Research on Aerodynamics of Multiple Rotors

● **Responsible Representative**

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● **Abstract**

This research is aiming to clarify the complex flow fields around the multiple-rotor type drones and eVTOLs (electrically driven Vertical.Take-Off and Landing aircraft) through high-fidelity CFD simulations. The noise from the multiple rotors, the multiple rotors in ground effect, and the downwash from the rotors and the outwash on the ground are analysed so far.

Ref. URL: https://www.aero.jaxa.jp/eng/research/frontier/rotary/

● **Reasons and benefits of using JAXA Supercomputer System**

The flow fields around rotary wings are essentially unsteady and associate with blade deformation and pitch variations. Both temporal and spatial high-resolutions are generally required for the high-fidelity CFD simulations, which are computationally very costly. Utilization of high-end super-computing capabilities are a must requirement for this kind of research.

● **Achievements of the Year**

In FY2020, a quadrotor drone as shown in Fig. 1 hovering above a ground plane is studied. The flight performance of the drone in ground effect and the structure of the flow field are investigated. As a referrence, a single rotor hovering at a height of 0.5 rotor diameter is shown in Fig. 2 together the flow field represented by iso-surfaces of the Q-criterion. It can be seen that the downwash from the rotor flows along the ground plane and spread out evenly. For the quadrotor drone, as shown in Fig. 3, the structure of the flow field is complex. Flow recirculation is observed in the inner part of the drone, which indicates a bit of flight performance degradation could occur at this flight height. The flow on the ground is shown in Fig. 4. Along the plane crossing the rotor centers, the outwash resembles that of the single rotor. But along the central plane between the rotors, the outwash extends to a higher altitude, this may cause influences on the persons nearby.
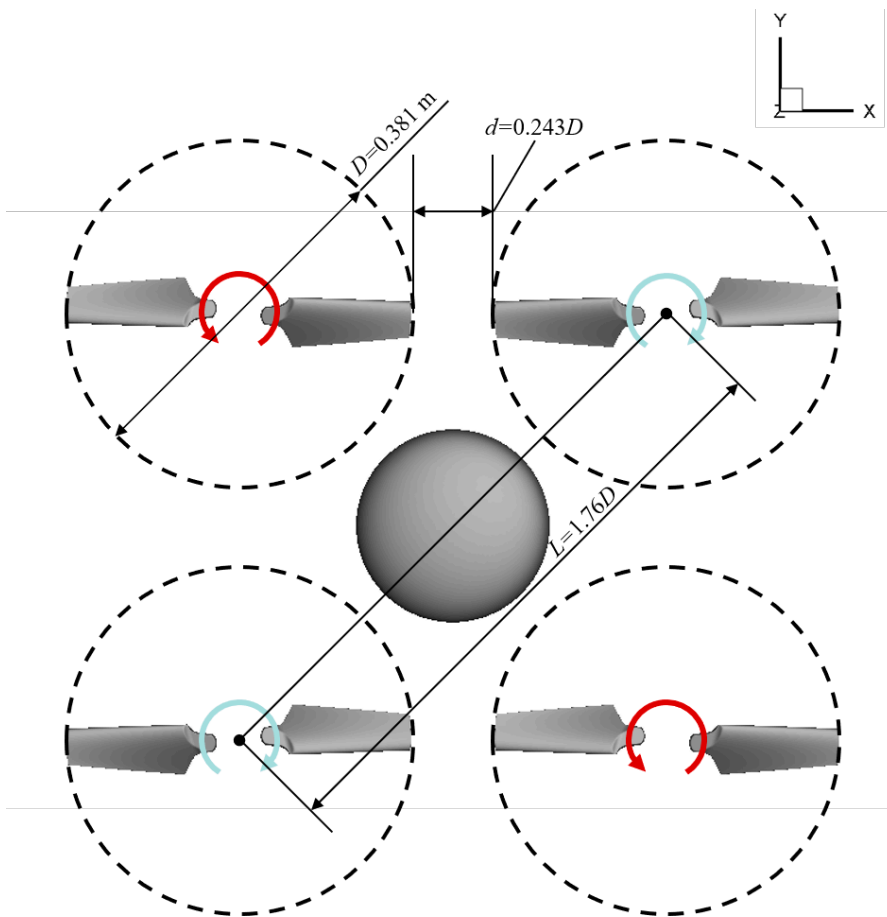
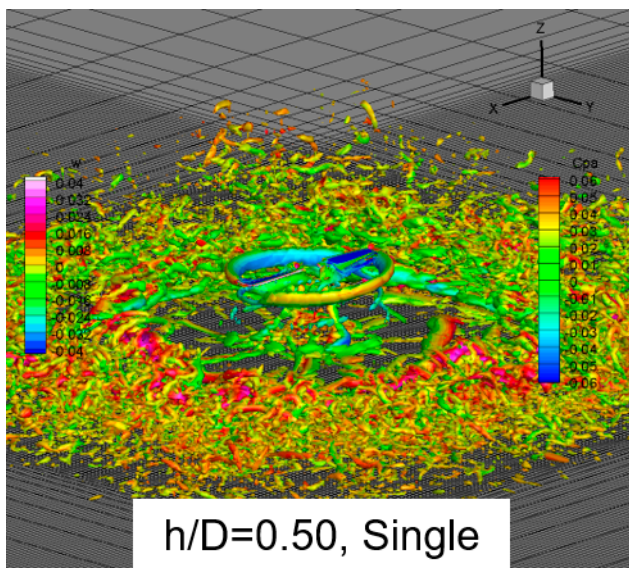Fig. 1: A variable-pitch-controlled quadrotor drone model

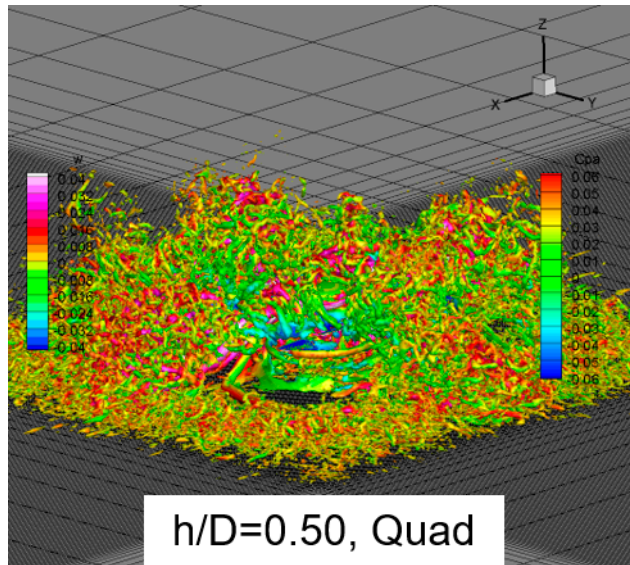Fig. 2: Flow field of a single rotor in ground effect

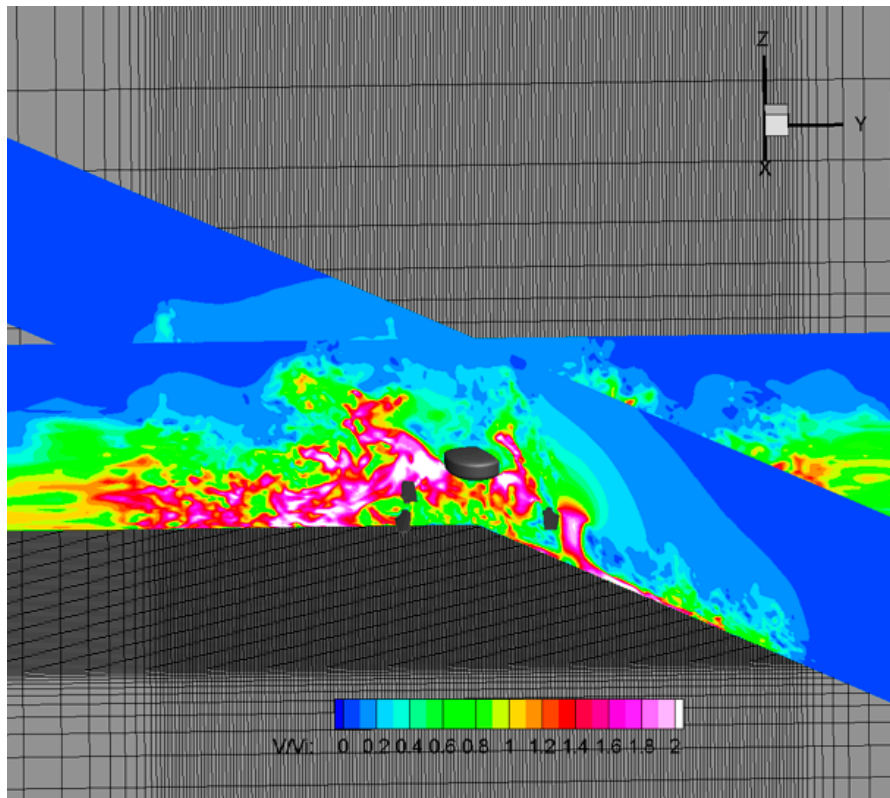Fig. 3: Flow field of the quadrotor drone in ground effect

Fig. 4: Sectional downwash and outwash of the quadrotor drone

● **Publications**

- Peer-reviewed papers

1) Yasutada Tanabe, Hideaki Sugawara, Shigeru Sunada, Koichi Yonezawa, Hiroshi Tokutake:Quadrotor Drone Hovering in Ground Effect, Journal of Robotics and Mechatronics, Vol. 33, No. 2, 2021.

- Non peer-reviewed papers

1) Yasutada Tanabe, Hideaki Sugawara, Shigeru Sunada, Hiroshi Tokutake, Koichi Yonezawa : Numerical Simulation of a Multicopter in Ground Effect, 58th Aircraft Symposium, Online, November 25-27, 2020.

● **Usage of JSS**

●   **Computational Information**

Process Parallelization Methods	N/A
Thread Parallelization Methods	OpenMP
Number of Processes	1
Elapsed Time per Case	2000 Hour(s)

●   **Resources Used(JSS2)**

Fraction of Usage in Total Resources[*1](%): 0.32

Details

Computational Resources		
System Name	Amount of Core Time (core x hours)	Fraction of Usage[*2](%)
SORA-MA	114,010.97	0.02
SORA-PP	248,096.23	1.94
SORA-LM	0.00	0.00
SORA-TPP	106,568.94	10.06

File System Resources		
File System Name	Storage Assigned (GiB)	Fraction of Usage[*2](%)
/home	3,553.26	3.26
/data	14,210.65	0.27
/ltmp	2,664.57	0.23

Archiver Resources		
Archiver Name	Storage Used (TiB)	Fraction of Usage[*2](%)
J-SPACE	6.24	0.21

[*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.

● **Resources Used(JSS3)**

Fraction of Usage in Total Resources[*1](%): 0.39

Details

Computational Resources		
System Name	Amount of Core Time (core x hours)	Fraction of Usage[*2](%)
TOKI-SORA	296,580.56	0.06
TOKI-RURI	499,531.47	2.86
TOKI-TRURI	19,187.89	1.55

File System Resources		
File System Name	Storage Assigned (GiB)	Fraction of Usage[*2](%)
/home	4,552.15	3.12
/data	19,505.65	0.33
/ssd	1,165.62	0.61

Archiver Resources		
Archiver Name	Storage Used (TiB)	Fraction of Usage[*2](%)
J-SPACE	6.24	0.21

[*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.