Research and development of prediction technology for thermal and aerodynamic characteristics of hypersonic vehicle

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Abstract

Strong shock waves are generated around a flying object at hypersonic speeds, and the high-temperature gas compressed by the shock waves causes strong heat transfer to the hypersonic vehicle. The objective of this research is to establish a technique to reproduce such a flow field around a hypersonic vehicle by CFD and to accurately evaluate the aerodynamics and heating applied to the vechicle.

Reasons and benefits of using JAXA Supercomputer System

The flight conditions of hypersonic vehicles often have high Reynolds numbers, which necessitates the evaluation of turbulent heating. Since this study aims to evaluate turbulent heating with high accuracy using Direct Numerical Simulation (DNS) and Large Eddy Simulation (LES), a three-dimensional unsteady analysis is inevitably required. The computational cost of such a large-scale three-dimensional analysis is very high, and analysis using a supercomputer is essential.

Achievements of the Year

In hypersonic wind tunnel tests, freestream disuturbances become an initial source that causes turbulent transitions in the wind tunnel model. Therefore, it is necessary to accurately reproduce the freestream disuturbances in order to accurately perform DNS of turbulent transitions in wind tunnel tests. It is known that the freestream disuturbances of wind tunnels are mainly due to noise emitted by the turbulent boundary layer that develops on the nozzle wall. In this study, a DNS analysis was performed on the turbulent boundary layer that develops at the M=7 nozzle wall of the hypersonic wind tunnel. Figure 1 shows the process of turbulent transition of the boundary layer on the M=7 nozzle wall and the noise emitted by the turbulent boundary layer. The results of DNS enable us to evaluate the intensity and frequency components of freestream disturbances of the hypersonic wind tunnel.

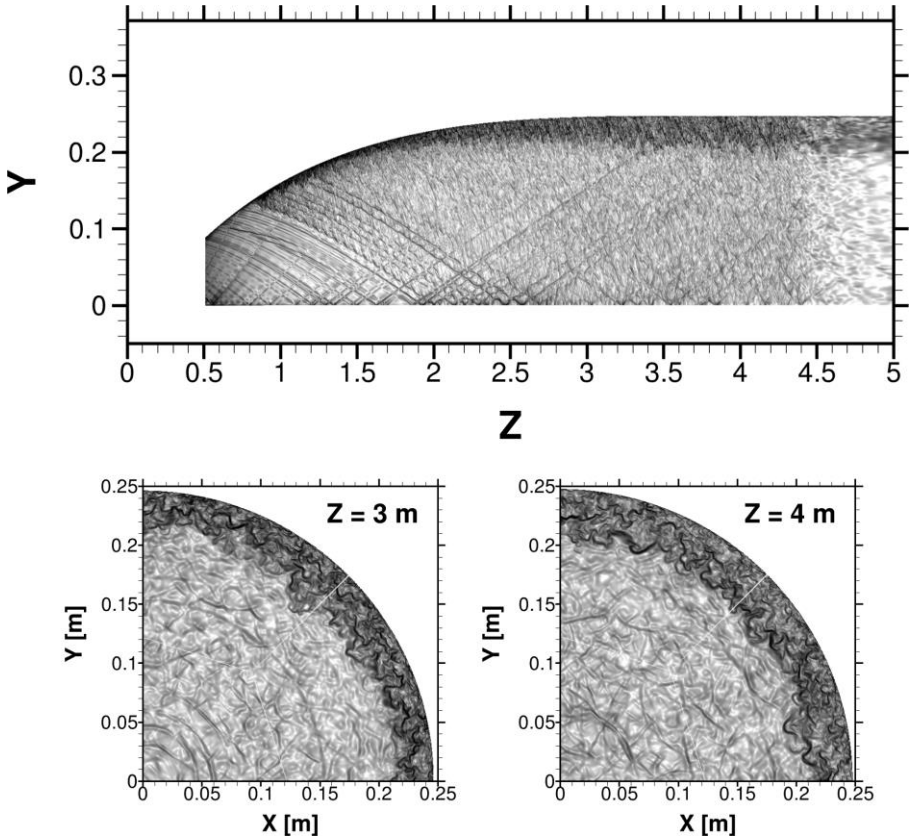

Fig. 1: DNS of turbulent transitions on the M=7 nozzle wall of a hypersonic wind tunnel, visualizing the noise emitted from the turbulent boundary layer by means of a pseudo-Schlieren image.

Publications

- Oral Presentations

1) Shingo Matsuyama, "DNS on Turbulent Transitions in a Hypersonic Boundary Layer Induced by External Disturbances", 55th Fluid Dynamics Conference / the 41st Aerospace Numerical Simulation Symposium, 2023.

2) Shingo Matsuyama, "DNS of Boundary Layer Turbulent Transition in a Hypersonic Wind Tunnel", 67th Space Sciences and Technology Conference, 2023.

3) Shingo Matsuyama, "DNS of Boundary-Layer Turbulent Transition on the Nozzle Wall of Hypersonic Wind Tunnels", Symposium on Shock Waves in Japan 2023, 2024.

Usage of JSS

Computational Information

Process Parallelization Methods	MPI
Thread Parallelization Methods	OpenMP
Number of Processes	8000 - 20770
Elapsed Time per Case	230 Hour(s)

- **JSS3 Resources Used**

Fraction of Usage in Total Resources[*1](%): 0.74

Details

Computational Resources		
System Name	CPU Resources Used (core x hours)	Fraction of Usage[*2](%)
TOKI-SORA	18,277,692.79	0.83
TOKI-ST	23,715.93	0.03
TOKI-GP	0.00	0.00
TOKI-XM	0.00	0.00
TOKI-LM	183,544.35	13.98
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	261.49	0.22
/data and /data2	3,085.18	0.02
/ssd	603.30	0.06

Archiver Resources		
Archiver Name	Storage Used (TiB)	Fraction of Usage[*2] (%)
J-SPACE	2.23	0.01

[*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)	1,223.60	0.55

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