Studies on nonlinear vortex dynamics in the later-stage of laminar-turbulent transition in compressible boundary layers

● **Responsible Representative**

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● **Abstract**

In hypersonic transitional flows, there are many complicated factors such as density fluctuation and temperature fluctuation due to the co-existence of the region slower than the speed of sound and the region faster than the speed of sound inside the boundary layer. Detailed investigations into the vortex dynamics occurring inside the boundary layers are expected. In this study, we aim to clarify the nonlinear vortex dynamics especially in the late-stage by conducting direct numerical simulations of laminar-turbulent transition in compressible boundary layers observed in hypersonic flows. Also, we develop a mathematical methodology to directly introduce vortices responsible for the late stage to the boundary layers, and its computational methods.

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

For the investigation of boundary layer transition of hypersonic flows, numerical simulation is a central tool because measurement is difficult due to the existence of acoustical disturbance in a wind tunnel. Because boundary layer transition is susceptible to disturbance, and in addition transition is hard to occur due to strong compressibility, powerful supercomputers that enable high-accuracy large-scale computation are necessary to get results in a short time period.

● **Achievements of the Year**

A new method that evaluates dominant local dynamics by skeletonization, mathematical term decomposition and the re-combination of a reduced number of dominant terms around the skeleton points is proposed to clarify the dynamics of hairpin vortices generated during the boundary-layer transition under free-stream turbulence (Fig.1). The present method enables the automatic finding and categorization of the variations of the sets of dominant terms that govern local dynamics during the evolution of hairpin vortices.
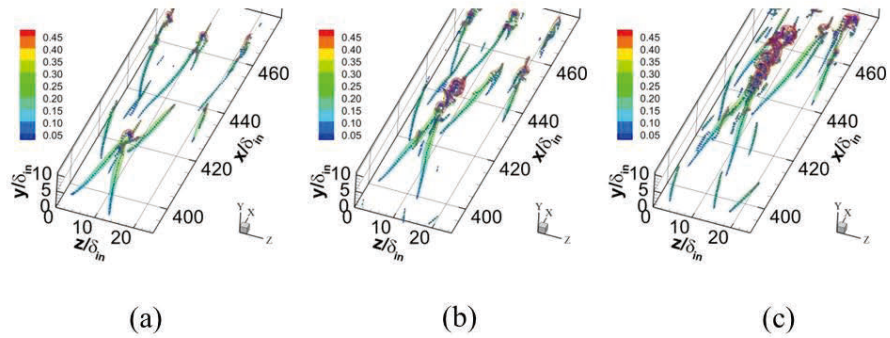
Fig. 1: Time evolution of hairpin and satellite vortices represented by the skelton points (blue points) and the transparent iso-surfaces (Free-Stream Turbulence Level=0.5%). The color on the iso-surfaces is Mach number. (a) t=258.0δin/u∞ (b) t=281.5δin/u∞ (c) t=305.0δin/u∞

● **Publications**

- Peer-reviewed papers

Kazuo Matsuura, "Algorithmic Exploration of Dominant Terms Around Hairpin Vortices Generated During Boundary-Layer Transition Under Free-Stream Turbulence," Int. J. Environ. Impacts, Vol. 3, No. 1 (2020).

- Non peer-reviewed papers

Kazuo Matsuura, Yasuhide Fukumoto, A Study on Clustering of Hairpin Vortices in Transitional Boundary-Layer, 24th Japan Society of Fluid Mechanics, Chushikoku-Kyushu Branch, pp. 1-2 (2019).

● **Usage of JSS2**

● **Computational Information**

Process Parallelization Methods	MPI
Thread Parallelization Methods	Automatic Parallelization
Number of Processes	16 - 64
Elapsed Time per Case	168 Hour(s)

● **Resources Used**

Fraction of Usage in Total Resources[1](%): 0.00

Details

Computational Resources		
System Name	Amount of Core Time (core x hours)	Fraction of Usage[2](%)
SORA-MA	7,281.63	0.00
SORA-PP	0.00	0.00
SORA-LM	0.00	0.00
SORA-TPP	0.00	0.00

File System Resources		
File System Name	Storage Assigned (GiB)	Fraction of Usage*2(%)
/home	9.54	0.01
/data	95.37	0.00
/ltmp	1,953.13	0.17

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.