

The Effect of Protuberant Devices on Aerodynamic Characteristics of Slender Body Vehicle

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Subject Category: JSS2 Inter-University Research

URL: <https://www.jss.jaxa.jp/en/ar/e2018/9097/>

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● Abstract

It is important for rocket developments to quantitatively estimate the influence of protuberances in the flight vehicles which create asymmetry of flow around the vehicles and aerodynamic forces. Using fluid numerical computation, it is expected that we obtain a guideline for the protuberance choice in the future rocket development by conducting systematic and fundamental aerodynamic study on protuberance 1) positions and 2) sizes allowed to arbitrary flight vehicles.

Ref. URL: http://www.aero.ynu.ac.jp/index_en.html

● Reasons for using JSS2

This study needs expensive numerical fluid analyses around flight vehicles equipped with protuberances. Therefore, it is unrealistic that this scale of numerical calculations be carried out 100 times with workstations in the university, requiring 2.5 million grid points. Therefore, we use JSS2 in order to ensure larger memories and to save the cost of numerical calculations.

● Achievements of the Year

The figure shows the pressure coefficient distribution in the cross section at 80% of the total length of the body with the azimuthal angle of protuberance $\phi = 45 \text{ deg.}$, $\phi = 90 \text{ deg.}$, $\phi = 135 \text{ deg.}$ and no projection (No Pro.) At attack of angle (AoA) = 15 deg. The vertical axis is the dimensionless height ($z / (D/4)$) of the body, and the horizontal axis is the pressure coefficient C_p ($\phi = 180 \text{ deg.}$ is the windward side of the body). Focusing on the port side (solid line) of the body, differences due to the azimuthal angle of protuberance can be seen. This is considered to be due to the separation vortices generated on the protuberance side leaving the body. When the absolute value distribution of the vorticity in the body axis direction is visualized, it can be confirmed that the vortices on the port side are separated from the body as ϕ decreases. Therefore, the surface pressure was different between the port and the starboard, which contributed to the increase of the side force. In addition, as a result of

examining the side force at each azimuthal angle of protuberance $\phi = 25$ deg., it was found that the maximum value is at $\phi = 45$ deg., and the side force can be reduced when the protuberance is located upwind.

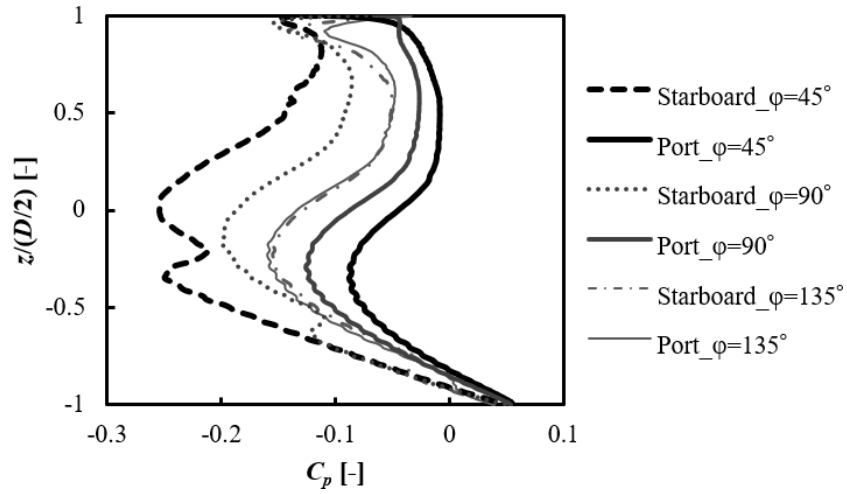


Fig. 1: C_p distributions surrounding a cross section at $x/L = 0.8$ and $AoA = 15$ deg. for each azimuthal angle (ϕ)

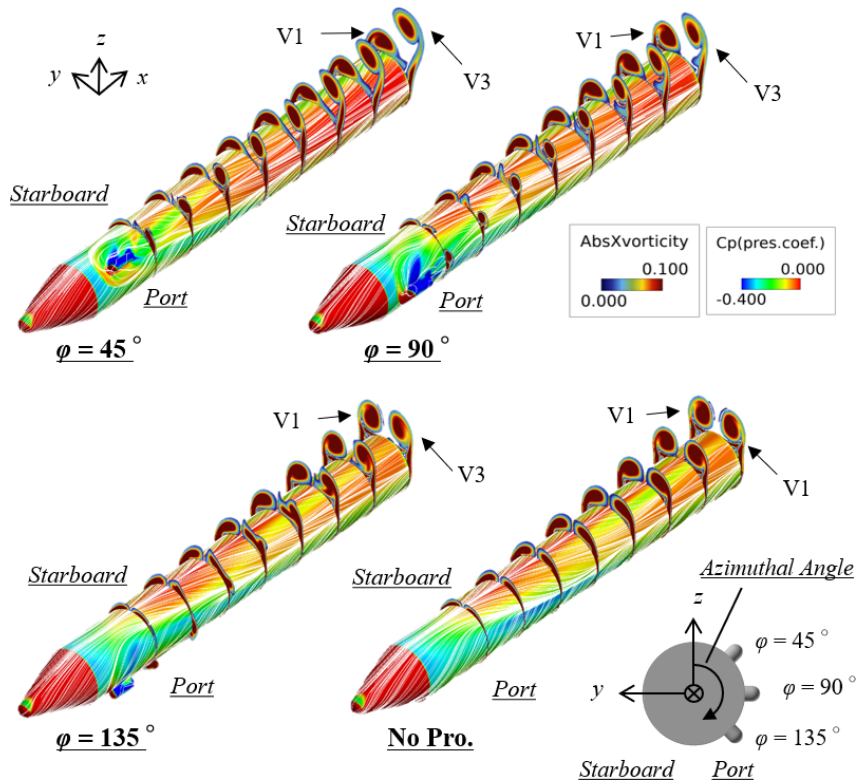


Fig. 2: 2D ($y-z$) planes colored with vorticity magnitude in each case: planes of $0.1 L$ interval from $0.3L$ to $1.0L$ with a C_p surface contour (perspective view) at $AoA = 15$ deg.

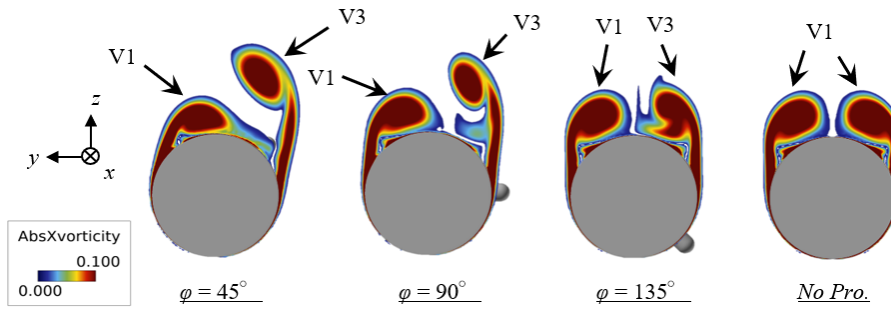


Fig. 3: 2D (y-z) planes colored with vorticity magnitude in each azimuthal angle (phy) case and No pro. case at AoA = 15 deg. at x/L = 0.8 plane

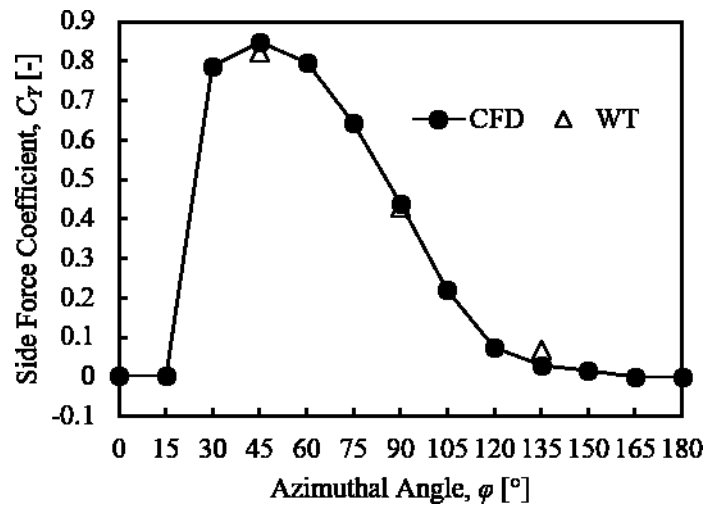


Fig. 4: Side force coefficient C_Y vs azimuthal angle (phy) by 15 deg. steps in Front case at AoA = 15 deg

● **Publications**

- Peer-reviewed papers

1) Kawauchi Kazuaki, Toshiaki Harada, Keiichi Kitamura, Satoshi Nonaka, “Experimental and Numerical Investigations of Slender Body Side Force with Asymmetric Protuberances,” Journal of Spacecraft and Rockets (Accepted).

2) Toshiaki Harada, Keiichi Kitamura, Satoshi Nonaka, “Roll Moment Characteristics of Supersonic Flight Vehicle Equipped with Asymmetric Protuberance,” The 31st ISTS Special Issue of Transaction of JSASS (Accepted).

- Non peer-reviewed papers

Toshiaki Harada, Kawauchi Kazuaki, Keiichi Kitamura, Satoshi Nonaka, “Side Force Characteristics of Supersonic Flight Vehicle Equipped with Asymmetric Protuberance,” AIAA Science and Technology Forum 2019, 2019-0299

- Oral Presentations

1. Kazuaki KAWAUCHI, Toshiaki HARADA, Keiichi KITAMURA, Satoshi NONAKA, “Experimental and Numerical Study of Side Force on Slender Body with Asymmetric Protuberance,” Symposium on Flight Mechanics and Astrodynamics
2. Kazuaki KAWAUCHI, Toshiaki HARADA, Keiichi KITAMURA, Satoshi NONAKA, “Wind Tunnel Experiment on Slender body Aerodynamics with Asymmetric Protuberance at Mach 1.5,” JSSUME2018 (15th Joint Symposium between Sister Universities in Mechanical Engineering)
3. Kazuaki KAWAUCHI, Toshiaki HARADA, Keiichi KITAMURA, Satoshi NONAKA, “Supersonic Wind Tunnel Tests on Aerodynamic Characteristics of Slender Body with Asymmetric Protuberance,” the 49th JSASS Annual Meeting

- Poster Presentations

Toshiaki Harada, Kazuaki Kawauchi, Keiichi Kitamura, Satoshi Nonaka, “CFD on Side Force Characteristic of Slender Flight Vehicle with Asymmetric Protuberance,” the 62nd Space Sciences and Technology Conference

● Usage of JSS2

● Computational Information

Process Parallelization Methods	MPI
Thread Parallelization Methods	N/A
Number of Processes	320
Elapsed Time per Case	8 Hour (s)

● Resources Used

Fraction of Usage in Total Resources*1 (%): 0.11

Details

Computational Resources		
System Name	Amount of Core Time (core x hours)	Fraction of Usage* ² (%)
SORA-MA	736,396.53	0.09
SORA-PP	29,040.50	0.23
SORA-LM	2,272.36	1.06
SORA-TPP	0.00	0.00

File System Resources		
File System Name	Storage Assigned (GiB)	Fraction of Usage* ² (%)
/home	16.21	0.02
/data	9,344.11	0.16
/ltmp	3,320.31	0.28

Archiver Resources		
Archiver Name	Storage Used (TiB)	Fraction of Usage* ² (%)
J-SPACE	4.75	0.17

*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.