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

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Responsible Representative

Yasuhiro Mizobuchi, Aviation Technology Directorate, Aircraft Lifecycle Innovation Hub

Contact Information

Shingo Matsuyama(matsuyama.shingo@jaxa.jp)

Members

Masanori Harada, Nagayoshi Hiromitsu, Kotaro Iguchi, Yuta Kusakabe, Hideki Moriai, Koutarou Munenaga, Shingo Matsuyama, Taisei Miyoshi, Yuichi Taniguchi

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

Combustion LES analysis of a rocket combustor with a single coaxial injector was performed using a laminar flamelet model for hydrogen and oxygen diffusion flame. Compared to the high-resolution LES analysis using the detailed reaction model, the cost of LES analysis was successfully reduced to 1/24.

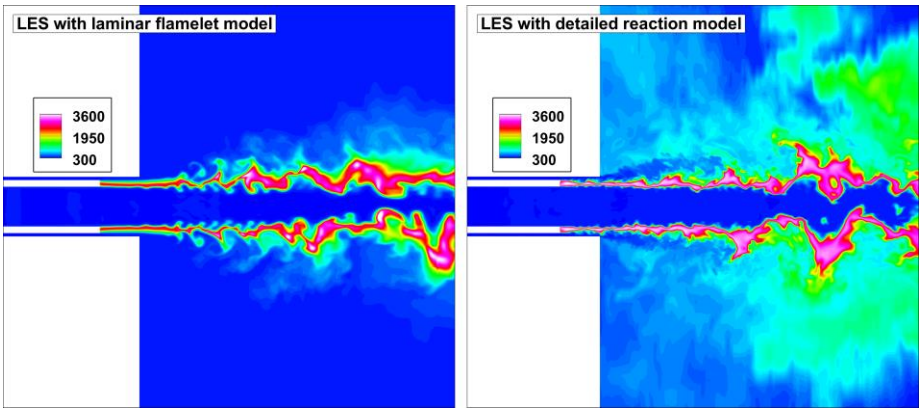

Fig. 1: Results of combustion LES for a hydrogen-oxygen diffusion flame in a coaxial injector. Instantaneous temperature contours by (left) laminar flamelet model and (right) detailed reaction model are shown.

Publications

- Oral Presentations

1) Shingo Matsuyama, "LES of a single-element rocket combustor using a laminar flamelet model", The 60th Japanese Combustion Symposium, K115, 2022.

2) Taisei Miyoshi, Shingo Matsuyama, Hideki Moriai, "Investigation on the flow field of the rocket engine coaxial injector," The 60th Japanese Combustion Symposium, A324, 2022.

3) Shingo Matsuyama, "Development of a High-Order Spatially Accurate Unstructured Grid Solver Using Many-Block Method," Symposium on Shock Waves in Japan, 2023.

4) Shingo Matsuyama, "Large-Eddy Simulation of a Shear Coaxial Jet Flame," JSASS Northern Branch 2016 Annual Meeting, 2023.

Usage of JSS

Computational Information

Process Parallelization Methods	MPI
Thread Parallelization Methods	OpenMP, Automatic Parallelization
Number of Processes	212 - 1504
Elapsed Time per Case	200 Hour(s)

- **JSS3 Resources Used**

Fraction of Usage in Total Resources[*1](%): 0.66

Details

Computational Resources		
System Name	CPU Resources Used (core x hours)	Fraction of Usage[*2](%)
TOKI-SORA	17,949,959.07	0.78
TOKI-ST	1,993.42	0.00
TOKI-GP	0.00	0.00
TOKI-XM	0.00	0.00
TOKI-LM	1,281.71	0.09
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	115.72	0.10
/data and /data2	2,994.29	0.02
/ssd	1,092.57	0.15

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)	78.59	0.05

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