Numerical Fluid Analysis of Supersonic Flying Vehicle

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Abstract

Supersonic parachutes, which are an effective means of deceleration for planetary exploration, and rockets, which are a means of space transportation, fly at supersonic speeds. The unsteady flow around the supersonic parachute and the protrusions on the rocket surface are factors that hinder the stable flight of supersonic vehicles. The effects of these factors on aerodynamic characteristics are not yet clear, and there is a limit to the knowledge that can be obtained from wind tunnel tests. Therefore, numerical analysis of supersonic parachutes and rockets with protrusions is performed to obtain aerodynamic data under supersonic velocity conditions.

Reasons and benefits of using JAXA Supercomputer System

In this research, it is necessary to accurately capture the complex flow field around supersonic parachutes of the DGB and DS types and the vortex around the projectile of a rocket with a projectile, and numerical calculations using a high-resolution computational grid require a large amount of cost. Therefore, a supercomputer capable of performing large-scale calculations in a short period of time is required.

Achievements of the Year

Aerodynamic Characteristics of Supersonic Parachutes

Numerical analysis was performed for two types of supersonic parachutes with opening area of the DGB and DS types shown in Fig.1, assuming a uniform flow Mach number of 2.0, to consider the effect of the angle of attack. As a result, it was found that when the canopy angle of attack is small, the DS type has a smaller drag coefficient variation than the DGB type, but the local pressure difference, as shown in Fig. 2, may cause damage.

Aerodynamic characteristics of a rocket with protuberance

One protuberance was attached to the downwind side of the forward part of the body, and the height and width of the protuberance were varied by 5% of the diameter of the body, respectively, for an elongated body with a slenderness ratio of 8.9, as shown in Fig. 3. The uniform flow Mach number was set to 1.5 and the angle of attack

to 15 deg.. Interesting results were obtained when only the width of the protuberance was varied, as shown in Fig. 3. It is clear that the vortex asymmetry does not change when the protuberance width is varied, nor does the side force.

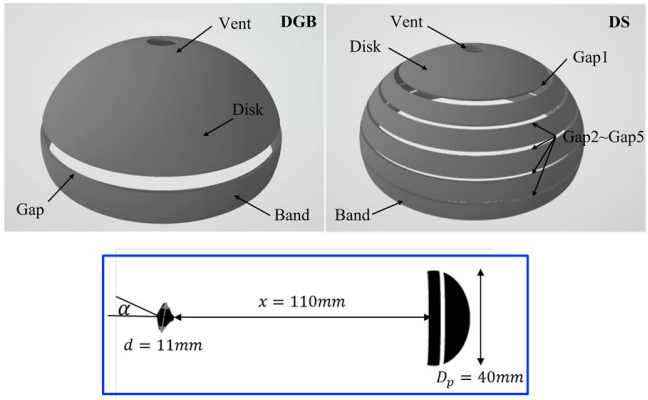

Fig. 1: Model for Analysis

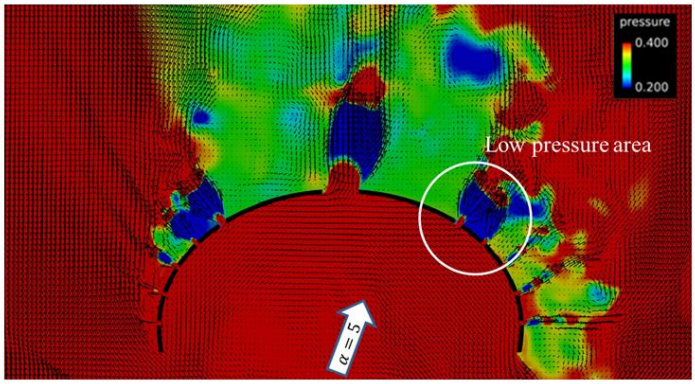

Fig. 2: Pressure

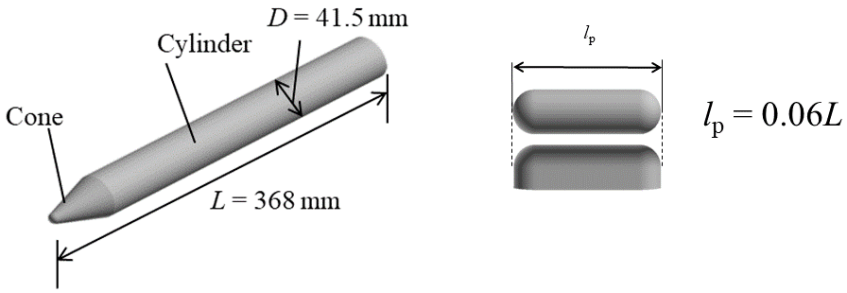

Fig. 3: Model for Analysis

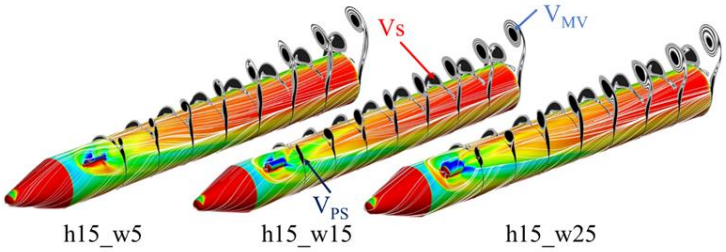

Fig. 4: Visualization of vortices

Publications

- Oral Presentations

1) Nimura,K., Tsutsui, F., Kitamura, K., and Nonaka, S,"Numerical Analysis on Effect of Surface Protuberance Sizes on Side Force of Supersonic Slender Body",54th Conference on Fluid Dynamics / 40th Symposium on Aerospace Numerical Simulation Technology (Aiina: Iwate Prefecture Information Exchange Center, Morioka City, June 29, 2022)

2) Nimura,K., Tsutsui, F., Kitamura, K., and Nonaka, S.: Aerodynamic Effects of Surface Protuberance Sizes on Slender-Bodied Supersonic Vehicle, AIAA-2023-0241, AIAA SciTech Forum 2023, National Harbor, MD & Online, Jan.2023

- Poster Presentations

1)Magara,M., Kitamura, K., :Numerical Flow Analysis on Pressure Fluctuations inside and outside Supersonic Parachutes with Different Canopy Configurations, 66th Space Science and Technology Conference, Novenber 1st-4th 2022.

Usage of JSS

Computational Information

Process Parallelization Methods	MPI
Thread Parallelization Methods	Automatic Parallelization
Number of Processes	512 - 2048
Elapsed Time per Case	72 Hour(s)

JSS3 Resources Used

Fraction of Usage in Total Resources[*1](%): 0.28

Details

Computational Resources		
System Name	CPU Resources Used (core x hours)	Fraction of Usage[*2](%)
TOKI-SORA	5,216,651.52	0.23
TOKI-ST	56,531.96	0.06
TOKI-GP	0.00	0.00
TOKI-XM	0.00	0.00
TOKI-LM	222,734.66	14.93
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	260.33	0.24
/data and /data2	40,980.00	0.32
/ssd	4,336.67	0.60

Archiver Resources		
Archiver Name	Storage Used (TiB)	Fraction of Usage*2 (%)
J-SPACE	24.89	0.11

*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)	4,306.61	3.00

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