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

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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

Ring tone is a kind of feedback sound emitted from a system in which pressure waves generated when vortices from a nozzle collide with a downstream obstacle, propagate upstream, and regulate the timing of further vortex ejection from the nozzle. This year, we placed a ring downstream of the

subsonic jet and clarified the mechanism of ring tone generation. Figure 1 shows how volumetric vortical regions interact with the ring.

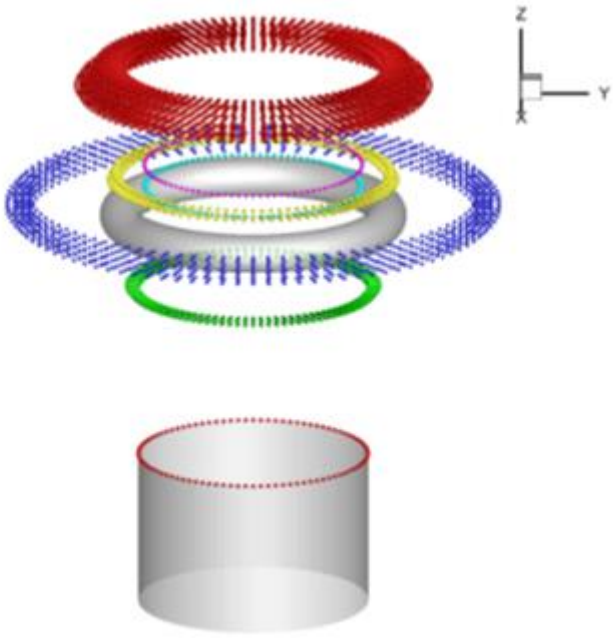

Fig. 1: Interaction with volumetric vortical regions and the ring

Publications

- Peer-reviewed papers

1. K. Matsuura, K. Mukai, M.A. Langthjem,
"Computational and experimental study on ring tone,"
WIT Transactions on Engineering Sciences, Vol. 132, pp. 141-151 (2021).
2. K. Matsuura,
"Numerical evaluation of the regions of high energy dissipation for different free-stream turbulence in transitional low-pressure turbine flows,"
Proc. of the 15th International Conference on Heat Transfer, Fluid Mechanics and Thermodynamics, pp. 1538-1543.
3. Kazuo Matsuura, Yasuhide Fukumoto,
"Hierarchical Clustering Method of Volumetric Vortical Regions with Application to the Late-Stage of Laminar-Turbulent Transition,"
Physical Review Fluids, pp.1-32 (2022) (accepted).

Usage of JSS

Computational Information

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

JSS3 Resources Used

Fraction of Usage in Total Resources[*1](%): 0.01

Details

Computational Resources		
System Name	CPU Resources Used (core x hours)	Fraction of Usage[*2](%)
TOKI-SORA	89,103.17	0.00
TOKI-ST	0.02	0.00
TOKI-GP	0.00	0.00
TOKI-XM	0.00	0.00
TOKI-LM	3,699.37	0.28
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	20.00	0.02
/data and /data2	200.00	0.00
/ssd	200.00	0.05

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.