Physics and Modeling in Hypersonic and Transonic Flow toward Establishing Reentry Technology

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Abstract

An expansion tube, a shock wind tunnel that generates hypersonic flow, is expected to be a wind tunnel that can experimentally simulate the flow at superorbital reentry on the ground. In the expansion tube, turbulent transition is considered to adversely affect the state of the test flow. However, the mechanism of turbulent transition is not clear. In this study, numerical simulations were conducted to investigate the mechanism of turbulent transition in an expansion tube.

Reasons and benefits of using JAXA Supercomputer System

In order to investigate the possibility of turbulent transition, it is important to capture the propagation of small disturbances. Hence, high-resolution numerical simulation with less numerical perturbation and dissipation is required. However, such numerical simulation requires a large computational cost. Therefore, it is necessary to use the supercomputer owned by JAXA.

Achievements of the Year

An artificial disturbance was added to the boundary layer behind a shock wave propagating in an expansion tube, and the development of the disturbance was investigated. Specifically, a shock wave propagating in an expansion tube was transformed into shock stationary frame, which is an inertial system in which the shock wave appears to be stationary, using the shock speed, and was considered as a quasi-steady flow field. In addition, blowing / suction disturbance was randomly added to the wall of the boundary layer behind the shock wave. The pressure fluctuations due to the disturbances showed that a specific wavelength appeared behind the disturbance source, and the pressure waves disturbed the shock front, resulting in larger disturbances being emitted downstream of the shock (Fig. 1). This result suggests that the shock wave front oscillates due to the interaction between the boundary layer and the instability of the shock wave front, which induces turbulent transition in the boundary layer

downstream of the shock wave.

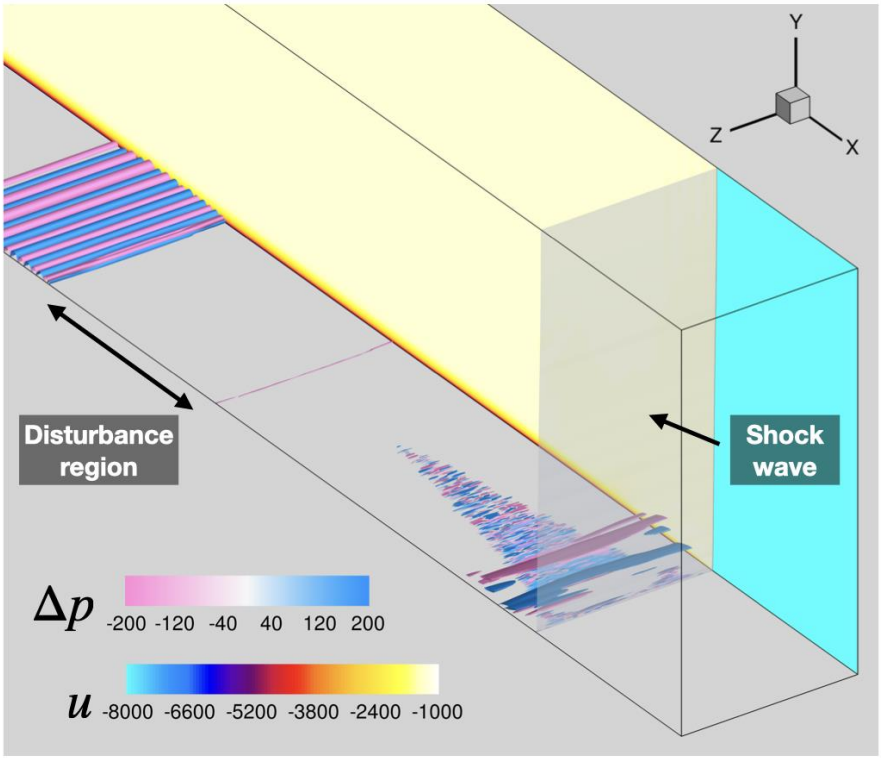

Fig. 1: The stability of the flow field is numerically investigated by adding artificial disturbances behind the propagating shock wave.

Publications

- Peer-reviewed papers

1) Hiroki Sakamoto, Shintaro Sato, Naofumi Ohnishi, Numerical Simulation of Shock Attenuation with Real Gas Effects and a Turbulent Boundary Layer in the Expansion Tube, Shock waves, Vol. 34, 539, 2024.

2) Hiroki Sakamoto, Shintaro Sato, Naofumi Ohnishi, Hypersonic Boundary Layer Instability in Long-Distance Propagation of Shock Wave, Proceedings of the 34th International Symposium on Shock Waves, accepted for publication, 2024.

- Oral Presentations

1) Hiroki Sakamoto, Shintaro Sato, Naofumi Ohnishi, Numerical Study on Hypersonic Boundary Layer Behind a Propagating Shock Wave in an Expansion Tube, 10th International Workshop on Radiation of High Temperature Gases for Space Missions, Oxford, September, 2024.

Usage of JSS

Computational Information

Process Parallelization Methods	MPI
Thread Parallelization Methods	N/A
Number of Processes	24 - 4800
Elapsed Time per Case	24 Hour(s)

JSS3 Resources Used

Fraction of Usage in Total Resources[*1](%): 0.46

Details

Computational Resources		
System Name	CPU Resources Used (core x hours)	Fraction of Usage[*2](%)
TOKI-SORA	2,780,181.95	0.13
TOKI-ST	3,093,463.62	3.18
TOKI-GP	0.00	0.00
TOKI-XM	0.00	0.00
TOKI-LM	3,618.50	0.26
TOKI-TST	421.46	0.01
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	490.00	0.33
/data and /data2	162,920.00	0.78
/ssd	5,020.00	0.27

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)	3.98	0.00

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