

## Reynolds Number Effect on Transonic Aerodynamic Characteristics of Slender Body

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### ● Abstract

In order to obtain the drag value of a slender body such as rockets from a wind tunnel test, the drag correction considering cavity pressure and base pressure is typically required to remove the effect of a sting. At first in this study, the correcting method have been investigated by using the CFD results which successfully reproduced the wind tunnel test of a slender body. In addition, to obtain more practical slender body aerodynamic characteristics, the body size of the computational object was extended from the experimental scale ( $Re \approx 10^6$ ) to the actual flight scale ( $Re \approx 10^6$ ). Then, the difference in aerodynamic characteristics between the wind test scale and the actual flight scale is evaluated, and it contributes to the aerodynamic design of the actual space transport aircraft.

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

In this research, there were many calculation cases because we handled various shapes and angles of attack, and the number of grid points was very large because we required high-resolution results. For this reason, we needed to use the supercomputer.

### ● Achievements of the Year

First, regarding the cavity pressure correction, the cavity pressure was assumed to be the same as the uniform flow static pressure, and the forebody drag coefficient obtained from each of the wind tunnel test and CFD were compared. As a result, the accuracy was within 1 %. On the other hand, when the cavity pressure is assumed to be vacuum, this error is found to be as large as about 13 %. Thus, it was found that it is appropriate to assume that the cavity pressure is equivalent to the uniform flow static pressure even under the condition that a shock wave exists around the body. Regarding the base pressure correction, it was found that the error can be minimized by avoiding the local high pressure region (Figure 1) that appears on the upwind and leeward side. Figure 2 shows the results (drag coefficient) of the actual flight Reynolds number calculation at Mach 0.9 and an angle of attack of 0 degree. For comparison, the results of the wind tunnel test Reynolds number calculation are also shown here.

From this result, it is found that the viscous friction component of the forebody drag is 23 to 30% smaller in the case of the actual Reynolds number. However, since this value accounts for a small proportion of the total drag, it does not significantly affect the total drag. As a result, it is found that the error between the calculation of the actual flight Reynolds number and the wind test Reynolds number was relatively small (6 %).

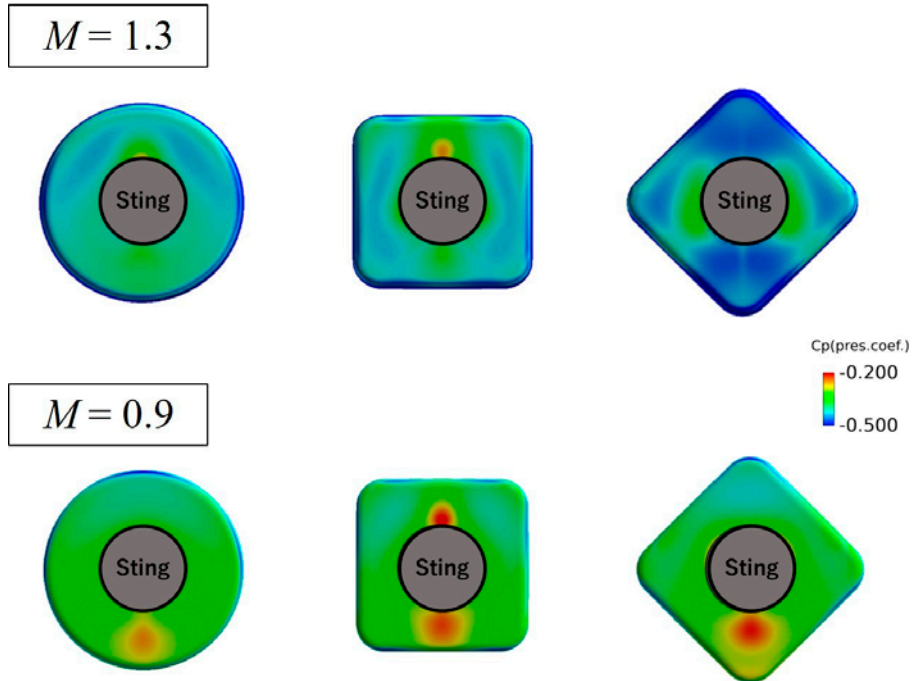


Fig. 1: Base pressure distribution of various shapes

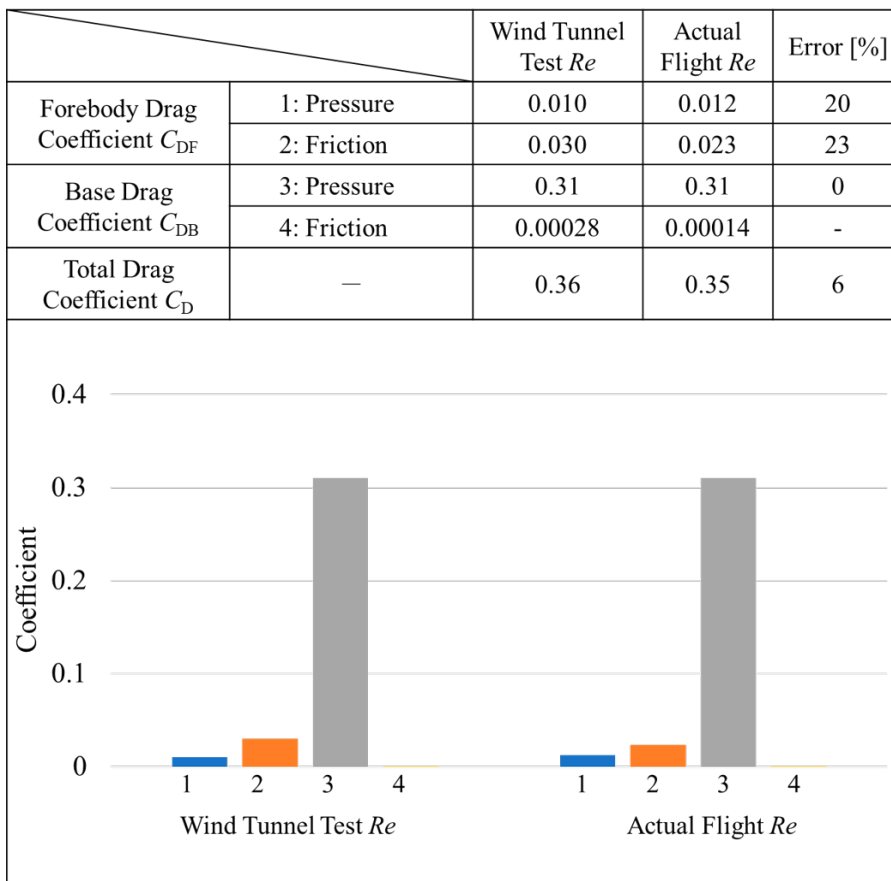


Fig. 2: Reynolds number effect ( $M = 0.9$ ,  $AoA = 0$  deg.)

● **Publications**

- Oral Presentations

1) Hayato Kawashima, Keiichi Kitamura, Satoshi Nonaka, "Drag Correction using Transonic Wind Tunnel Test and CFD Result -Effect of Base Pressure Measurement Position-", Dynamics Symposium of Space Navigation, Japan (Online), December,2020.

● **Usage of JSS**

● **Computational Information**

Process Parallelization Methods	MPI
Thread Parallelization Methods	N/A
Number of Processes	96 - 512
Elapsed Time per Case	10 Hour(s)

- **Resources Used(JSS2)**

Fraction of Usage in Total Resources<sup>\*1</sup>(%): 0.15

Details

Computational Resources		
System Name	Amount of Core Time (core x hours)	Fraction of Usage <sup>*2</sup> (%)
SORA-MA	685,553.65	0.13
SORA-PP	21,395.62	0.17
SORA-LM	1,585.70	0.93
SORA-TPP	0.00	0.00

File System Resources		
File System Name	Storage Assigned (GiB)	Fraction of Usage <sup>*2</sup> (%)
/home	6.68	0.01
/data	4,787.45	0.09
/ltmp	1,367.19	0.12

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.

- **Resources Used(JSS3)**

Fraction of Usage in Total Resources\*1(%): 0.01

Details

Computational Resources		
System Name	Amount of Core Time (core x hours)	Fraction of Usage*2(%)
TOKI-SORA	0.00	0.00
TOKI-RURI	4.91	0.00
TOKI-TRURI	0.00	0.00

File System Resources		
File System Name	Storage Assigned (GiB)	Fraction of Usage*2(%)
/home	478.74	0.33
/data	9,784.70	0.16
/ssd	114.44	0.06

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.