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# Dynamic Stability Analysis of Reentry Capsule with Detached-Eddy Simulation

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## Introduction

It is known that blunt-body re-entry vehicles tend to oscillate at transonic speeds. This dynamic instability is one of the big problems for development of re-entry vehicles[1]. In JAXA, the HTV-R (H-II Transfer Vehicle - Return) vehicle concept is studied[2]. To investigate dynamic instabliity of the HRV, the re-entry capsule of the HTV-R, we have conducted free rotation tests in a transonic wind tunnel[3] and free flight tests in a ballistic range.

In this study, CFD is implemented to understand the flow field and reveal mechanisms of the dynamic instability. By using a forced oscillation method, damping coefficients are computed. The computed coefficients are compared with that of experiments.

## Computational Conditions and Methods

CFD is implemented under the conditions where a large oscillation is observed in the wind tunnel test. The capsule diameter is 150 mm, and the corresponding Reynolds number is $2.4\times10^6$. Mach number is 1.1. The trimmed angle is 25.7° and the amplitude of the oscillation is 5.6°. The frequency is 17.4Hz. In this study, the model with a sting is also computed to assess the support interferences.

An unstructured-grid flow solver FaSTAR is used. This solver was validated for computations of aerodynamic derivatives for the standard dynamic model (SDM)[4]. FaSTAR solves the full Navier-Stokes equations using a cell-center finite volume method. The HLLEW method is used for the numerical flux computations. The spatial accuracy is second order with the U-MUSCL method. To compute the unsteady flow, we employ the dual time stepping method with the second-order backward difference. The LU-SGS implicit method is used for the time integration. As a turbulence model, the Spalart-Allmaras Detached Eddy Simulation (SA-SED) is employed. The whole grid is rotated to simulate the forced oscillation. The grid was generated with an automatic grid generator HexaGrid (Fig.1). The most cells are Cartesian grids, whereas the layer grids are generated near the body surface to resolve the turbulent boundary layer.

## Results

Figure 2 shows the instantaneous Mach number contours for the two cases with and without the sting. Generally, the flow is separated at the shoulder of the vehicle. However, the flow is attached on the upper side for the high angles of attack. This reattachment causes hysteresis loops of pitching moment as shown in Fig. 3. Figure 4 shows the calculated damping coefficients with and without the sting. The blue plots are the experimental data[3].

Here, the positive damping coefficients mean unstable. The CFD results agree well with the experiments. This instability is caused around the trimmed angle. In addition, the support interference is not so large under this condition.

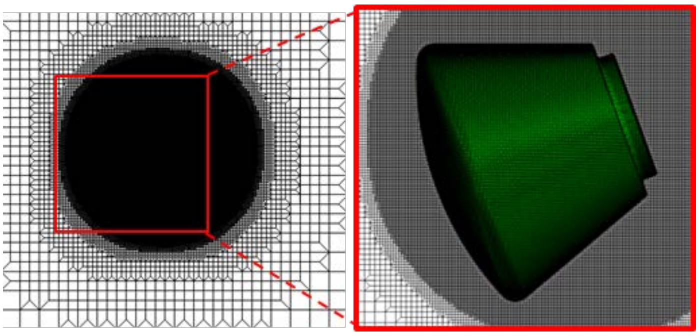
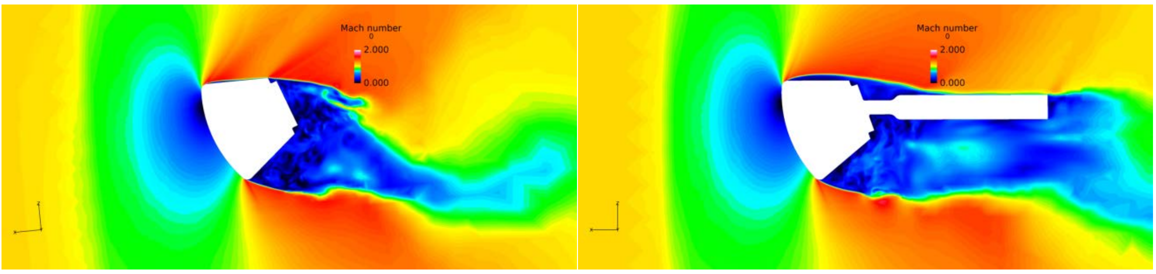


**Figure 1 Grid aroud the capusle**



**(a) Without sting** **(b) With Sting**

**Figure 2 Mach number contours**

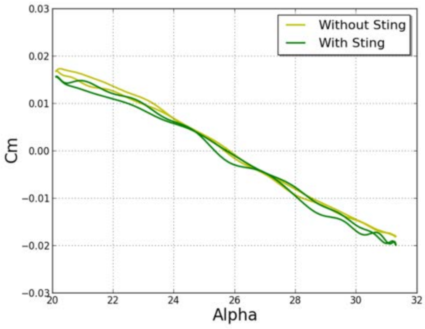


**Figure 3 $C_m$ history**

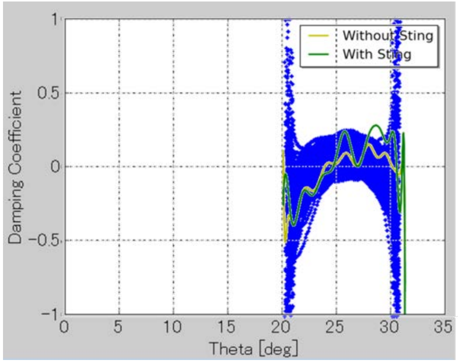


**Figure 4 Damping coefficient**

## REFERENCES

[1] C. D. Kazembla, et al., Survey of Blunt Body Dynamic Stability in Supersonic Flow, AIAA paper 2012-4509, 2012.

[2] Y. Suzuki, et al., Concept Study of HTV-R (HTV-Return), Proceedings of the 29th ISTS, 2013.

[3] S. Koga, et al., Dynamic Stability Testing of a Reentry Lifting Capsule in a Transonic Wind Tunnel, AIAA SciTech 2014 (to be published).

[4] A. Hashimoto, et al., Unsteady Analysis of Aerodynamic Derivatives on Standard Dynamics Model, AIAA paper 2013-0343, 2013.