Research on unsteady flow simulation toward prediction of full flight envelope

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Abstract

The transonic buffet is one of the unsteady phenomena on the normal shock wave, which stands on an aircraft wing in transonic flow, and can affect aircraft safety. We aim to develop the Embedded Large Eddy Simulation (ELES) to improve buffet prediction accuracy and help aircraft design. In our plan, the ELES method will be tested on two-dimensional airfoils and finally adopted to commercial aircraft with complex, three-dimensional shapes.

We also develop the global stability analysis method, which is attracting attention as a low computational cost and high accuracy method for the prediction of buffet. In this research, we develop a global stability analysis code for buffet prediction.

Ref. URL: https://www.aero.jaxa.jp/eng/research/basic/numerical/issac/

Reasons and benefits of using JAXA Supercomputer System

Since the ELES method needs high-resolved computation for the wall turbulence, the simulation requires enormous computational resources that our desktop workstations cannot privide. Furthermore, the large amounts of simulation data also require vast storage and GPU resources to save and visualize them.

The resources provided by JSS is also essencial to perform the gloval stability analysis in this research. While conventional local stability is a one dimensional analysis limited to simple shapes, global stability analysis can handle any arbitrary flow field having three-dimensional complex shape. However, to achieve high-accuracy, large computational power is required and JAXA Supercomputer System is needed.

Achievements of the Year

We tested the ELES method by conducting a numerical simulation of transonic buffet flow over an OAT15A airfoil. The visualization of the shock wave and vortex structures on the suction side (figure 1) shows that the shock-boundary-layer interaction is simulated with reasonable accuracy. Also, the time-averaged distribution of the pressure coefficient (figure 2) shows good agreement with experimental results. We believe this year's achievements are the world's first report of numerical simulation of transonic buffet via ELES method.

Let us explain about the achevements on the global stability analysis. In order to perform global stability analysis for three-dimensional complex shapes, we developed and verified an global stability analysis code (FaSTAR-GSA) based on the fluid analysis code FaSTAR. A swept wing flow analysis was performed using FaSTAR-GSA and compared with the JTWT2 wind tunnel tests (figure 3). FaSTAR-GSA supports turbulence, shock waves, complex shapes, 3D and large-scale grids, being the highest performance global stability code in the world.

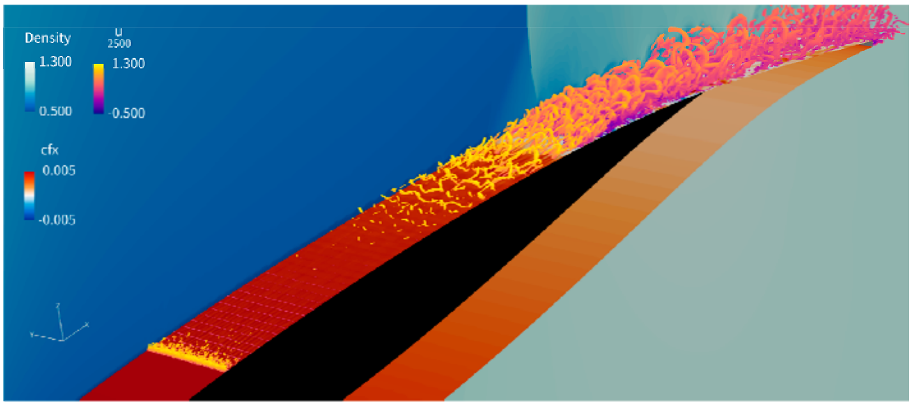

Fig. 1: Shock wave and vortex structures on OAT15A airfoil

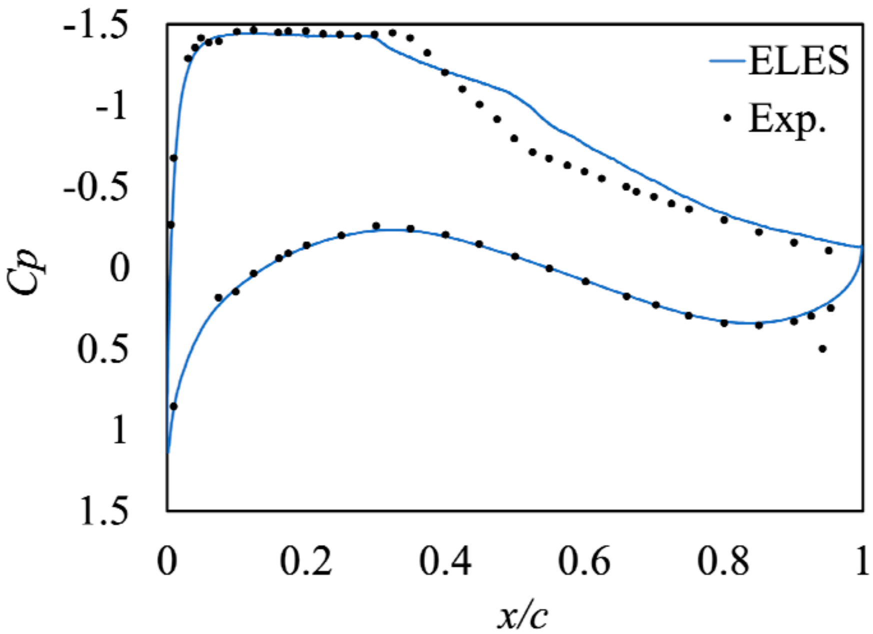

Fig. 2: Pressure coefficients on the wall

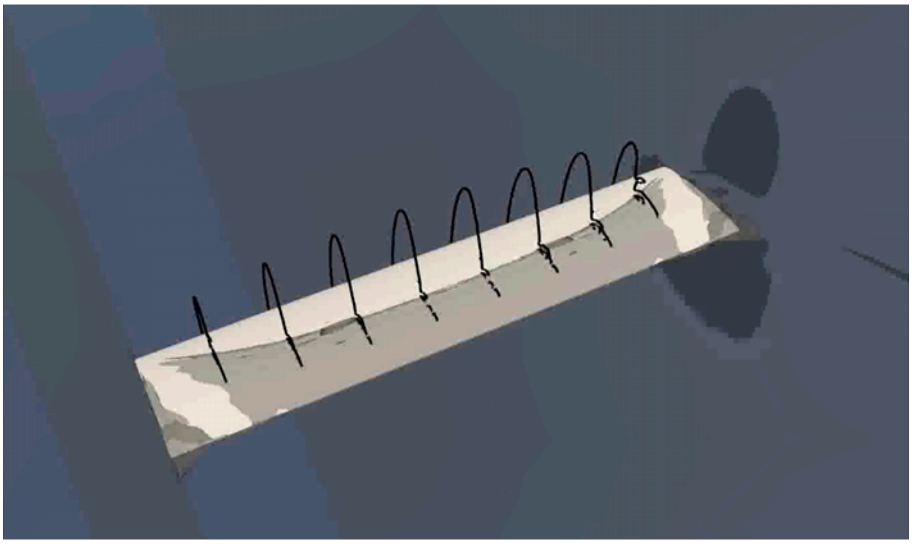

Fig. 3: Global stability analysis results of JTWT2 buffet wind tunnel test (Video. Video is available on the web.)

Publications

- Peer-reviewed papers

1) Sansica A, Ohmichi Y, Robinet JC and Hashimoto A. Laminar Supersonic Sphere Wake Unstable Bifurcations. Physics of Fluids, 2020, vol 32, no. 126107. DOI:10.1063/5.0031599

2) Sansica A, Hashimoto A and Ohmichi Y. Global Stability Analysis of the JAXA H-II Transfer Vehicle Re-Entry Capsule. Springer IUTAM Bookseries, 2020

- Non peer-reviewed papers

1) Sansica A, Hashimoto A, Koike S and Kouchi T. Side-Wall Effects on the Global Stability of Swept and Unswept Supercritical Wings at Buffet Conditions. JAXA-SP, 2020

- Oral Presentations

1) Sansica A, Hashimoto A, Koike S and Kouchi T. Side-Wall Effects on the Global Stability of Swept and Unswept Supercritical Wings at Buffet Conditions. 52nd Fluid Dynamics Conference / 38th Aerospace Numerical Simulation Symposium ,2020.

2) Kojijma Y, Hashimoto A. On numerical simulation for transonic buffet with Embbeded-LES method. 52nd Fluid Dynamics Conference / 38th Aerospace Numerical Simulation Symposium, 2020.

3) Hashimoto A, Kanamori M, Kirihara R, Matsuzaki T, Nakamoto K, Hayashi K, Steady and Unsteady computation on NASA-CRM with FaSTAR at low speeds and high angles of attack, 52nd Fluid Dynamics Conference / 38th Aerospace Numerical Simulation Symposium, 2020.

4) Matsuzaki T, Ishida T, Kanamori M, Hashimoto A, Unsteady Flow Simulation around NASA-CRM by Lattice Boltzmann Method with Multi-Block Cartesian Grid, 52nd Fluid Dynamics Conference / 38th Aerospace Numerical Simulation Symposium, 2020.

Usage of JSS

- **Computational Information**

Process Parallelization Methods	MPI
Thread Parallelization Methods	N/A
Number of Processes	256 - 5760
Elapsed Time per Case	1000 Hour(s)

- **Resources Used(JSS2)**

Fraction of Usage in Total Resources*1(%): 2.79

Details

Computational Resources		
System Name	Amount of Core Time (core x hours)	Fraction of Usage*2(%)
SORA-MA	13,721,446.33	2.60
SORA-PP	639,449.89	5.01
SORA-LM	21,897.52	12.86
SORA-TPP	0.00	0.00

File System Resources		
File System Name	Storage Assigned (GiB)	Fraction of Usage*2(%)
/home	670.45	0.61
/data	55,552.58	1.07
/ltmp	16,379.30	1.40

Archiver Resources		
Archiver Name	Storage Used (TiB)	Fraction of Usage*2(%)
J-SPACE	46.25	1.53

*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.

- **Resources Used(JSS3)**

Fraction of Usage in Total Resources[*1](%): 2.73

Details

Computational Resources		
System Name	Amount of Core Time (core x hours)	Fraction of Usage[*2](%)
TOKI-SORA	14,156,009.87	3.05
TOKI-RURI	64,481.69	0.37
TOKI-TRURI	864.02	0.07

File System Resources		
File System Name	Storage Assigned (GiB)	Fraction of Usage[*2](%)
/home	1,332.70	0.91
/data	121,280.85	2.03
/ssd	7,083.80	3.70

Archiver Resources		
Archiver Name	Storage Used (TiB)	Fraction of Usage[*2](%)
J-SPACE	46.25	1.53

[*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.