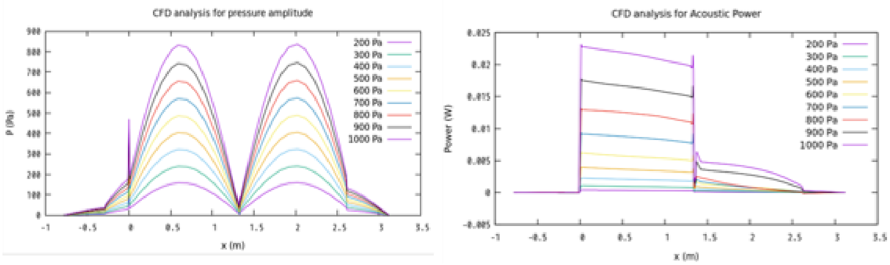

Fig. 2: Distributions of pressure amplitude (left) and acoustic power (right) along resonator duct

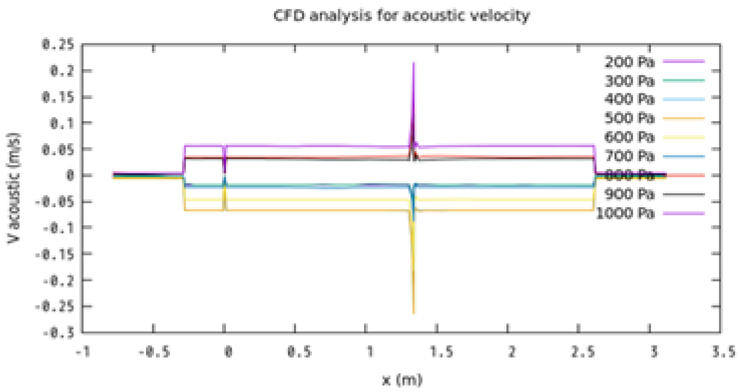

Fig. 3: Distributions of time-averaged velocity in the axial direction along resonator duct

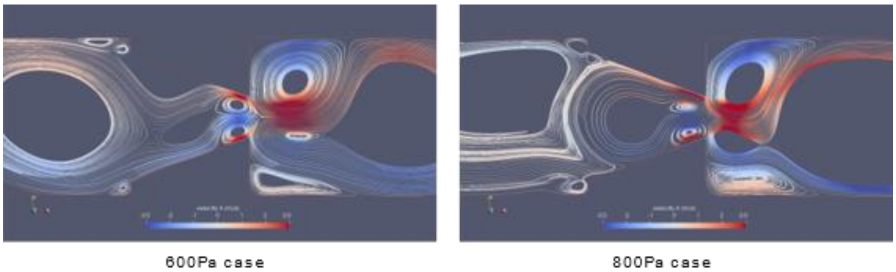

Fig. 4: Comparison of streamlines based on time-averaged velocity field (600Pa case : left, 800Pa case : right)

Publications

N/A

Usage of JSS

- **Computational Information**

Process Parallelization Methods	MPI
Thread Parallelization Methods	OpenMP
Number of Processes	1 - 7
Elapsed Time per Case	700 Hour(s)

- **JSS3 Resources Used**

Fraction of Usage in Total Resources[*1](%): 0.02

Details

Computational Resources		
System Name	CPU Resources Used (core x hours)	Fraction of Usage[*2](%)
TOKI-SORA	466,964.39	0.02
TOKI-ST	0.00	0.00
TOKI-GP	0.00	0.00
TOKI-XM	0.00	0.00
TOKI-LM	0.00	0.00
TOKI-TST	0.00	0.00
TOKI-TGP	0.00	0.00
TOKI-TLM	0.00	0.00

File System Resources		
File System Name	Storage Assigned (GiB)	Fraction of Usage[*2] (%)
/home	0.00	0.00
/data and /data2	0.00	0.00
/ssd	0.00	0.00

Archiver Resources		
Archiver Name	Storage Used (TiB)	Fraction of Usage[*2] (%)
J-SPACE	0.00	0.00

[*1]: Fraction of Usage in Total Resources: Weighted average of three resource types (Computing, File System, and Archiver).

[*2]: Fraction of Usage：Percentage of usage relative to each resource used in one year.

- **ISV Software Licenses Used**

ISV Software Licenses Resources		
	ISV Software Licenses Used (Hours)	Fraction of Usage[*2] (%)
ISV Software Licenses (Total)	0.00	0.00

[*2]: Fraction of Usage：Percentage of usage relative to each resource used in one year.