Development of low cost rotor blade evaluation method and its application to Mars helicopter rotor blade

Report Number: R22EACA59
Subject Category: JSS Inter-University Research
URL: https://www.jss.jaxa.jp/en/ar/e2022/20767/

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Abstract

In the exploration of Mars using helicopters and portable unmanned drones on the Earth, multi-rotor types with smaller aspect ratios of rotor blades are utilized, because they must be foldable and compact. A low-cost blade evaluation method based on blade element momentum theory has been established, which assumes that the aerodynamic performance of the blade element is representative at 75% span position for high aspect ratio blades. However, it has been observed that this method yields results that deviate significantly from the result by high-fidelity computational fluid dynamics for smaller aspect ratio blades. In this study, we investigated the optimal position of the representative airfoil section and the number of sections required to provide aerodynamic coefficients for the airfoil. We then used evolutionary computation to design an optimal drone for Mars exploration.

Reasons and benefits of using JAXA Supercomputer System

In this study, we conducted an optimal design using evolutionary computation. Since the design target is the sectional airfoil shape, a 2D airfoil evaluation is required for each design solution in addition to blade element momentum theory. Although the application of evolutionary computation became possible due to the low-cost evaluation method, which is based on the blade element momentum theory, it is necessary to use JSS3, as it is a numerical calculation governed by the Navier-Stokes equations. JSS3's capability is also required when conducting numerical calculations based on the immersed boundary method for confirmation purposes.

Achievements of the Year

For blades with an aspect ratio of approx. 4, we conducted verification of appropriate span positions as shown in Figure 1. As a result of applying a triangular wing, we obtained good agreement with high-fidelity CFD when representing 65% span position for high thrust coefficient (CT). Based on this, we conducted evolutionary computation to evaluate the construction method, and a shape (Figure 2 top) that exceeds the previous optimal shape was discovered. Furthermore, we confirmed that the optimization process was also clean, as we obtained good agreement in the comparison between the evaluation results using the proposed design method and high-fidelity numerical fluid dynamics.

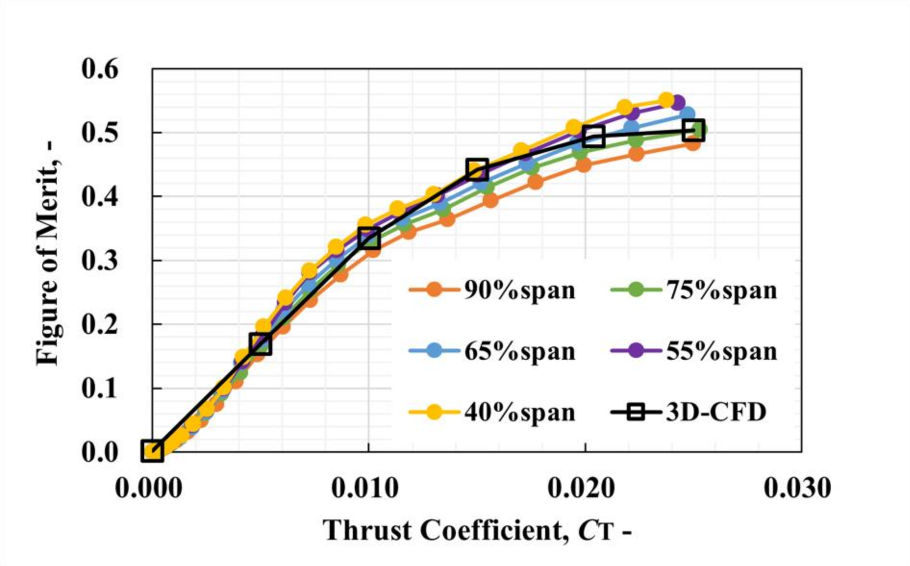

Fig. 1: Relationship between representative airfoil section position, thrust coefficient (CT), and Figure of Merit (FOM).

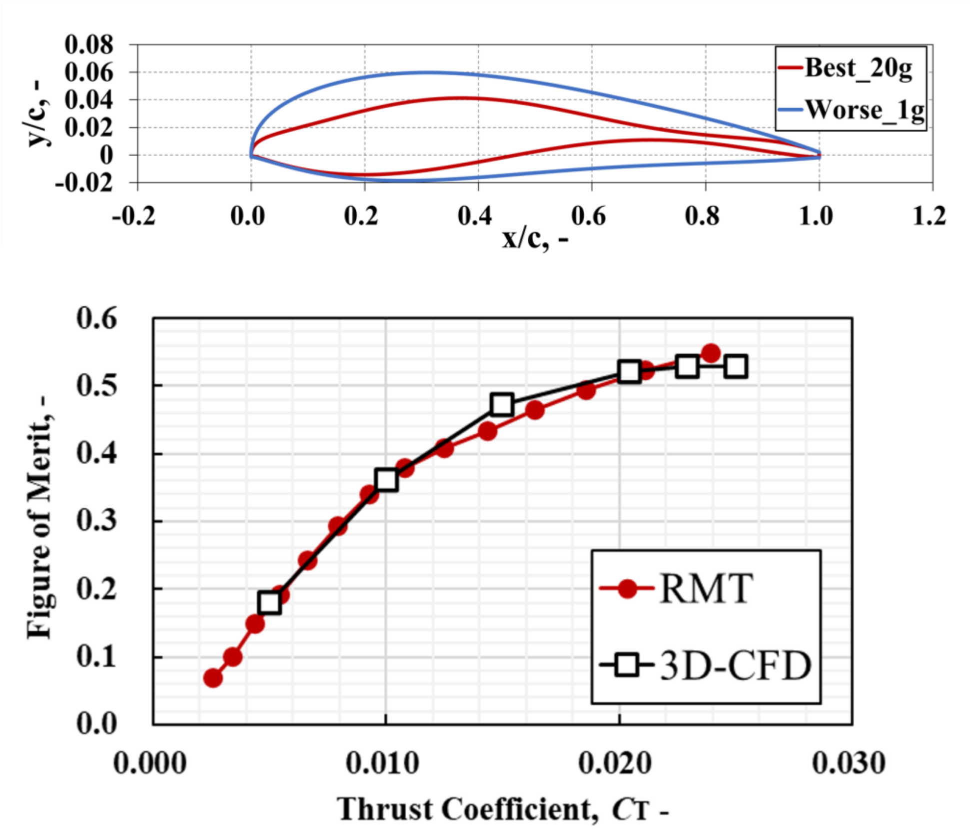

Fig. 2: Comparison between the blade airfoil section obtained as the optimal solution and high-fidelity CFD.

Publications

- Oral Presentations

Kikuchi, D., and Kanazaki, M., "Improvement of RMT and Optimization of Blade Section Shapes for Mars Exploration Drones," Space Sciences and Technology Conference, Kumamoto, Nov., 2022.

Usage of JSS

- **Computational Information**

Process Parallelization Methods	MPI
Thread Parallelization Methods	OpenMP
Number of Processes	32
Elapsed Time per Case	2 Hour(s)

- **JSS3 Resources Used**

Fraction of Usage in Total Resources*1(%): 0.02

Details

Computational Resources		
System Name	CPU Resources Used (core x hours)	Fraction of Usage*2(%)
TOKI-SORA	287,624.51	0.01
TOKI-ST	89,345.16	0.09
TOKI-GP	0.00	0.00
TOKI-XM	0.00	0.00
TOKI-LM	0.00	0.00
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	296.67	0.27
/data and /data2	12,392.33	0.10
/ssd	353.33	0.05

Archiver Resources		
Archiver Name	Storage Used (TiB)	Fraction of Usage[*2] (%)
J-SPACE	2.02	0.01

[*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)	22.36	0.02

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