Research on numerical simulation techniques for complex flows

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Abstract

Fluid simulation in the aerospace field targets flow fields with turbulence and chemical reactions around aircraft and spacecraft. In addition, simulations of combustors for gas turbine engines and rocket engines sometimes have to deal with complex geometries. This study aims to establish numerical simulation techniques that can analyze such a wide variety of physical phenomena and complex geometries with high accuracy and efficiency.

Reasons and benefits of using JAXA Supercomputer System

Since turbulence analysis by Direct Numerical Simulation (DNS) and Large Eddy Simulation (LES) is the primary tool in this study, a three-dimensional unsteady analysis must be performed. In addition, governing equations for a large number of chemical species produced by chemical reactions must be solved in the analysis of combustion flows. The computational cost of such an analysis is so high that it is impossible without the use of a supercomputer.

Achievements of the Year

A new SGS model for LES was developed by modeling the SGS stress transport equation through a priori testing using the DNS database of turbulent plane jets. With the developed model, LES was performed for turbulent plane jet with Re=10,000 using a grid with a resolution 6 times coarser than the DNS (1/216 grid points), showing that the LES with the SGS stress transport equation model reproduces the DNS velocity field very well (Figure 1).

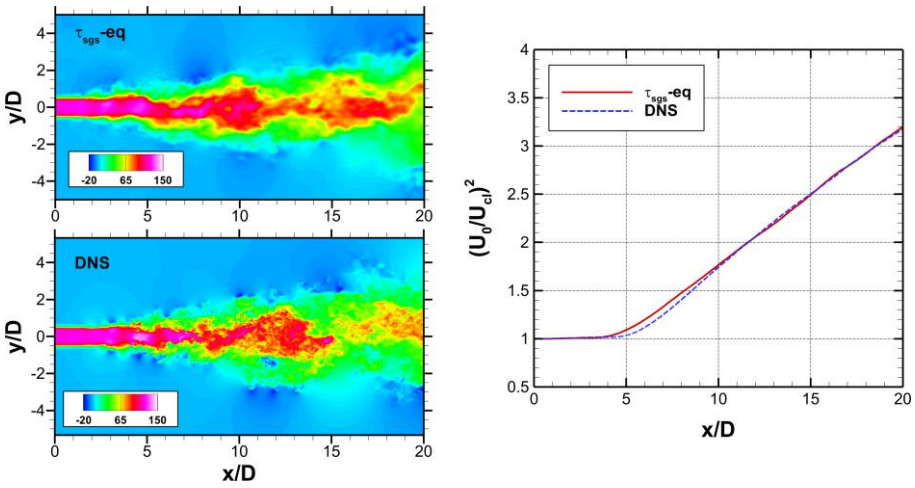

Fig. 1: Results of LES for a turbulent plane jet with Re=10,000 using the SGS stress transport equation model. Comparison of LES and DNS for the instantaneous velocity field (left) and time-averaged velocity field along the jet center-line (right).

Publications

- Non peer-reviewed papers

1) Shingo Matsuyama, "Oh, Are You Using That SGS Model in the Wrong Way?", Proceedings of the 55th Fluid Dynamics Conference / the 41st Aerospace Numerical Simulation Symposium, JAXA-SP-23-009, p.265-274, 2024.

- Oral Presentations

1) Shingo Matsuyama, "Oh, Are You Using That SGS Model in the Wrong Way?", 55th Fluid Dynamics Conference / the 41st Aerospace Numerical Simulation Symposium.

2) Shingo Matsuyama, "LES of turbulent plane jet using an SGS stress equation model", JSFM Annual Meeting 2023, 2023.

3) Shingo Matsuyama, "LES of turbulent plane jet at Re=10^4 using an SGS stress equation model", the 37th Computational Fluid Dynamics Symposium, 2023.

4) Shingo Matsuyama, "LES Modeling with SGS Stress Transport Equations", the 39th TSFD Symposium, 2024.

Usage of JSS

Computational Information

Process Parallelization Methods	MPI
Thread Parallelization Methods	OpenMP
Number of Processes	750 - 1500
Elapsed Time per Case	10 Hour(s)

- **JSS3 Resources Used**

Fraction of Usage in Total Resources[*1](%): 1.08

Details

Computational Resources		
System Name	CPU Resources Used (core x hours)	Fraction of Usage[*2](%)
TOKI-SORA	29,201,399.41	1.32
TOKI-ST	40,391.64	0.04
TOKI-GP	0.00	0.00
TOKI-XM	106.74	0.06
TOKI-LM	1,395.79	0.11
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	124.61	0.10
/data and /data2	8,913.71	0.05
/ssd	984.08	0.09

Archiver Resources		
Archiver Name	Storage Used (TiB)	Fraction of Usage[*2] (%)
J-SPACE	30.01	0.11

[*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)	495.20	0.22

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