

## Research on dynamic attitude stability evaluation of high-speed flying objects using CFD

Report Number: R23EACA60

Subject Category: JSS Inter-University Research

URL: <https://www.jss.jaxa.jp/en/ar/e2023/23764/>

### ● Responsible Representative

Koji Miyaji, Professor, Yokohma National University

### ● Contact Information

Koji Miyaji(miyaji@ynu.ac.jp)

### ● Members

Koji Miyaji, Hiromi Yahata

### ● Abstract

Using Computational Fluid Dynamics (CFD), this study aims to evaluate the static and dynamic attitude stability of high-speed flying objects. In particular, our analysis focuses on the High-Mach Integrated Control experiment (HIMICO), which is being jointly developed by multiple universities with JAXA. We will utilize both a generic time-marching method for unsteady flows and a computationally efficient time-spectral method for periodic unsteady flows to compare their computational accuracies. In attitude and trajectory calculations, we aim to improve the accuracy of trajectory prediction and attitude control by quantitatively determining dynamic stability coefficients, which have often been evaluated using simplified methods in the past.

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

For steady and unsteady Computational Fluid Dynamics (CFD) aerodynamic analysis around high-speed flying objects with complex shapes, a supercomputer capable of high-speed calculations is necessary. In JSS3, not only self-developed codes but also execution of analysis tools provided by JAXA are possible.

### ● Achievements of the Year

(Figure 1) illustrates the body configuration and computational overview. The flight Mach number is set to 5 at a mean angle of attack  $\alpha_M=0$ , and a forced pitch oscillation with an amplitude  $\alpha_0=1$  [deg] is applied about the center of gravity. The dimensionless angular frequency, normalized by the airflow velocity and semi-wingspan, is set to 0.025 (corresponding to a real frequency of 34.4 [Hz]). The CFD computational grid is generated using JAXA's HexaGrid with approximately 7.6 million grid points.

Considering the motion equation of rigid body pitch oscillation, the damping component is derived from the component of the pitching moment history shifted by 90 [deg.] in phase from the reference forced oscillation. This yields the dynamic stability coefficient (pitch-damping sum). In the CFD calculations using a second-order time-

marching method, the results for time steps of  $\Delta t=10$  (approximately  $1/930$  of the forced oscillation period) and  $\Delta t=5$  (approximately  $1/1860$  of the same period) are compared. Furthermore, for the periodic solution using the time-spectral method, the results for truncation orders of Fourier modes (Num. Harmonics) 1 and 2 are compared.

(Figure 2) shows the comparison of the pitch-damping sum for these four cases. While the difference due to the mode order NH is small, a clear difference is observed due to  $\Delta t$ . The results for  $\Delta t=5$  and the time-spectral method are in good agreement, with the computational time for  $NH=1$  being less than  $1/5$ .

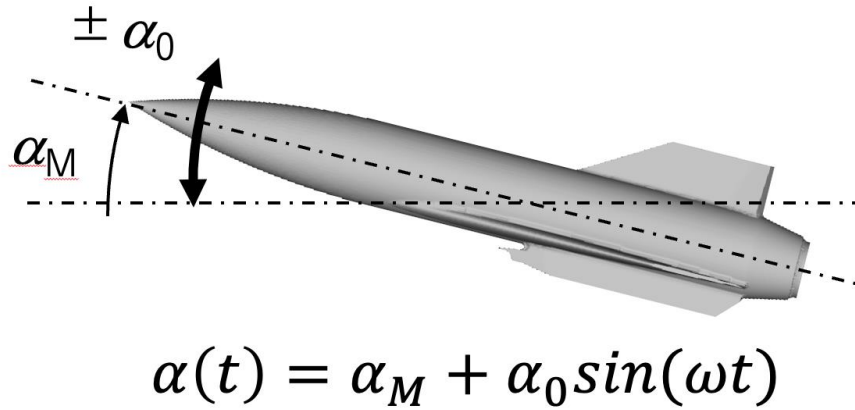


Fig. 1: Body configuration and computational overview

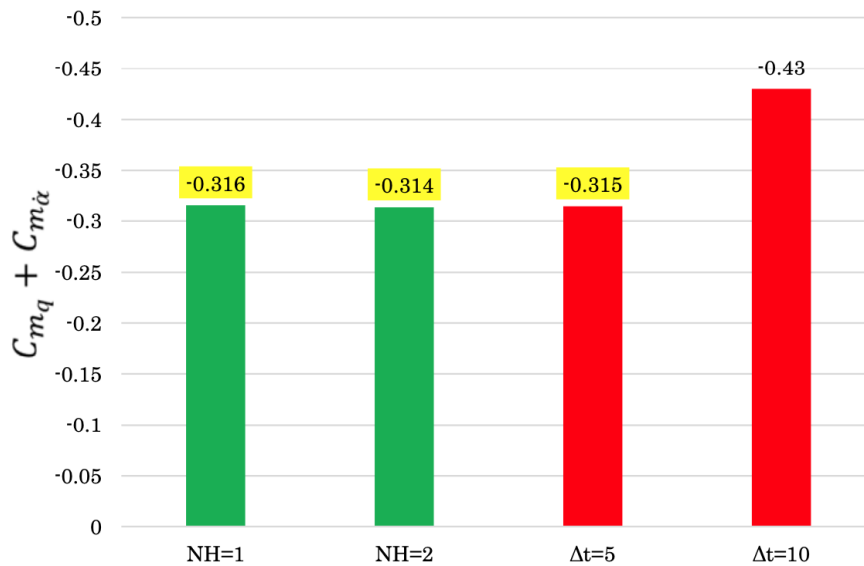


Fig. 2: Influence of mode number or time-step size on the pitch-damping sum

#### Publications

N/A

## ● Usage of JSS

### ● Computational Information

|                                 |           |
|---------------------------------|-----------|
| Process Parallelization Methods | MPI       |
| Thread Parallelization Methods  | N/A       |
| Number of Processes             | 192       |
| Elapsed Time per Case           | 4 Hour(s) |

### ● JSS3 Resources Used

Fraction of Usage in Total Resources\*1(%): 0.00

#### Details

| Computational Resources |                                      |                        |
|-------------------------|--------------------------------------|------------------------|
| System Name             | CPU Resources Used<br>(core x hours) | Fraction of Usage*2(%) |
| TOKI-SORA               | 6,382.99                             | 0.00                   |
| TOKI-ST                 | 795.41                               | 0.00                   |
| TOKI-GP                 | 0.00                                 | 0.00                   |
| TOKI-XM                 | 0.00                                 | 0.00                   |
| TOKI-LM                 | 0.62                                 | 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* <sup>2</sup> (%) |
| /home                 | 0.00                   | 0.00                                |
| /data and /data2      | 0.00                   | 0.00                                |
| /ssd                  | 0.00                   | 0.00                                |

| Archiver Resources |                    |                                     |
|--------------------|--------------------|-------------------------------------|
| Archiver Name      | Storage Used (TiB) | Fraction of Usage* <sup>2</sup> (%) |
| J-SPACE            | 0.00               | 0.00                                |

\*<sup>1</sup>: Fraction of Usage in Total Resources: Weighted average of three resource types (Computing, File System, and Archiver).

\*<sup>2</sup>: 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<br>(Hours) | Fraction of Usage* <sup>2</sup> (%) |
| ISV Software Licenses<br>(Total) | 0.00                                  | 0.00                                |

\*<sup>2</sup>: Fraction of Usage : Percentage of usage relative to each resource used in one year.