Study on Physics and Modeling of Turbulent Transitions in Boundary Layer of Hypersonic Flows

● **Responsible Representative**

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● **Abstract**

An expansion tube, a ground-based facility that generates hypersonic flow, is expected to be a shock wind tunnel that can experimentally simulate the flow at superorbital reentry. There is concern that turbulent transition in the expansion tube may have adverse effects on the state of the test flow. However, it is not clear whether turbulent transition can actually occur. In this study, numerical simulations were conducted to investigate the possibility of turbulent transition in an expansion tube.

● **Reasons and benefits of using JAXA Supercomputer System**

In order to investigate the possibility of turbulence transition, it is important to capture the propagation of small disturbances. Hence, high-resolution numerical simulation suppressing numerical perturbations and dissipation is required. However, such a numerical simulation requires a high 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 flow field behind 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, and numerical simulations are conducted. In addition, blowing / suction disturbance was randomly added to the wall of the boundary layer behind the shock wave. According to the variation of the downstream wall pressure with the added disturbance, a specific wavelength is found to grow (Fig. 1). This suggests that the added disturbance grew due to flow instability and turbulent transitions might occur in the expansion tube.
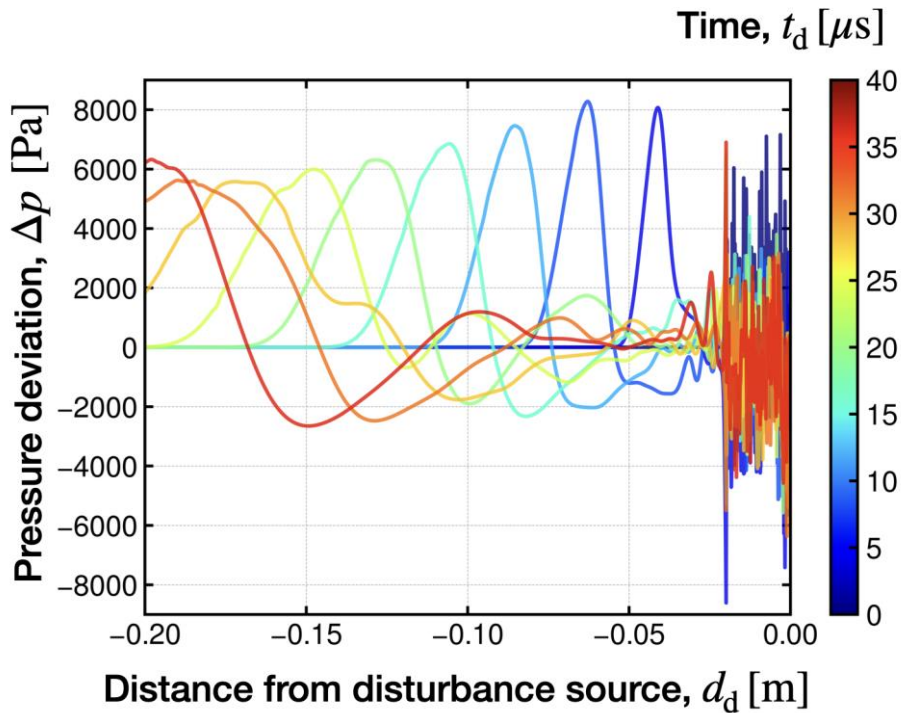
Fig. 1: Deviation of the pressure on the wall behind the disturbance location. The
line colors indicate the time since the disturbance was added.

● **Publications**

   - Non peer-reviewed papers

   1) Hiroki Sakamoto, Shintaro Sato, and Naofumi Ohnishi, "Computation of Hypersonic Boundary Layer Transition behind Propagating Shock Wave", AIAA Paper 2023-1233.

   2) Yasuhito Okano, Shintaro Sato, Naofumi Ohnishi, and Hiroki Nagai, "Numerical Study on Suppression of Reentry Capsule Dynamic Instability in Transonic Flow", AIAA Paper 2023-0811.

   - Oral Presentations

   1) Hiroki Sakamoto, Shintaro Sato, and Naofumi Ohnishi, "Computation of Hypersonic Boundary Layer Transition behind Propagating Shock Wave", AIAA SciTech 2023 Forum, Washington D.C., January 2023.

   2) Yasuhito Okano, Shintaro Sato, Naofumi Ohnishi, and Hiroki Nagai, "Numerical Study on Suppression of Reentry Capsule Dynamic Instability in Transonic Flow", AIAA SciTech 2023 Forum, Washington D.C., January 2023.

● **Usage of JSS**

● **Computational Information**

Process Parallelization Methods	MPI
Thread Parallelization Methods	N/A
Number of Processes	12 - 2160
Elapsed Time per Case	120 Hour(s)

● **JSS3 Resources Used**

Fraction of Usage in Total Resources[*1](%): 0.42

Details

Computational Resources		
System Name	CPU Resources Used (core x hours)	Fraction of Usage[*2](%)
TOKI-SORA	2,227,770.99	0.10
TOKI-ST	2,584,039.87	2.58
TOKI-GP	0.00	0.00
TOKI-XM	1,289.16	0.81
TOKI-LM	9,802.54	0.66
TOKI-TST	90,148.96	2.38
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	23.33	0.02
/data and /data2	30,820.00	0.24
/ssd	233.33	0.03

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)	0.00	0.00

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

- **ISV Software Licenses Used**