Research on High-Speed Fluid Dynamics

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Abstract

To conduct fundamental research on high-speed fluid dynamics such as aerodynamic design of Mars drones

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Reasons and benefits of using JAXA Supercomputer System

High-fidelity flow simulations such as the large eddy simulations are required to analyze Mars drones.

Achievements of the Year

In order to realize a Mars airplane that flies in the Martian atmosphere, it is expected that the aerodynamic performance of the aircraft will be improved by making good use of the aerodynamic interference between the propeller and the main wing. In FY2024, we conducted a computational fluid simulation to clarify the effect of the spanwise position of the propeller and nacelle on fixed-wing and propeller performance under the flight conditions of the Mars airplane (Fig. 1). As a result, it was revealed that the centrally-located type has higher propeller performance, but the wingtip-located type has better fixed-wing performance, so that the wingtip-located type is superior overall. However, it was also shown that its superiority is lower in the Martian environment compared to the Earth environment.

We conducted a direct numerical simulation aimed at effectively applying riblets, a viscous drag reduction device, to aerospace aircraft (Figs. 2 and 3). It was revealed that by designing riblets taking compressibility into consideration, higher performance can be obtained than in the case of incompressible flow. In addition, it was confirmed that while the drag reduction performance of riblets can be improved under an adverse pressure gradient, under a favorable pressure gradient, although riblets reduce drag, their effect is weakened. These results show that the drag reduction performance of riblets can be uniformly expressed by the groove width non-dimensionalized by the friction velocity on a smooth surface, regardless of the presence or absence of compressibility or pressure

gradient.

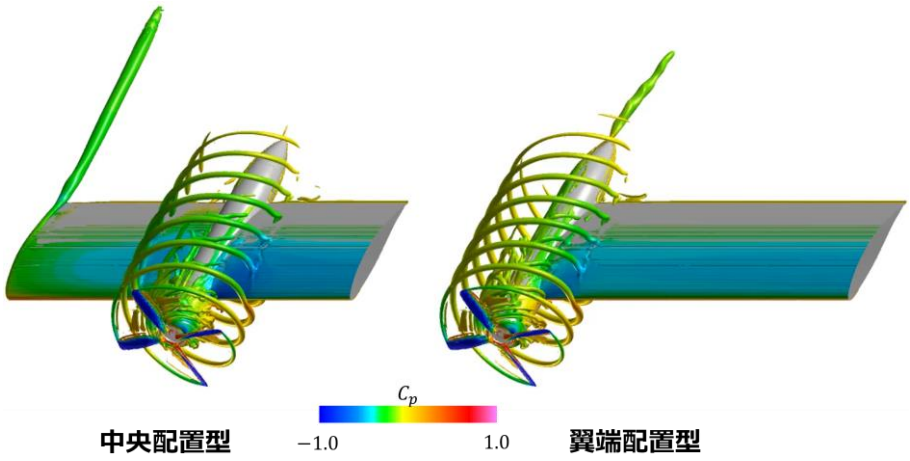

Fig. 1: Propeller-wing interference in the flight environment of a Mars airplane. Q-value isosurface and surface pressure coefficient distribution.

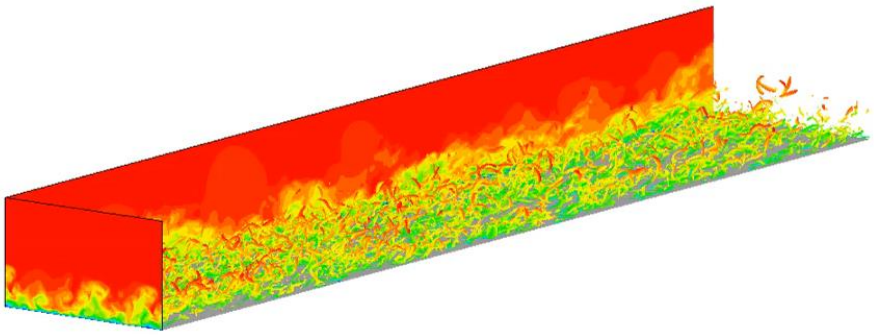

Fig. 2: Turbulence field developing on the smooth surface. The isosurface of the Q value is colored by the flow velocity.

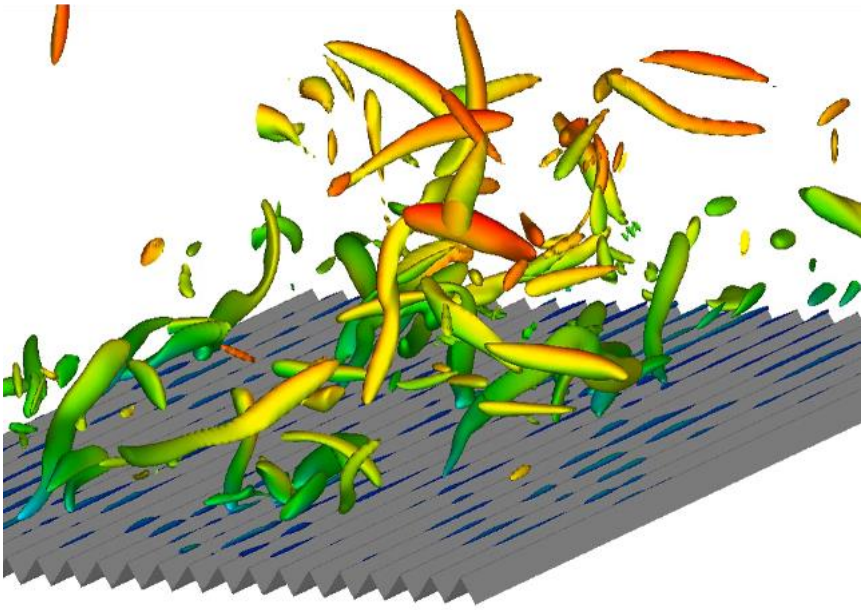

Fig. 3: Turbulence field developing on the riblet surface. The isosurface of the Q value is colored by the flow velocity.

Publications

- Peer-reviewed papers

Naruhiko Nimura and Akira Oyama, Multiobjective Evolutionary Topology Optimization Algorithm Using Quadtree Encoding, IEEE Access, Vol. 12, pp. 73839-73848, DOI: 10.1109/ACCESS.2024.3404594, 23 May 2024.

- Invited Presentations

Akira Oyama, High-Altitude Flight Test of a Mars Airplane Using a High-Altitude Balloon, AIAA SCITECH 2025 Forum, 6-10 January, 2025.

- Oral Presentations

1. Shu Ota, Naruhiko Nimura, and Akira Oyama, Multiobjective Aerodynamic Topology Optimization with Quadtree Genetic Programming and Local Search, AIAA SCITECH 2025 Forum, Orlando, Florida, 6-10 January, 2025

2. Kento Kaneko, Akira Oyama and Aiko Yakeno, Pressure Gradient Effects on the Riblet Performance at Cruising Speed of Transonic Aircraft, 1st European Fluid Dynamics Conference, Aachen, Germany, 16-20 September, 2024.

3. Masayuki Sasaki and Akira Oyama, Numerical Analysis of Aerodynamic Interference between Propeller and Fixed Wing of Mars, 1st European Fluid Dynamics Conference, Aachen, Germany, 16-20 September, 2024.

4. Ryutaro Onishi and Akira Oyama, Aerodynamic Interference Between Rotors of Mars Multicopter in Compressible Flow, 1st European Fluid Dynamics Conference, Aachen, Germany, 16-20 September, 2024.

5. Yuriko Shiratsuchi, Kento Kaneko, Shion Okada, Akira Oyama, Kazuhiko Yamada and Hiroto Tanaka, Conceptual Design of Micro-size Mars Airplane for Observing Dust, 34th Congress of the International Council of the Aeronautical Sciences, Florence, Italy, 9-13 September, 2024.

6. Kento Kaneko, Akira Oyama, and Aiko Yakeno, Viscous Drag Reduction Effect of Riblet at Cruising Speed

of Transonic Aircraft, AIAA Aviation Forum, Las Vegas, NV, 29 July - 2 August, 2024.

7. Akira Oyama and Naruhiko Nimura, Development of Multiobjective Aerodynamic Three-Dimensional Shape Optimization Method, 12th International Conference on Computational Fluid Dynamics, Kobe, Japan, 14-19 July, 2024.

8. Takeshi Sawada, Akira Oyama, Yusuke Maru, Hiroyasu Manako, Studies on Effect of Interaction of Coaxial Jets on Thrust of Air-breathing Rocket, 9th European Congress on Computational Methods in Applied Sciences and Engineering, Lisbon, Portugal, 3-7 June, 2024.

Usage of JSS

Computational Information

Process Parallelization Methods	MPI
Thread Parallelization Methods	OpenMP
Number of Processes	64 - 384
Elapsed Time per Case	300 Hour(s)

JSS3 Resources Used

Fraction of Usage in Total Resources[*1](%): 0.92

Details

Computational Resources		
System Name	CPU Resources Used (core x hours)	Fraction of Usage[*2](%)
TOKI-SORA	22,882,648.77	1.05
TOKI-ST	389,941.81	0.40
TOKI-GP	0.69	0.00
TOKI-XM	0.00	0.00
TOKI-LM	260.14	0.02
TOKI-TST	76.36	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	2,739.00	1.85
/data and /data2	369,450.00	1.77
/ssd	17,570.00	0.94

Archiver Resources		
Archiver 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.

- **ISV Software Licenses Used**

ISV Software Licenses Resources		
	ISV Software Licenses Used (Hours)	Fraction of Usage*2 (%)
ISV Software Licenses (Total)	2,257.88	1.54

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