Low-cost rotary wing design applied to design optimization of roter blade for Mars helicopter

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Abstract

In this study, we devised rotor blades using thin corrugated airfoils as a concept for storing Mars exploration helicopters in sizes and shapes suitable for rocket transport. Numerical calculations and optimal design were conducted from the perspectives of aerodynamics and propulsion. The optimal design involved evaluations based on two-dimensional airfoil assessments using momentum theory and global exploration using Bayesian optimization, resulting in superior airfoils compared to NASA's Mars helicopter. The optimal design results were verified using three-dimensional CFD with overset grids, and basic evaluations of structural feasibility were also conducted, confirming the solution's promise.

Reasons and benefits of using JAXA Supercomputer System

In this study, we conducted an optimal design using global optimization. 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

Based on the results of the previous year's study, this research conducted airfoil optimization using the Tree-structured Parzen Estimator, a type of Bayesian optimization. As a result, we obtained a corrugated airfoil with better aerodynamic performance than the initial airfoil and the airfoil used in NASA's Mars helicopter, which was used as a comparison benchmark. This airfoil was applied to a rotor blade and evaluated using CFD with overset grids (Figure 1), revealing that the corrugated structure is useful for suppressing flow separation.

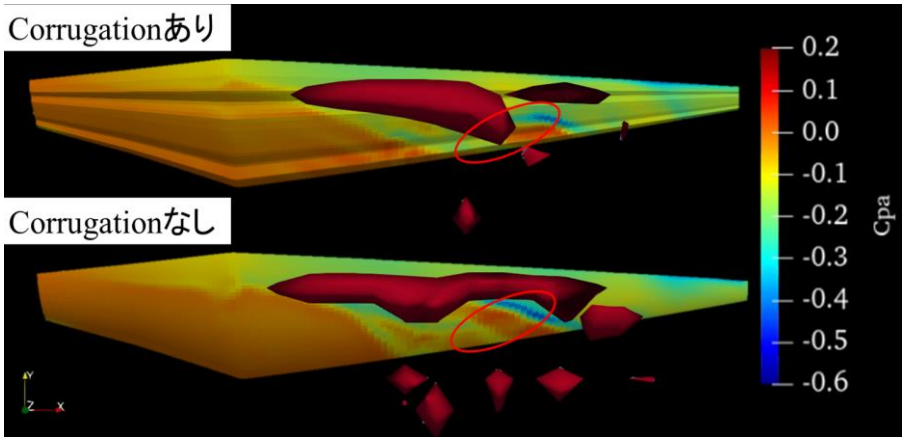

Fig. 1: Numerical result by means of CFD for the blade of a rotary wing with the corrugated airfoil.

- **Publications**

  N/A

- **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](%): 0.14

Details

Computational Resources		
System Name	CPU Resources Used (core x hours)	Fraction of Usage[*2](%)
TOKI-SORA	3,229,461.33	0.15
TOKI-ST	191,407.37	0.20
TOKI-GP	0.00	0.00
TOKI-XM	0.00	0.00
TOKI-LM	4,069.43	0.29
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	0.00	0.00
/data and /data2	2,535.00	0.01
/ssd	0.00	0.00

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)	608.62	0.42

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