Numerical fluid analysis of hypersonic aerodynamic heating during sacecraft re-entry.

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Abstract

The aim of this study is to simulate aerodynamic heating around a vehicle flying at hypersonic speeds in the atmosphere and to identify flight conditions and vehicle designs that help reduce heat flux to the surface.

The expected outcome is a reduction in convective heat flux during hypersonic flight for fully reusable spaceplanes and hypersonic air craft. As a result, this would reduce the weight of thermalprotection systems for high-speed vehicles, ultimately improving the feasibility in terms of overall system's weight.

Reasons and benefits of using JAXA Supercomputer System

Currently, for obtaining analytical values of the aerodynamic performance and thermal protection of upper-stage rockets and lifting bodies, extensive meshes for boundary layer resolution and high-precision calculation methods are computationally feasible using FaSTAR on the JAXA supercomputer.

Achievements of the Year

Before conducting a hypersonic thermal-aerodynamic analysis of a lifting-body reentry vehicle, this study focused on visualizing the flow field around the vehicle and estimating aerodynamic coefficients in the transonic regimes.

A steady-state RANS analysis was performed using JAXA analysis tool, FaSTAR with the SST-2003 turbulence model. Figure 1 presents the surface pressure coefficient distribution and streamlines. These show that the flow around the lifting-body vehicle is dominated by vortices.

Next, as illustrated in Figure 2, the cross-sectional shape of the strake, which generates vortices, was modified. The total pressure distribution at the side of the vehicle, shown in Figure 3, revealed distinct characteristics. It was observed that as the strake angle increased, the size of the vortices decreased.

Going forward, the study will explore not only the strake's cross-sectional shape but also the planform and overall body shape to further enhance vortex lift effectively. Additionally, future analyses will incorporate aerodynamic heating, which poses the most severe conditions for a reentry vehicle.

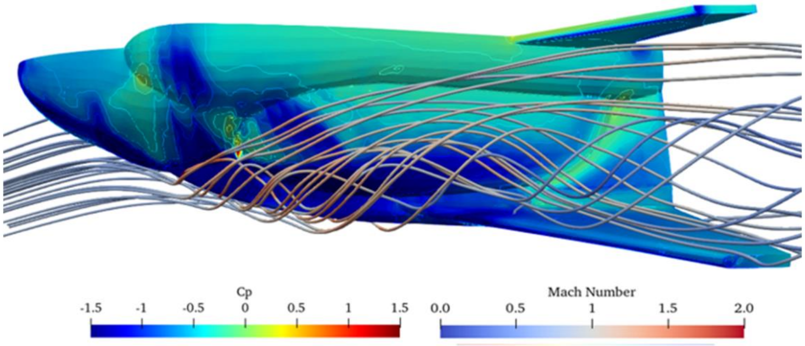

Fig. 1: Surface pressure distribution and streamlines at Mach 0.8, angle of attack 30 degrees.

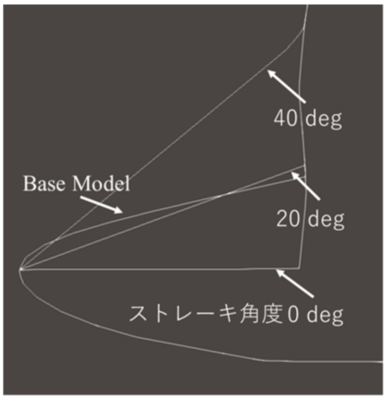

Fig. 2: Streamwise cross-sectional view of the modified strake shape.

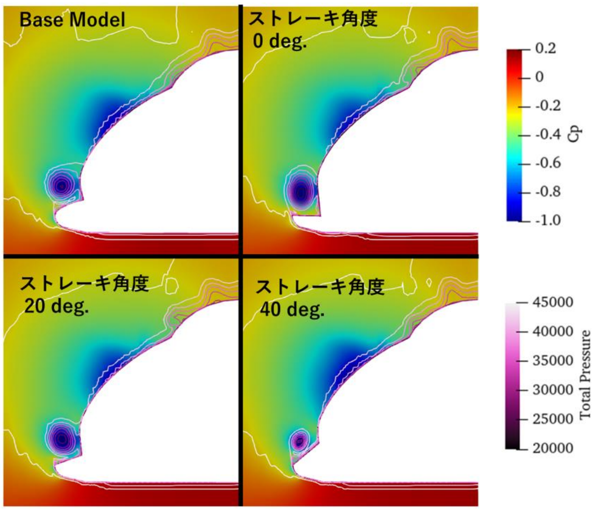

Fig. 3: Pressure distribution and total pressure distribution on cross-stream section at Mach 0.8, angle of attack 15 degrees.

Publications

- Oral Presentations

Kohei Koyama, Koyo Ando and Ko Ogasawara, "Analysis of Flow Separation and Vortex Lift on the Windward Side of a Lifting-Body Re-entry Vehicle in the Transonic Region.", 68th Space Sciences and Technology conference, 2024.

Usage of JSS

- **Computational Information**

Process Parallelization Methods	MPI
Thread Parallelization Methods	Automatic Parallelization
Number of Processes	100 - 240
Elapsed Time per Case	10 Hour(s)

- **JSS3 Resources Used**

Fraction of Usage in Total Resources[*1](%): 0.07

Details

Computational Resources		
System Name	CPU Resources Used (core x hours)	Fraction of Usage[*2](%)
TOKI-SORA	630,830.25	0.03
TOKI-ST	371,784.38	0.38
TOKI-GP	0.00	0.00
TOKI-XM	650.30	0.32
TOKI-LM	0.00	0.00
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	0.00	0.00
/data and /data2	0.00	0.00
/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)	0.00	0.00

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