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

Report Number: R22ECMP19
Subject Category: Competitive Funding
URL: https://www.jss.jaxa.jp/en/ar/e2022/20780/

Responsible Representative

Kazuyuki Nakakita, Aviation Technology Directorate, Aircraft Lifecycle Innovation Hub

Contact Information

Yoimi Kojima(kojima.yoimi@jaxa.jp)

Members

Masato Imai, Kohei Konishi, Kazuyuki Nakakita, Yoimi Kojima, Keita Ogura, Hideaki Sugawara, Takumi Yumino

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

As an example of an unsteady aerodynamic phenomenon, we focus on aeroacoustics generated by aircraft takeoff and landing. Previous studies have shown that aeroacoustics is strongly linked to the pressure fluctuations near the surface of the object. Therefore, we conducted flow control experiments using pulsed lasers to reduce thetrailing edge noise and confirmed a certain level of noise reduction (Fig. 1). The results of CFD simulation of the flow field during laser irradiation revealed a control mechanism in which laser application induces vortices on the airfoil surface and interfere the coherent structure that maintains the trailing edge noise (Fig. 2). This result contributes to the establishment of a new noise reduction method that does not require the modification of the airfoil.

Reference calculations were also performed for the simultaneous pressure, temperature, position, and deformation measurement test on the rotor blades of a helicopter. The computational grid is configured as shown in Fig. 3. The results of this calculation revealed that the prevailing currents in the wind tunnel are a major source of error. This calculation contributes to the improvement of experimental methods and the development of CFD technologies.

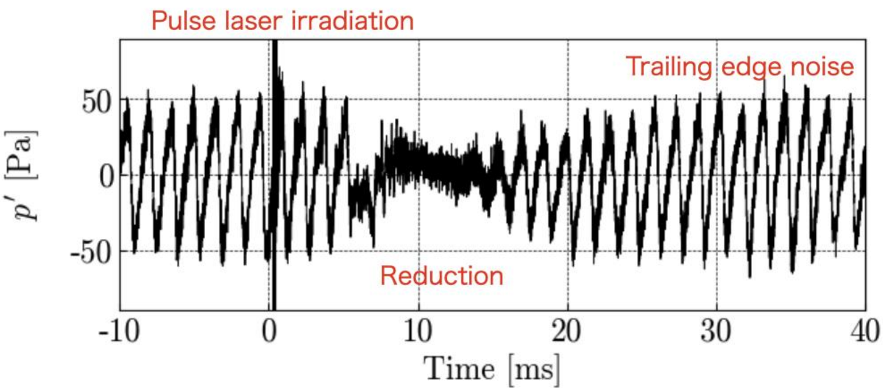


Fig. 1: Unsteady surface pressure fluctuation measured near the trailing edge of the airfoil in the wind tunnel test. The pulsed laser is irradiated at the time 0 ms.

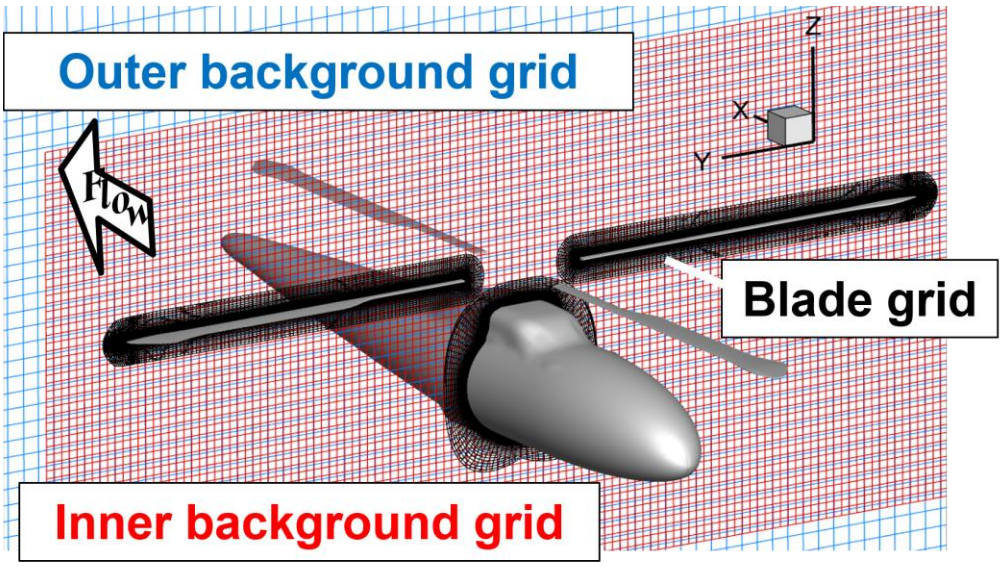
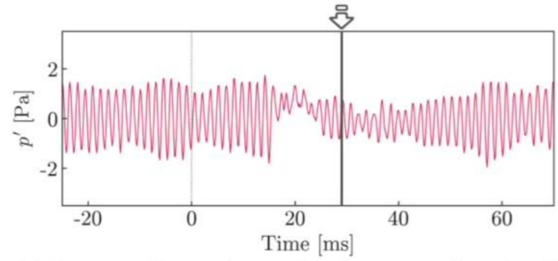
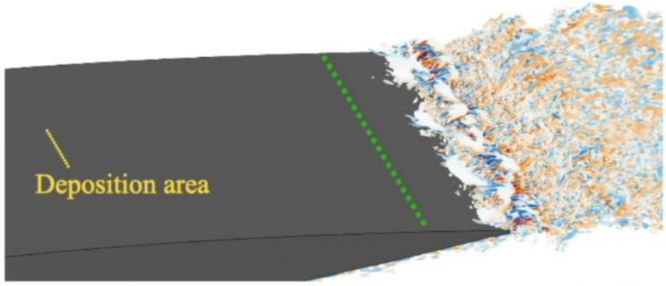


Fig. 2: Visualization of vortices on airfoil surface during laser application by CFD



(a) Pressure fluctuations p' [Pa] measured at far-filed.



(b) Vortices by iso-surface of Q-criterion$Q = 2 \times 10^6$ [s^{-2}] colored by x-wise vorticity

Fig. 3: Grid distribution of reference calculations for wind tunnel test on a helicopter. (Video. Video is available on the web.)

Publications

- Peer-reviewed papers

1) Ogura, K., Kojima, Y., Imai, M., Konishi, K., Nakakita, K. and Kameda, M. (2023), "Reduction of airfoil trailing-edge noise using a pulsed laser as an actuator," Actuators, Vol. 12, No. 1, 45.

2) Kojima, Y., Skene, C., Yeh, C.-A., Taira, K. and Kameda, M. (2023), "On the origin of quadrupole sound from a two-dimensional airfoil trailing edge," Journal of Fluid Mechancs, Vol. 958, A3.

- Oral Presentations

Ogura, K., Kojima, Y., Imai, M., Konishi, K., Nakakita, K. and Kameda, M. (2022) "Trailing edge noise coltrol by pulsed laser," 36th CFD Symposium, C03-2 (14 Desember, 2022, online)

Usage of JSS

- **Computational Information**

Process Parallelization Methods	MPI
Thread Parallelization Methods	N/A
Number of Processes	360 - 5760
Elapsed Time per Case	360 Hour(s)

- **JSS3 Resources Used**

Fraction of Usage in Total Resources[*1](%): 1.23

Details

Computational Resources		
System Name	CPU Resources Used (core x hours)	Fraction of Usage[*2](%)
TOKI-SORA	29,902,473.99	1.30
TOKI-ST	955,404.05	0.95
TOKI-GP	0.00	0.00
TOKI-XM	0.00	0.00
TOKI-LM	2,716.22	0.18
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	906.18	0.82
/data and /data2	62,786.76	0.48
/ssd	9,279.05	1.29

Archiver Resources		
Archiver Name	Storage Used (TiB)	Fraction of Usage[*2] (%)
J-SPACE	32.05	0.14

[*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)	2,350.44	1.64

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