Study of 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

Ref. URL: https://ladse.eng.isas.jaxa.jp/

Reasons and benefits of using JAXA Supercomputer System

Large eddy simulations are required for analysis of Mars drones.

Achievements of the Year

To design a rotor blade with better flight performance for pit craters' exploration of Mars by a Mars helicopter, multi-objective design optimization is performed in the design range including sharp leading edge and trailing edge shapes to design a rotor blade with higher flight performance on Mars. To evaluate the objective function, the lift-drag ratio at two angles of attack was used to account for the robustness against angle of attack. The flow fields of the obtained optimal solutions were compared with the flow field of an airfoil with good performance under low Reynolds number, and the characteristics of the airfoil were investigated. It was confirmed that the formation of the reattachment region of the separation due to the concave shape at the leading edge of the airfoil upper surface contributed to the increase in lift-drag ratio.

Reynolds number effect on aerodynamic interference of overlapping rotors is studied in low Reynolds number flow conditions. Results of three-dimensional Navier-Stokes simulations of overlapping rotors at different horizontal distance in Reynolds number of 5,000, 10,000, and 40,000 are compared. The results show that figure-of-merit (FM) decreases as Reynolds number decreases and FM monotonically decreases as horizontal distance decreases. This trend does not change for all

Reynolds number conditions. FM of the overlapping rotors doesn't exceed that of the single rotor at any overlap position in the current computational conditions. The results also show that the deterioration of FM due to interference of overlapping rotors becomes smaller at Reynolds number of 10,000 and lower and it does not change if the Reynolds number is lower than 10,000. From these results, we conclude aerodynamic interference of the overlapping rotors is relatively small for the Mars drone where the expected tip Reynolds number is about 10,000.

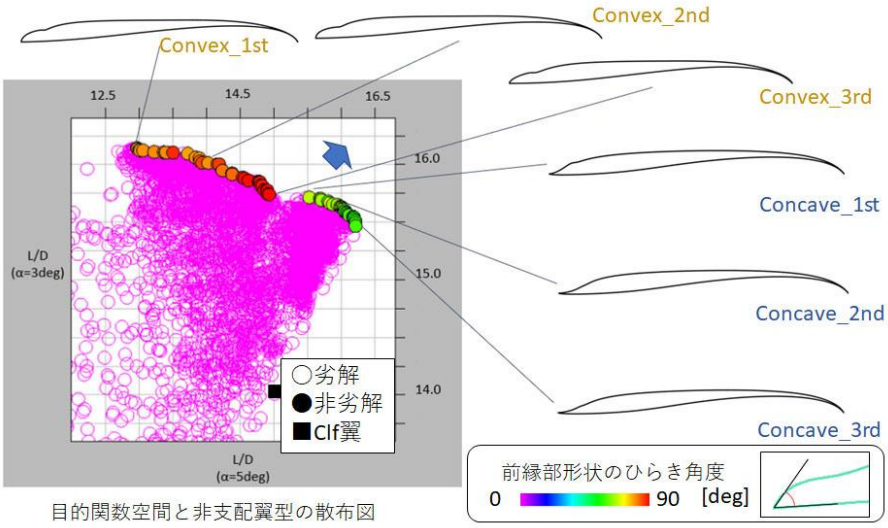

Fig. 1: Scatter plots of dominated and non-dominated solutions in the objective function space and the front edge opening angle of non-dominated solutions

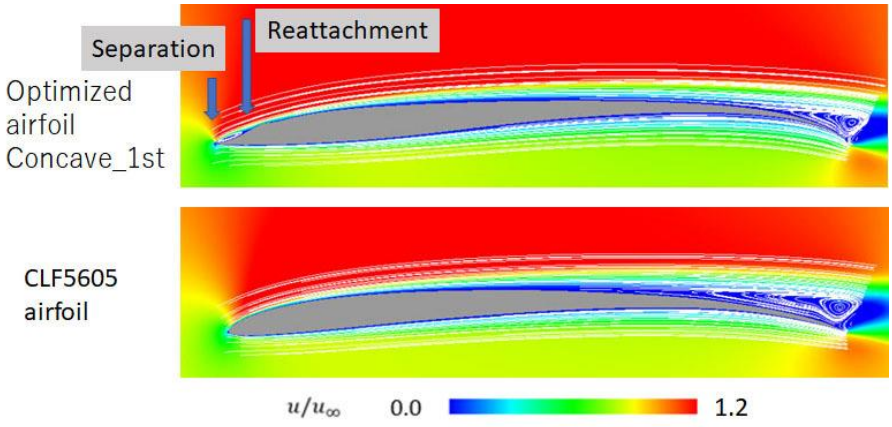

Fig. 2: Flow velocity distributions of optimized (top) and clf5605 (bottom) airfoils at angles of attack of 4 degrees.

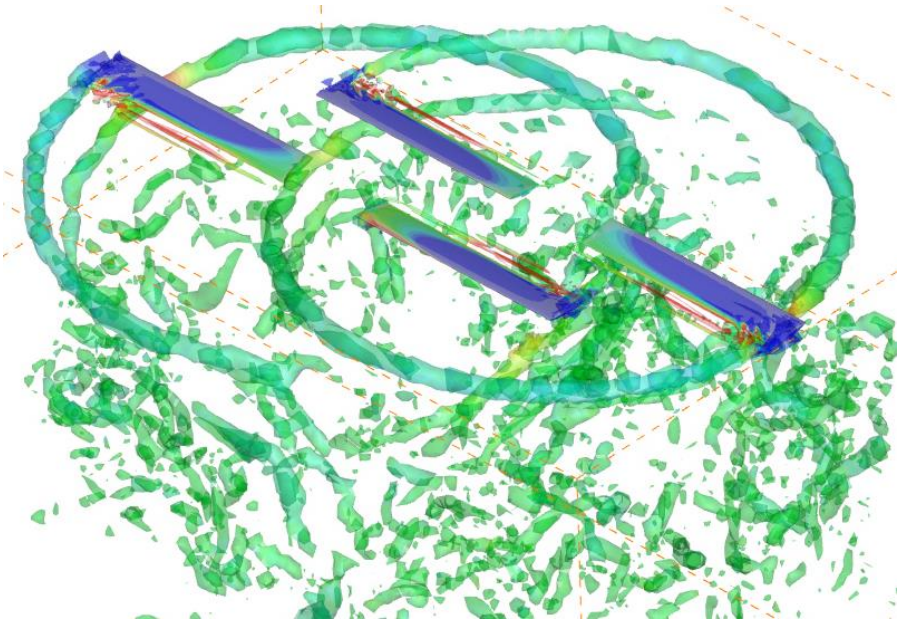

Fig. 3: isosurface of Q criterion around overlapping rotors colored by pressure

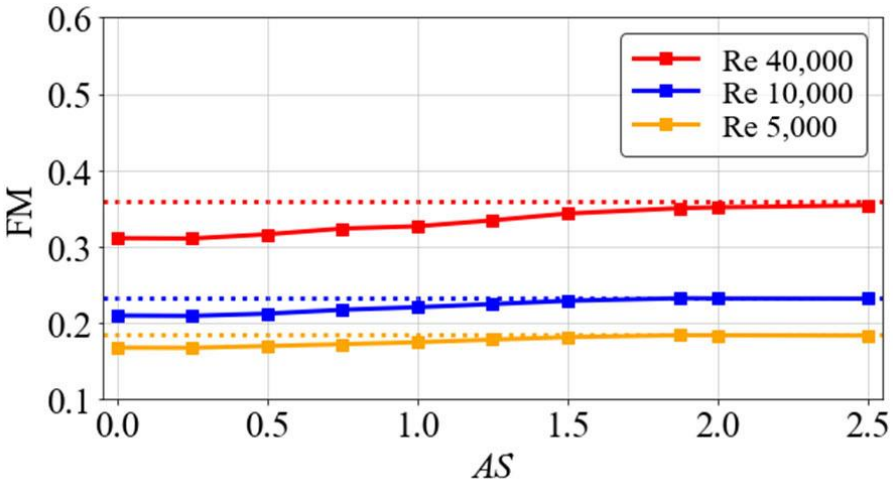

Fig. 4: Hovering efficiency(FM) of rotors with horizontal dintance (AS)

Publications

- Oral Presentations

Taniguchi, Shota, and Akira Oyama. Numerical Analysis of Propeller Mounting Position Effects on Aerodynamic Propeller/Wing Interaction. AIAA SCITECH 2022 Forum. San Diego, CA & Virtual Event, 3-7 January 2022.

Fukushima, Yuki, and Akira Oyama. Aerodynamic interaction of overlapping rotors for Mars drone. AIAA SCITECH 2022 Forum. San Diego, CA & Virtual Event, 3-7 January 2022.

Usage of JSS

Computational Information

Process Parallelization Methods	MPI
Thread Parallelization Methods	Automatic Parallelization
Number of Processes	1 - 37
Elapsed Time per Case	350 Hour(s)

JSS3 Resources Used

Fraction of Usage in Total Resources[*1](%): 1.71

Details

Computational Resources		
System Name	CPU Resources Used (core x hours)	Fraction of Usage[*2](%)
TOKI-SORA	33,868,554.89	1.65
TOKI-ST	1,929,108.95	2.38
TOKI-GP	0.00	0.00
TOKI-XM	0.00	0.00
TOKI-LM	1,352.73	0.10
TOKI-TST	2.50	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	3,373.67	3.36
/data and /data2	132,145.33	1.41
/ssd	11,028.33	2.85

Archiver Resources		
Archiver Name	Storage Used (TiB)	Fraction of Usage*2(%)
J-SPACE	19.05	0.13

*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)	1,448.47	1.01

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