Analysis and 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

To 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

This year, numerical analyses were carried out to elucidate the mechanisms of the TE noise using CFD and to study the establishment of CFD analysis techniques using heliblade wind tunnel test data.

For TE noise (blade trailing edge noise) generated from the NACA0012 airfoil, the influence of the grids was investigated using FaSTAR, and a data assimilation system was constructed with fewer observation points to reduce the deviation between the analytical solution and the wind tunnel test. The investigation of the grid effects confirmed that TE noise is strongly grid dependency and that its behaviour within the boundary layer is also dependent on the grid size out of the boundary layer. Furthermore, a correlation between the amplitude and the wall friction coefficient distribution was found for the pressure fluctuations on the wing surface caused by TE noise. Data assimilation experiments using the constructed data assimilation system suggested the possibility of reconstructing the flow field with TE noise using an ensemble Kalman filter with covariance expansion.

CFD analysis techniques around deformed helicopter blades using model deformation measurement (MDM) are being worked on. The MDM used in this study was acquired by the stereo digital image correlation, which provides several hundred thousand measurement points from instantaneous images. This year, the estimation technique for 3D deformed blade shapes necessary for CFD analysis of deformed blades was developed from these large-scale deformation measurement data, and the data was processed using JSS3 resources (Fig. 1).

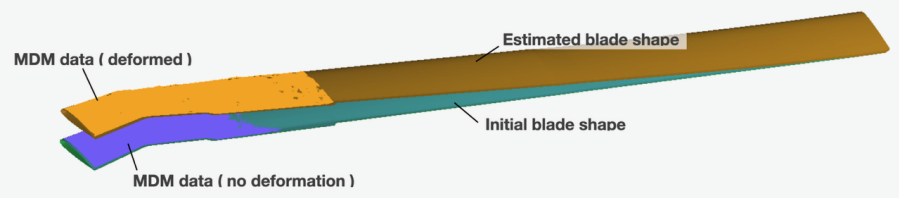

Fig. 1: A point cloud obtained by MDM and the blade deformation shape estimated by proposed method

Publications

- Oral Presentations

1. Saito, K., Yumino, T., Sugawara, H., Tanabe, Y., Kameda, M. (2023) "Numerical simulation of the aerodynamic interference between multiple rotors," 55th Fluid Dynamics Conference / 41st Aerospace Numerical Simulation Symposium (Jun. 12, 2023, National Olympics Memorial YOuth Center, Tokyo), 1E13.

2. Yumino, T., Sugawara, H., Tanabe, Y., Kameda, M. (2023) "Aerodynamic Performance Analysis of Multirotor with Multirotor Lift Offset (MRLO)," 61st Aircraft Sympodium (Nov. 15, 2023, Kitakyushu International Conference Center, Fukuoka), 1B07.

3. Konishi, K., Yumino, T., Saito, K., Imai, M., Sugawara, H., Tanabe, Y., Nakakita, K., Kameda, M. (2023) "Influence of the aeroelastic deformation to the flow around the rotor blade in hovering flight," 61st Aircraft Sympodium (Nov. 15, 2023, Kitakyushu International Conference Center, Fukuoka), 3B02

Imai, M., Nakakita, K. and Kameda, M. (2023) "DMD analysis of simultaneous pressure and deformation data of a deformed wing measured by random-dot PSP," AIAA Aviation 2023 Forum (12-16 June 2023, Manchester Grand Hyatt, San Diego, CA, U.S.A.), AIAA 2023-3537.

Usage of JSS

Computational Information

Process Parallelization Methods	MPI
Thread Parallelization Methods	OpenMP
Number of Processes	1 - 720
Elapsed Time per Case	120 Hour(s)

- **JSS3 Resources Used**

Fraction of Usage in Total Resources[*1](%): 1.82

Details

Computational Resources		
System Name	CPU Resources Used (core x hours)	Fraction of Usage[*2](%)
TOKI-SORA	32,789,996.70	1.48
TOKI-ST	4,796,759.67	5.18
TOKI-GP	0.00	0.00
TOKI-XM	0.00	0.00
TOKI-LM	19,590.93	1.49
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	2,550.46	2.12
/data and /data2	233,777.75	1.44
/ssd	16,252.62	1.54

Archiver Resources		
Archiver Name	Storage Used (TiB)	Fraction of Usage*2 (%)
J-SPACE	26.78	0.10

*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)	2,388.79	1.08

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