High-efficiency control of unsteady aerodynamic phenomena based on simultaneous measurement of pressure, temperature, position, and deformation

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Abstract

We will establish a method for simultaneous measurement of pressure, temperature, position, and deformation for flow around a wing, and use this method to elucidate unsteady aerodynamic phenomena around airfoils with elastic deformation and movement, and to investigate highly efficient control methods to suppress aeroacoustics, which is a problem during takeoff and landing of aircraft.

Reasons and benefits of using JAXA Supercomputer System

WeTo simulate small unsteady aerodynamic phenomena with high fidelity by CFD solver, a high-density grid is required, and the data size produced is enormous. Therefore, larger computational resources and advanced computers are essential, so JSS will be used.

Achievements of the Year

For the trailing-edge (TE) noise emitted by the NACA0012 airfoil, we attempted to reduce the discrepancies between CFD analyses using FaSTAR and wind tunnel experiments. A three-dimensional CFD analysis was performed using an effective angle of attack to account for flow distortion in the open-jet wind tunnel(FIg.1). This resulted in improved prediction accuracy of the pressure-side fluctuation spectrum, with the transition location on the airfoil surface becoming closer to the experimental results. In addition, data assimilation was applied to the FaSTAR analysis. Data assimilation is a technique that incorporates information from wind tunnel experiments into numerical simulations to improve prediction accuracy. In this study, the Ensemble Kalman Filter, a sequential data assimilation method, was employed. The results showed qualitative improvements in the prediction accuracy near the puressure-side surface of the airfoil under TE noise generation conditions. These findings significantly contribute to the establishment of a high-fidelity analysis method for TE noise.

For helicopter blade analysis, a platform for CFD analysis using blade deformation shapes measured in a wind tunnel was constructed. As a demonstration calculation, we compared the boundary layer transition positions on the blade obtained from wind tunnel tests and those predicted by the calculations to identify issues with the current transition model. The method developed here enables quantitative evaluation of the flow field for blades with moving deformation, both experimentally and computationally.

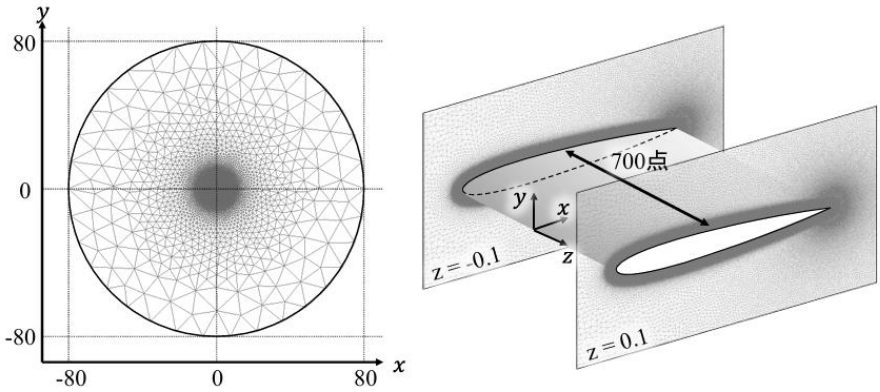

Fig. 1: Numerical grids overview (Left: Overall view of the two-dimensional lattice; Right: Lattice configuration in the spanwise direction)

Publications

- Peer-reviewed papers

K. Konishi, K. Saito, K. Takamura, H. Sugawara, K. Nakakita, M. Kameda, "CFD Analysis of UH-60A Rotor Blades in Hover Using an Integrated Platform for Wind Tunnel Tests and Numerical Simulations," International Journal of Computational Fluid Dynamics, 2025 (accepted)

- Oral Presentations

1. Saito, K., Imai, M., Konishi, K., Takamura K., Sugawara, H., Tanabe, Y., Nakakita, K., Kameda M. (2024) "Measurement of Deformation of Helicopter Blade Model using Stereo-DIC, " 56th Fluid Dynamics Conference / 42st Aerospace Numerical Simulation Symposium (Jun. 3, 2024, Kakuix kouryu Ctr., Kagoshima Pref.Kagoshima CityYamashitacho), 1B04.

2. Konishi, K., Saito, K., Imai, M., Sugawara, H., Tanabe, Y., Kameda M. (2024) "Aeroelastic Flow Simulations around the Rotor Blade Using the Model Deformation Measurement Data, " 56th Fluid Dynamics Conference / 42st Aerospace Numerical Simulation Symposium (Jun. 3, 2024, Kakuix kouryu Ctr., Kagoshima Pref.Kagoshima CityYamashitacho), 1B05.

3. Abe, K., Konishi, K., Kojima, Y., Kameda M. (2024) "Reconstruction of flow around an airfoil with TE noise by data assimilation, " 56th Fluid Dynamics Conference / 42st Aerospace Numerical Simulation Symposium (Jun. 4, 2024, Kakuix kouryu Ctr., Kagoshima Pref.Kagoshima CityYamashitacho), 2A03.

4. Itsuki M., Konishi, K., Kojima, Y., Kameda M. (2024) "Quantitative evaluation of CFD solutions for TE noise radiated from a twodimensional airfoil, " 56th Fluid Dynamics Conference / 42st Aerospace Numerical Simulation Symposium (Jun. 3, 2024, Kakuix kouryu Ctr., Kagoshima Pref.Kagoshima CityYamashitacho), 1A12.

Usage of JSS

Computational Information

Process Parallelization Methods	MPI
Thread Parallelization Methods	N/A
Number of Processes	1 - 8640
Elapsed Time per Case	591 Hour(s)

JSS3 Resources Used

Fraction of Usage in Total Resources[*1](%): 1.37

Details

Computational Resources		
System Name	CPU Resources Used (core x hours)	Fraction of Usage[*2](%)
TOKI-SORA	25,382,048.23	1.16
TOKI-ST	3,586,839.02	3.68
TOKI-GP	0.00	0.00
TOKI-XM	0.00	0.00
TOKI-LM	30,532.81	2.20
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	2,497.80	1.68
/data and /data2	213,677.21	1.02
/ssd	11,102.98	0.59

Archiver Resources		
Archiver Name	Storage Used (TiB)	Fraction of Usage*2 (%)
J-SPACE	17.59	0.06

*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)	666.34	0.46

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