Numerical analysis for optimal design of helicopter rotor blades

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Abstract

A cooperative study of rotor blade optimization methods is being conducted by JAXA, DLR, and ONERA to validate rotor blade analysis tools and optimization methods, and to accumulate knowledge. In this fiscal year, optimization of the blade shape considering the trade-off between hovering and forward flight performances was conducted. In preparation for the low-noise optimization to be conducted in the next fiscal year, simulations of baseline blade considering elastic deformation was performed and a reasonable deformation profile was obtained. In optimization, the performance of the obtained design solution must be evaluated accurately, and performance evaluation by CFD analysis is important.

Reasons and benefits of using JAXA Supercomputer System

In CFD-based optimization, a large number of cases with several design variables need to be performed in the CFD analysis, and the use of a supercomputer is essential; DLR/ONERA is conducting a similar HPC-based optimization, and comparison and study using results obtained using a supercomputer is appropriate.

Achievements of the Year

A common rotor blade optimization problem was set up among the three organizations (JAXA-DLR-ONERA), and CFD was used to optimize the shape of the rotor blades. In addition, elastic deformation analysis related to noise performance optimization was conducted, which will be carried out in the following years.

Figure 1 illustrates the lift distribution on the rotor surface of the optimal blade under forward flight conditions. During forward flight, the rotor blades are subjected to asymmetric flow fields on the advancing and retreating sides. The optimized rotor blades share a large lift at the front (180deg) and aft(0deg) of the rotor.

Figure 2 illustrates the tip vortices generated by the blades during forward flight with the helicopter shaft tilted backward and forward. The positional relationship between the blade and vortices changes with the shaft angle,

and a greater or lesser blade-vortex mutual interference appears.

Figure 3 shows an overview of the elastic deformation analysis. A coupled analysis of blade flap-lead/lag-twist deformation and aerodynamics is performed. It can be seen that the blade exhibits complex deformation due to the asymmetric flow field on the advancing and retreating sides, as well as the operation at different pitch angles for each azimuth.

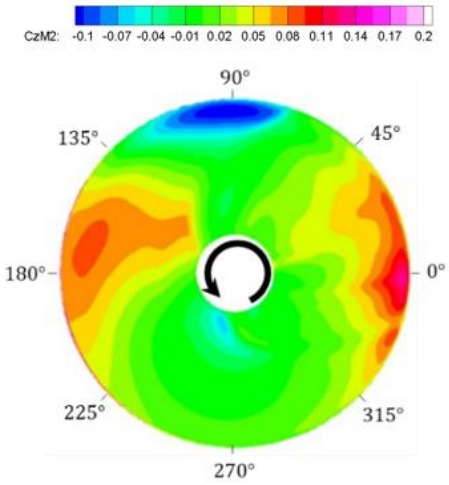

Fig. 1: Lift force distribution on rotor surface (CzM2)

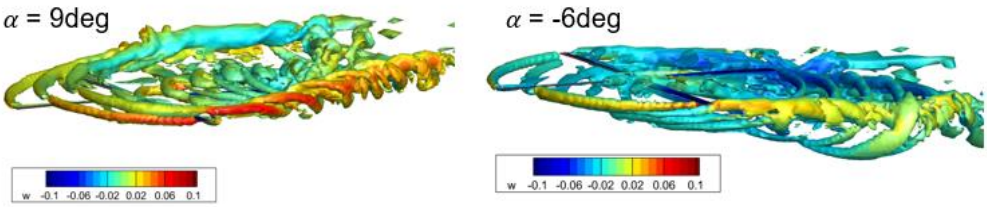

Fig. 2: Visualization of flow field around rotor during forward flight (alpha: shaft angle)

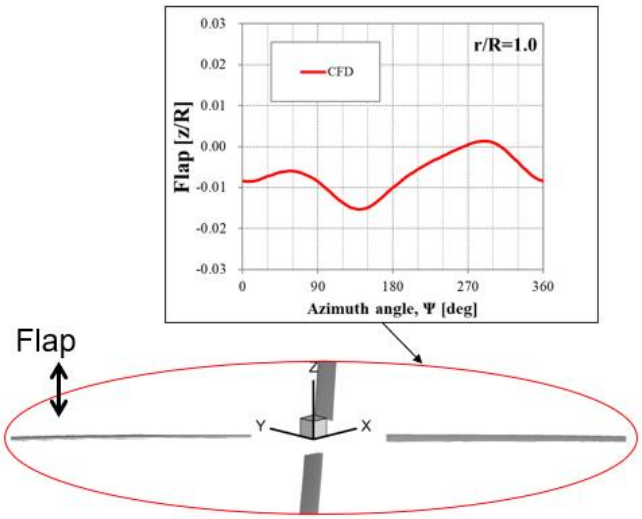

Fig. 3: Schematic of elastic deformation analysis of blades

Publications

- Peer-reviewed papers

Wilke, G., Bailly, J., Kimura, K., and Tanabe, Y., "JAXA-ONERA-DLR Cooperation: Results from Rotor Optimization in Hover", CEAS Aeronautical Journal, Vol. 13, pp. 313-333, April 2022

- Oral Presentations

Kimura, K., Wilke, G., Bailly, J., and Tanabe, Y., "JAXA-ONERA-DLR Cooperation: Results from Rotor Optimization in Forward Flight", 48th European Rotorcraft Forum, Winterthur, Switzerland, September 2022

Usage of JSS

Computational Information

Process Parallelization Methods	N/A
Thread Parallelization Methods	OpenMP
Number of Processes	1
Elapsed Time per Case	200 Hour(s)

- **JSS3 Resources Used**

Fraction of Usage in Total Resources[*1](%): 0.07

Details

Computational Resources		
System Name	CPU Resources Used (core x hours)	Fraction of Usage[*2](%)
TOKI-SORA	450,956.15	0.02
TOKI-ST	379,894.87	0.38
TOKI-GP	0.00	0.00
TOKI-XM	0.00	0.00
TOKI-LM	0.00	0.00
TOKI-TST	48,049.66	1.27
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	101.66	0.09
/data and /data2	13,466.11	0.10
/ssd	654.15	0.09

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)	0.00	0.00

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