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 for using of JSS2

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

New results are obtained regarding vortical structures generated downstream of a protuberance place in a boundary layer, and secondary hairpin vortices generated in a transitional boundary layer.

Regarding instability that promotes the deformation and bifurcation of a hairpin vortex, a relationship between the circulation magnitude of a leg and the linear stability of a shear layer is investigated.

Also, a new fully-nonlinear disturbance equation is derived.

Computing it simultaneously with a DNS, both linear and nonlinear instability are investigated in a unified manner.

Publications

- Peer-reviewed papers

1) K. Matsuura, "DNS Study on the Effect of Free-Stream Turbulence on Hairpin-Vortex Evolution," Proc. of the 44th National Conference on Fluid Mechanics and Fluid Power, Dec. 14-16, 2017, Amrita University, Amritapuri Campus, Kollam, Kerala, India, pp. 1-4 (2017).

2) K. Matsuura, K. Matsui, N. Tani, "Effects of Free-Stream Turbulence on the Global Pressure Fluctuation of Compressible Transitional Flows in a Low-Pressure Turbine Cascade," International Journal of Numerical Methods for Heat & Fluid Flow, pp. 1-13 (2017) (accepted).

3) K. Matsuura, K. Matsui, N. Tani, T. Goto, "Compressible Transitional Boundary Layers Subjected to Rotor-Stator Interaction in a Low-Pressure Turbine," 53rd 3AF International Conference on Applied Aerodynamics, 26-28 March 2018, Salon de Provence, France, pp. 1-7 (2018).

Usage of JSS2

Computational Information

Parallelization Methods	MPI
Thread Parallelization Methods	Automatic Parallelizatio
Number of Processes	16 - 64
Elapsed Time per Case	168.00 hours

Resources Used

Fraction of Usage in Total Resources*1 (%): 0.05

Details

Computing Resources		
System Name	Amount of Core Time (core x hours)	Fraction of Usage*2 (%)
SORA-MA	448,337.82	0.06
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	009.54	0.01
/data	095.37	0.00
/ltmp	1,953.13	0.15

Archiver Resources		
Archiver System 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