Numerical Study on Aerodynamic Characteristics of Mars Aircraft and Mars Rocket

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Abstract

The ISAS/JAXA is leading a research and development project for various Mars aricrafts. In the Oyama Laboratory at the ISAS, experimental studies has been conducted to measure the aerodynamic characteristics of a Mars helicopter under low-pressure conditions simulating the Martian atmosphere. Furthermore, high-altitude flight tests for a Mars airplane has been conducted. In the present research, numerical simulations of the flow around various Mars aircrafts are coducted under the same conditions as the experiments, to elucidate the aerodynamic characteristics and flow physics.

In addition, research on a Mars sample return rocket has been conducted at the Oyama Laboratory of ISAS. Since it becomes the lower Reynolds numbers and higher Mach numbers on Mars compared to Earth, the knowledge about the optimal rocket shape suitable for Martian conditions is important. In the present study, numerical simulations of the flow around rockets in Martian conditions are conducted to determine the optimal Mars rocket shape based on its aerodynamic characteristics and flow physics.

Reasons and benefits of using JAXA Supercomputer System

We need to conduct the large-scale simulations on various Mars aircrafts and Mars rocket flows using "LANS3D", "rFlow3D" and "FaSTAR", which have been developed in JAXA.

Achievements of the Year

To clarify the effects of propeller-wing interaction in a Mars airplane, we investigated the influence of a swirl flow, simulating the propeller wake, on the laminar separation bubble of the airfoil in a low Reynolds number region. Based on the experimental conditions conducted at Tohoku University [1], the Reynolds number was set to 30,000. The propeller flow was simulated using the Actuator Disk Model and the Actuator Line Model. The numerical simulations were conducted using the LANS3D solver. Figure 1 shows the skin-friction coefficient distribution on the airfoil surface for each case, where the swirl number of the swirl flow was varied using the

Actuator Disk Model. The results indicate that the strength of the swirl flow significantly affects the region of the laminar separation bubble on both the upwash and downwash sides of the airfoil.

Additionally, to investigate the effects of wall interference on the aerodynamic characteristics of the rotor for a Mars helicopter, numerical simulations were performed on the hexarotor of the Mars helicopter "HAMILTON" [2] using rFlow3D. This year, as shown in Fig. 2, simulations were conducted on the hexarotor in an open space, providing insights into the characteristics of the flow field and aerodynamic performance.

Furthermore, following last year's studies, numerical simulations were conducted to examine the effects of Reynolds number and Mach number on the flow around a Mars rocket, targeting the configuration proposed in previous studies [3]. The Reynolds number, Mach number, and angle of attack were varied as parameters. The numerical simulations were conducted using FaSTAR,. Figure 3 presents the surface streamlines and pressure distribution on the upper side of the rocket at a Mach number of 0.95 and an angle of attack of 20 degrees, corresponding to the transonic region. The position of the shock waves generated on the upper and lower surfaces of the body was found to be strongly influenced by the Reynolds number, leading to variations in aerodynamic characteristics.

[1] Okawa, M., Nishimura, R., Ikami, T., and Nagai, H., "Unsteady Propeller Wake Interference on Wing in Tractor Configuration at Low-Reynolds-Number Condition", J. Aircraft, vol.62, pp. 3-12 (2025).

[2] Sugiura, M., Tanabe, Y., Sugawara, H., Kimura, K., Oyama, A., Sato, M., Yoshikawa, K., Buto, Y., Kanazaki, M., Kishi, Y., Kikuchi, D., and Minajima, T., “Blade Shape Optimization of Mars Helicopter Exploring Pit Craters”, VFS Forum 78-paper93, (2022).

[3] Jeffrey V. Bowles, Loc C. Huynh, and Veronica M. Hawke: Mars Sample Return : Mars Ascent Vehicle Mission & Technology Requirements, NASA/TM-2013-216511, (2013).

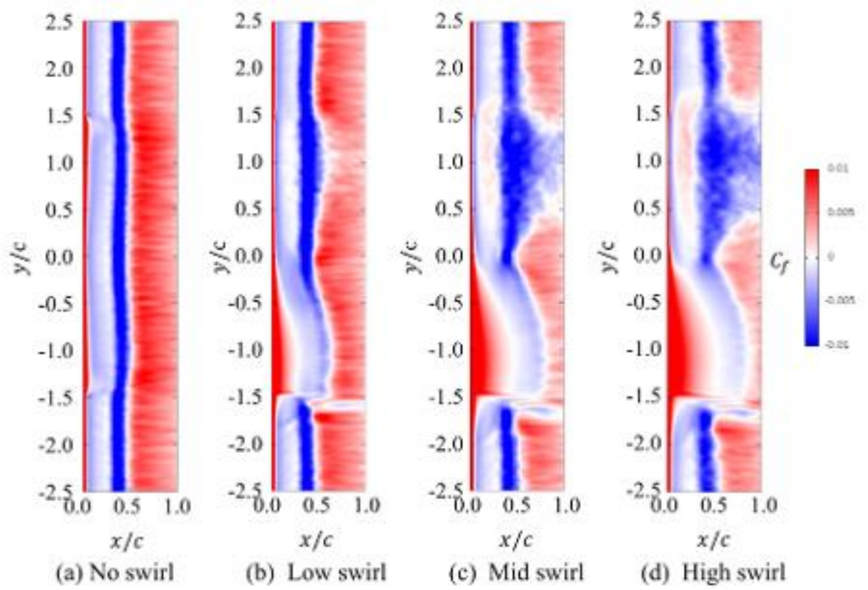

Fig. 1: Effect of swirl flow on distribution of skin friction

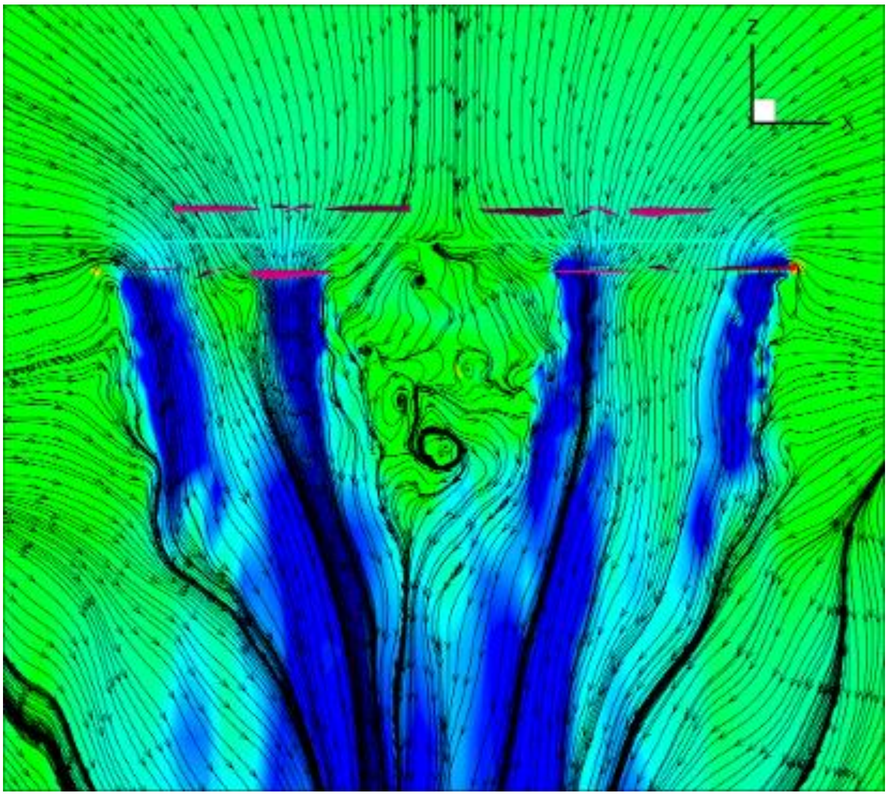

Fig. 2: Flow field around hexarotor in open space

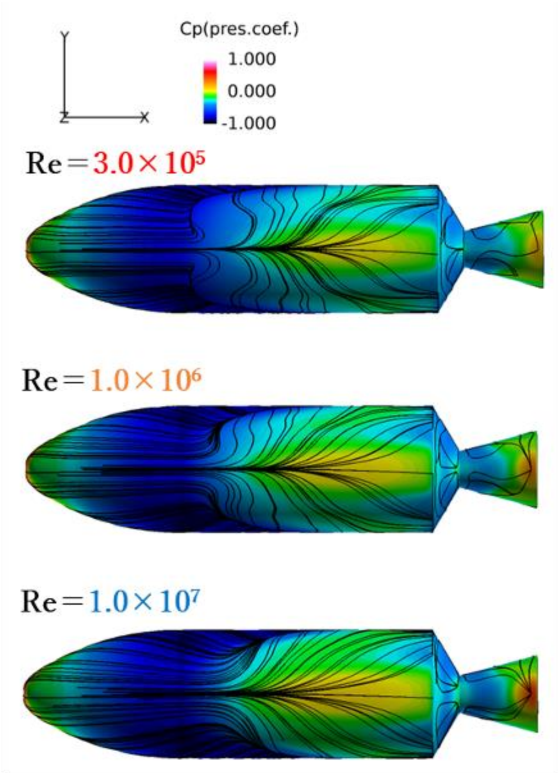

Fig. 3: Effect of Reynolds number on flow field on rocket surface

Publications

N/A

Usage of JSS

- **Computational Information**

Process Parallelization Methods	N/A
Thread Parallelization Methods	OpenMP
Number of Processes	1
Elapsed Time per Case	1920 Hour(s)

- **JSS3 Resources Used**

Fraction of Usage in Total Resources*1(%): 0.15

Details

Computational Resources		
System Name	CPU Resources Used (core x hours)	Fraction of Usage*2(%)
TOKI-SORA	3,007,534.33	0.14
TOKI-ST	39,112.71	0.04
TOKI-GP	0.00	0.00
TOKI-XM	0.00	0.00
TOKI-LM	1,265.84	0.09
TOKI-TST	37.55	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	1,559.00	1.05
/data and /data2	291,190.00	1.39
/ssd	5,020.00	0.27

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)	1,239.25	0.85

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