Optimal design of propellers for compound helicopters

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Responsible Representative

Kanako Yasue, Aviation Technology Directorate, team leader, Aircraft Life-cycle Innovation Hub, Airmobility Digital Design Team

Contact Information

Keita Kimura(kimura.keita@jaxa.jp)

Members

Fumihiro Kajiwara, Keita Kimura, Masahiko Sugiura, Hideaki Sugawara, Ryo Takahashi, Yasutada Tanabe

Abstract

The objective of this study is to implement the optimal design of side and tail propellers for JAXA's proposed compound helicopter. The shapes are optimized to meet the design target flight conditions, and performance evaluation is conducted in the process by CFD. The side propellers are designed to maintain hovering performance while satisfying the requirements of high-speed forward flight, and the tail propeller is designed to achieve twice the speed of a conventional helicopter. This fiscal year, we advanced our analysis based on Computational Fluid Dynamics (CFD) regarding the flow field around the designed propellers.

Reasons and benefits of using JAXA Supercomputer System

In the optimal design of propeller blades, it is necessary to conduct performance analysis of a large number of shapes within a set design variable space. In order to perform this concurrently, it is essential to utilize the computational power of a supercomputer.

Achievements of the Year

This fiscal year, we conducted visualization and analysis of the flow field as to side propeller operations, particularly focusing on the effects of interference with the main rotor. As an example, we introduce a case where CFD simulation has been carried out on the interference between the main rotor and side propeller during hovering condition.

Figure 1 illustrates the tip vortices of the main rotor and side propeller during hovering. In compound helicopters, the side propeller is positioned directly beneath the main rotor, so it is particularly affected by the downwash during hovering. The tip vortices generated by the side propeller can be seen moving diagonally downward from the propeller.

Figure 2 shows the vertical velocity distribution around the main rotor and side propeller during hovering. The color blue represents downward velocity, indicating a strong downwash from the main rotor. The rotating side propeller within the downwash introduces a swirl (rotational) component to the flow field, resulting in a complex flow pattern. In this state, the propeller experiences increased potential thrust due to the rotational speed of the blades and the downwash velocity acting on the blade elements.

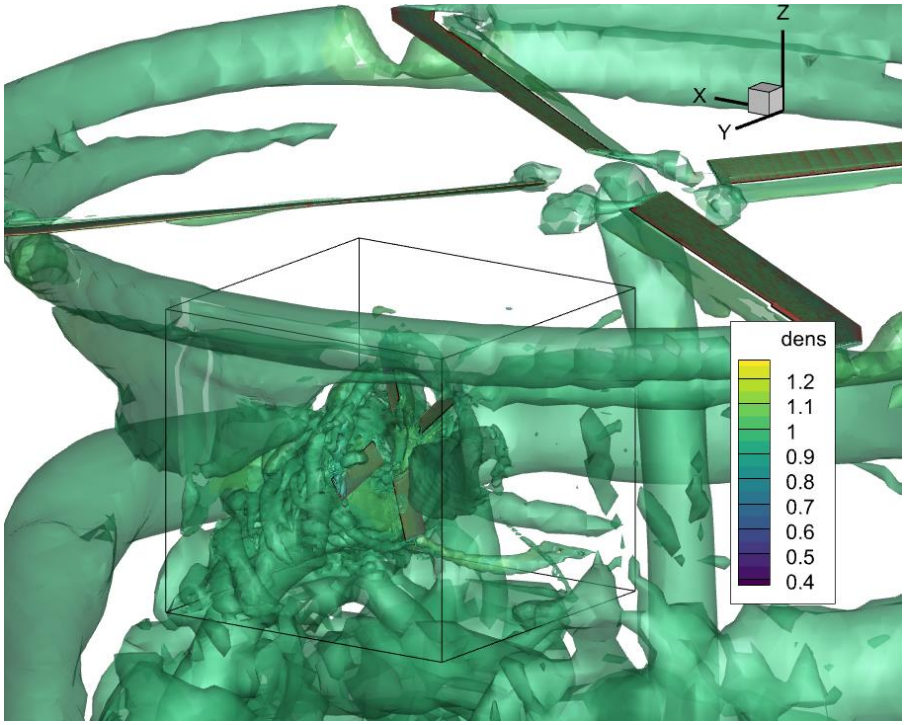

Fig. 1: Tip vortices visualization (Main rotor + side propeller, In hovering condition)

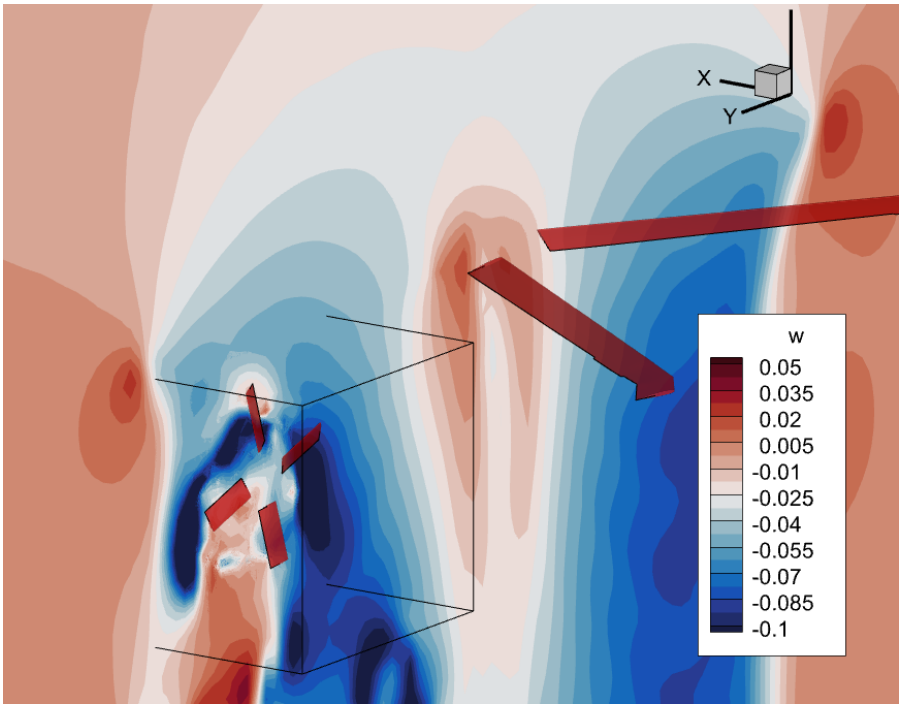

Fig. 2: Vertical velocity distribution (Main rotor + side propeller, In hovering condition)

Publications

- Peer-reviewed papers

K. Kimura, H. Sugawara., and Y. Tanabe, "Aerodynamic Interference between Main Rotor and Side Propellers of a Winged-type Compound Helicopter in Hover", TRANSACTIONS OF THE JAPAN SOCIETY FOR AERONAUTICAL AND SPACE SCIENCES, 66(5), 174-185.

- Oral Presentations

[1] K. Kimura, H. Sugawara, Y. Tanabe, "Wind Tunnel Testing of Propellers for a High-Speed Compound Helicopter," 61th Aircraft Symposium, 1B12, Kokura, Japan, 2023.

[2] K. Kimura, Y. Tanabe, H. Sugawara, "Optimal Design of Side Propellers for a Winged Compound Helicopter," 9th Asian/Australian Rotorcraft Forum, Nanjing, China, 2023.

Usage of JSS

Computational Information

Process Parallelization Methods	N/A
Thread Parallelization Methods	OpenMP
Number of Processes	1
Elapsed Time per Case	72 Hour(s)

JSS3 Resources Used

Fraction of Usage in Total Resources*1(%): 0.19

Details

Computational Resources		
System Name	CPU Resources Used (core x hours)	Fraction of Usage*2(%)
TOKI-SORA	672,254.71	0.03
TOKI-ST	1,313,051.14	1.42
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	1,282.32	1.06
/data and /data2	125,892.40	0.78
/ssd	31,306.95	2.96

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)	0.05	0.00

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