Research on low-cost LES and one-dimensional model for aeroengine combustor

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Abstract

There is a strong need to incorporate LES that can reproduce combustion phenomena with high fidelity into the design process to improve the efficiency of combustor development for aero and rocket engines, but combustion LES is not widely incorporated into the design process in actual development because of its extremely high computational cost. This research aims to reduce the cost of combustion LES to a level where it can be used for combustor design through reduced dimension modeling (ROM) and other means.

Reasons and benefits of using JAXA Supercomputer System

Modeling with methods such as ROM requires high-fidelity combustion LES data, but combustion LES requires solving the governing equations for a large number of species produced by chemical reactions as a three-dimensional unsteady problem. Such an analysis is computationally expensive and cannot be performed without the use of a supercomputer.

Achievements of the Year

A three-dimensional analysis of a supersonic cavity flow at Mach 2 was performed using implicit LES (ILES). Spatial higher-order interpolation (third-order accuracy for scalars and fifth-order accuracy for velocity components) enabled us to capture the three-dimensional structure of supersonic cavity flow with a relatively coarse grid of 1.6 million cells. The calculation was completed in about 7 hours per case using 32 nodes (1536 cores) of JSS3.

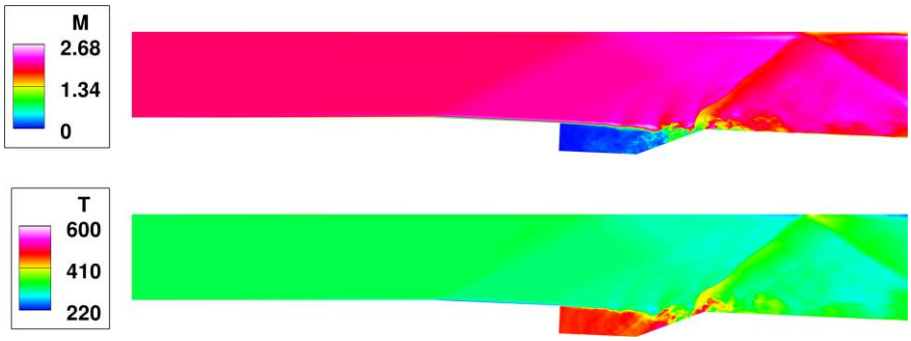

Fig. 1: Supersonic cavity flow obtained by ILES. Mach number (top) and temperature (bottom) distributions are shown.

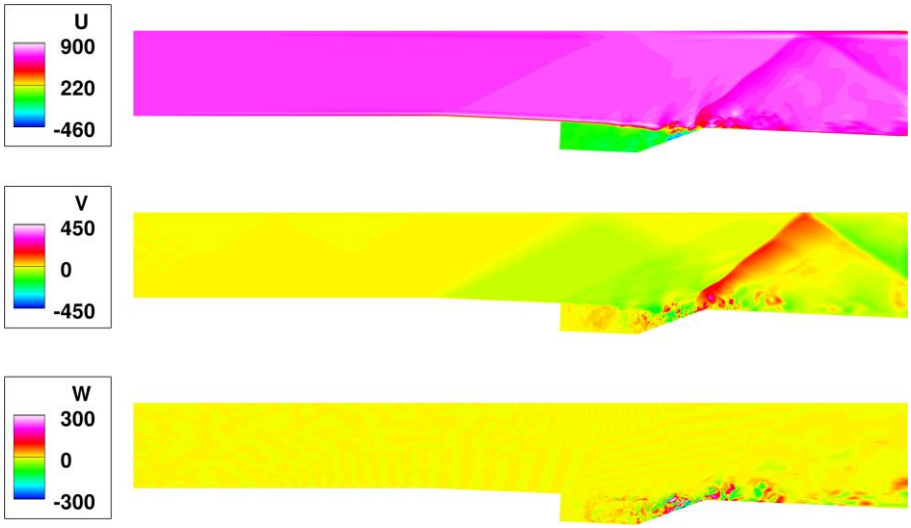

Fig. 2: Instantaneous velocity field in a supersonic cavity obtained by ILES.

Publications

- Oral Presentations

1) Taisei Miyoshi, Masanori Harada, Hideki Moriai, Shingo Matsuyama, "Investigation on flow field of a coaxial injector for rocket engines", the 55th Fluid Dynamics Conference / the 41st Aerospace Numerical Simulation Symposium, 2023.

2) Taisei Miyoshi, Masanori Harada, Shingo Matsuyama, Hideki Moriai, "A Study on the Influence of Detailed Reaction Mechanism on the Flow Field Analysis of Rocket Engine Coaxial Injector", the 61st Japanese Combustion Symposium, 2023.

3) Kotaro Iguchi, Kotaro Munenaga, Shingo Matsuyama, Hideki Moriai, "Study on low-cost prediction of cavity flame holder flow field in scramjet", the 63rd Conference on Aerospace Propulsion and Power, 2024.

4) Kotaro Iguchi, Kotaro Munenaga, Yohei Morishita, Kei Fukuzawa, Shingo Matsuyama, Hideki Moriai, "Study on flow field visualization of coaxial injectors for rocket engines", the 63rd Conference on Aerospace Propulsion and Power, 2024.

Usage of JSS

Computational Information

Process Parallelization Methods	MPI
Thread Parallelization Methods	OpenMP
Number of Processes	18 - 64
Elapsed Time per Case	48 Hour(s)

JSS3 Resources Used

Fraction of Usage in Total Resources[*1](%): 0.55

Details

Computational Resources		
System Name	CPU Resources Used (core x hours)	Fraction of Usage[*2](%)
TOKI-SORA	14,972,524.09	0.68
TOKI-ST	27,363.47	0.03
TOKI-GP	0.00	0.00
TOKI-XM	0.00	0.00
TOKI-LM	0.00	0.00
TOKI-TST	6.61	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	28.82	0.02
/data and /data2	1,801.18	0.01
/ssd	295.30	0.03

Archiver Resources		
Archiver Name	Storage Used (TiB)	Fraction of Usage*2 (%)
J-SPACE	0.39	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)	32.46	0.01

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