Aerodynamic Design of Spaceplanes and Dynamic Stability of Re-entry Capsules

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Abstract

We will establish a model-based design methodology for spaceplanes, and devise measures to improve the stability of atmospheric re-entry capsules and deployable flexible aeroshells entering the Martian atmosphere based on the understanding of the dynamic stability phenomena.

Reasons and benefits of using JAXA Supercomputer System

To conduct CFD analysis of entire spaceplanes and dynamic stability analysis of the capsules.

Achievements of the Year

A forced-vibration aerodynamic analysis was conducted to investigate the cause of unanticipated oscillations observed in the Hayabusa 2 re-entry capsule at subsonic speeds. The study examined the stability characteristics by analyzing aerodynamic coefficients and flow field structures. Three methods—URANS, DES, and IDDES—were employed to capture unsteady aerodynamic behavior. The results revealed substantial differences between URANS and the more advanced DES and IDDES methods. To further evaluate the influence of geometry on dynamic stability, parametric variations were introduced to a deployable flexible aeroshell concept. These included modifications to the center of gravity location, flare angle, and tube diameter. The flow fields around the vibrating aeroshell were analyzed to assess corresponding changes in dynamic stability. Among the parameters investigated, tube diameter exhibited the most pronounced effect, suggesting its critical role in governing stability behavior.

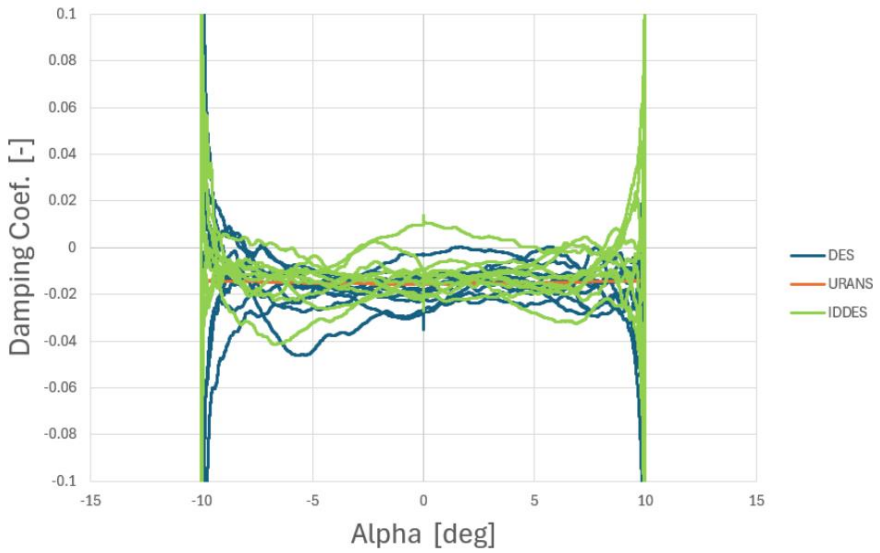

Fig. 1: A graph of the damping coefficient vs. angle of attack for each calculation method. All tend to be dynamically stable.

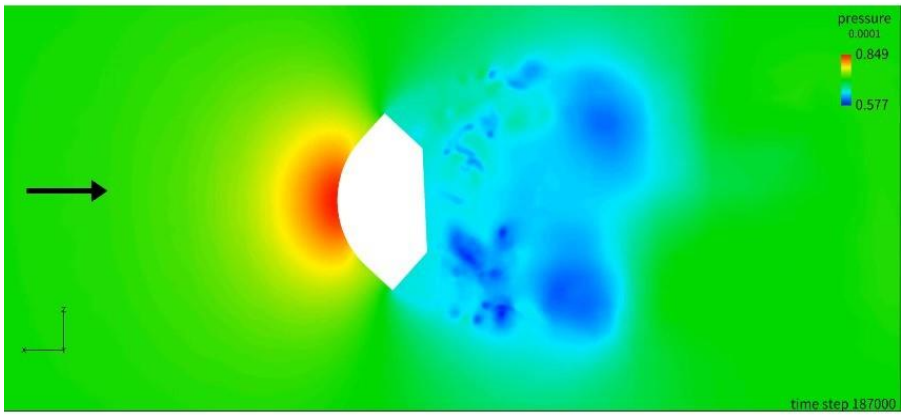

Fig. 2: Visualization of the pressure distribution in the flow field when IDDES is used as the calculation method. Smaller fluctuations are observed in the wake. (Video. Video is available on the web.)

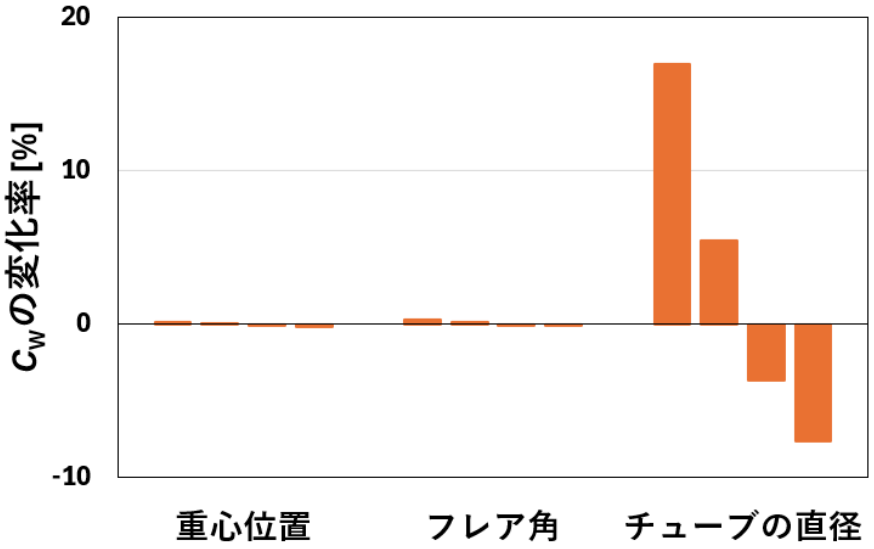

Fig. 3: The change in dynamic stability for each parameter was evaluated. It was found that changing the tube diameter has a large effect on dynamic stability.

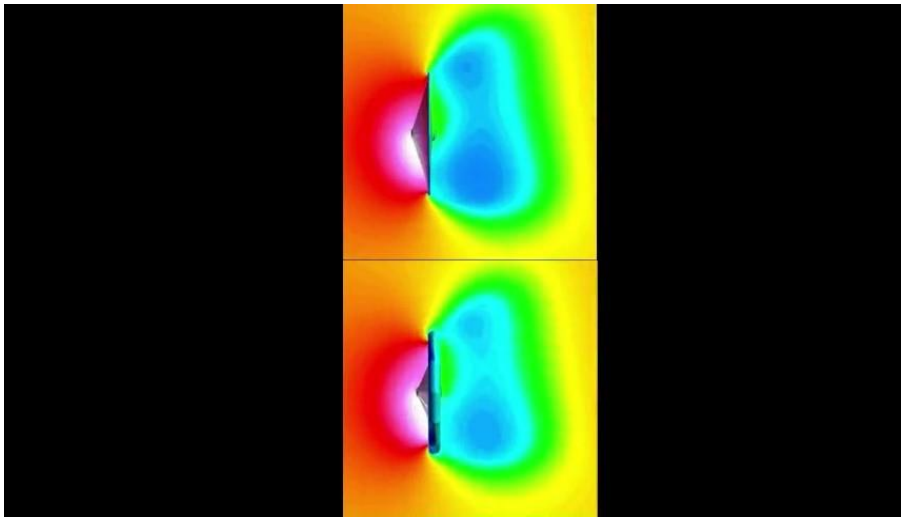

Fig. 4: An animation was created to visualize forced vibration for tube diameters of 60mm and 300mm, which showed the greatest difference in dynamic stability. It is observed that the magnitude of negative pressure differs in the wake region of the aeroshell. (Video. Video is available on the web.)

- **Publications**

  N/A

- **Usage of JSS**

- **Computational Information**

Process Parallelization Methods	MPI
Thread Parallelization Methods	OpenMP
Number of Processes	1024
Elapsed Time per Case	17 Hour(s)

- **JSS3 Resources Used**

Fraction of Usage in Total Resources[*1](%): 0.14

Details

Computational Resources		
System Name	CPU Resources Used (core x hours)	Fraction of Usage[*2](%)
TOKI-SORA	3,709,776.23	0.17
TOKI-ST	39,727.44	0.04
TOKI-GP	0.00	0.00
TOKI-XM	0.00	0.00
TOKI-LM	470.48	0.03
TOKI-TST	18.01	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	0.00	0.00
/data and /data2	61,240.00	0.29
/ssd	0.00	0.00

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)	603.26	0.41

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