Analyses of Hypersonic Flows around Capsules and Attitude Instability of Capsules

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Abstract

In this study, we try to enhance physical models for high temperature gas and numerical simulation method to accurately predict heating and aerodynamic characteristics at atmospheric entry. We aim to develop high fidelity simulation tool by demonstrating improvement of prediction accuracy by comparing experimental data and simulation results with the newly proposed model and method. In this year, we focus on the analysis of hypersonic flows inside a shock tube and around capsules in addition to attitude instability analysis for sample return capsules.

Reasons and benefits of using JAXA Supercomputer System

In order to evaluate uncertainties and dependence on nonequilibrium thermochemical models, configurations, and freestream conditions, supercomputer has been used to perform a large number of CFD runs by changing physical models, configurations, and flow conditions.

Achievements of the Year

In this study, qualitative evaluations of the rate coefficient for CO2 recombination reactions that occurs behind the Mars atmospheric entry capsule was conducted by comparing shock tube experiments and flow calculations using the JONATHAN code. In general, the backward rate coefficients of the chemical reactions are calculated from the detailed balance law, assuming chemical equilibrium. However, in environments where significant nonequilibrium is expected, such as capsule wake, there is no guarantee that the backward rate calculated from the detailed balance law is correct. Therefore, we attempeted to predict IR radiation intensity by experiment and calculation. For the experiment, IR radiation of a nonequilibrium flow created by a shock tube with the expansion nozzle(Fig.1), was measured. For the calculation, the intensity of IR radiation calculated using the JONATHAN code and SPRADIAN(Fig.2) were used. As a result, a difference was observed between the experimental and calculated intensity of IR radiation obtained in the downstream window in the nozzle(Fig.3). This suggests that the CO2 recombination reaction rate coefficient in the nonequilibrium environments may be larger than the value obtained by detailed balance law. We have also studied size dependence and Mach number dependence (M=0.8, 1.0, and 1.2) (Fig.4) of pitch motion of Hayabusa-type capsules using the JONATHAN-ALE code with Large-Eddy Simulation (LES).

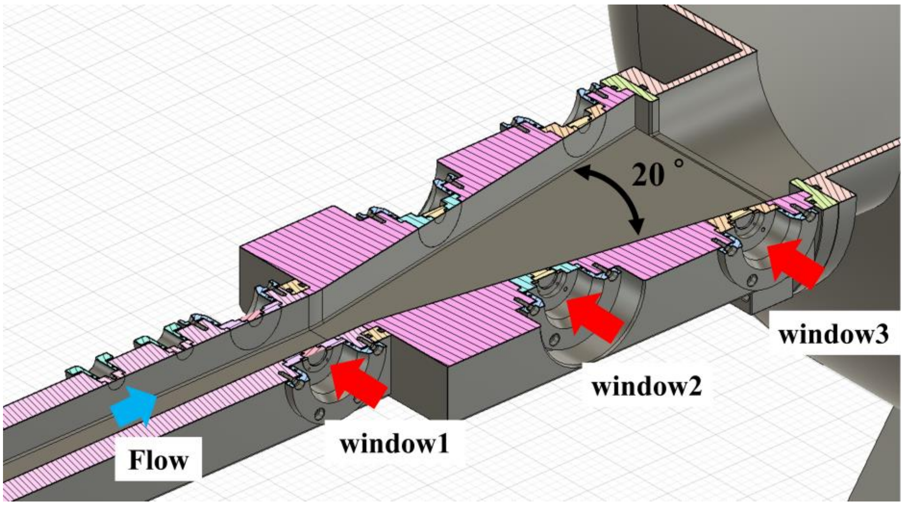

Fig. 1: The Shock Tube with expansion nozzle.

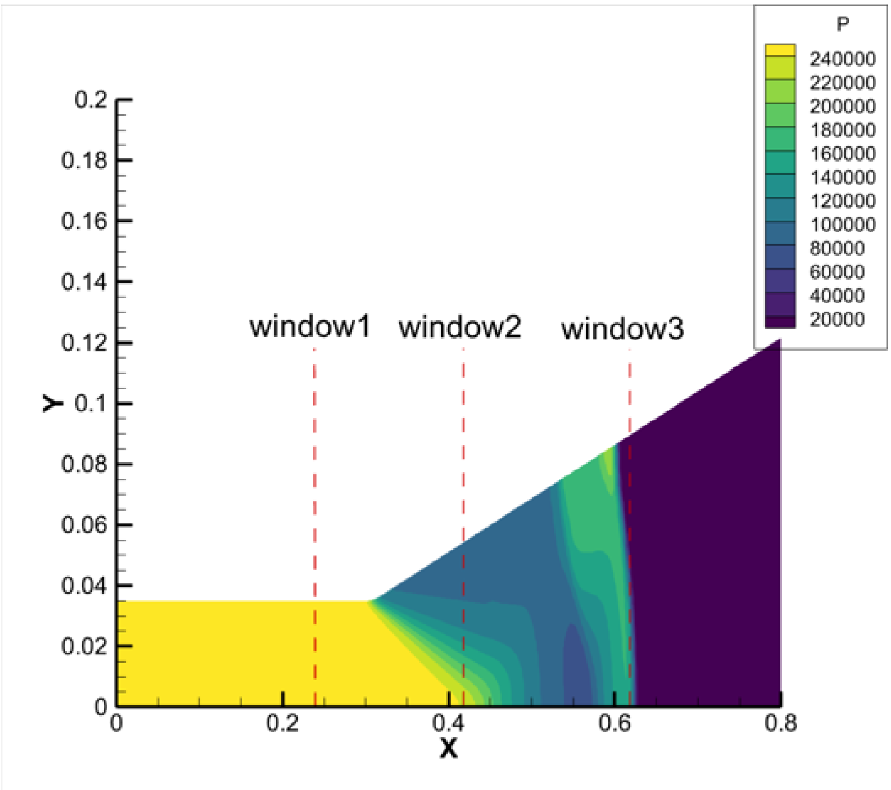

Fig. 2: A pressure contour diagram of shock wave flowing through expansion nozzle.

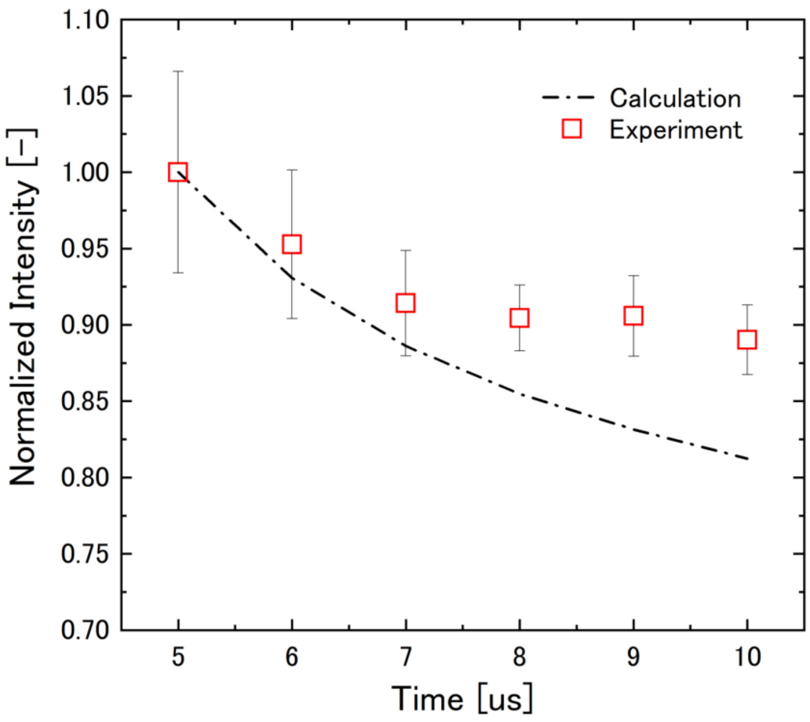

Fig. 3: Comparison of IR radiation intensity between experiments and calculations

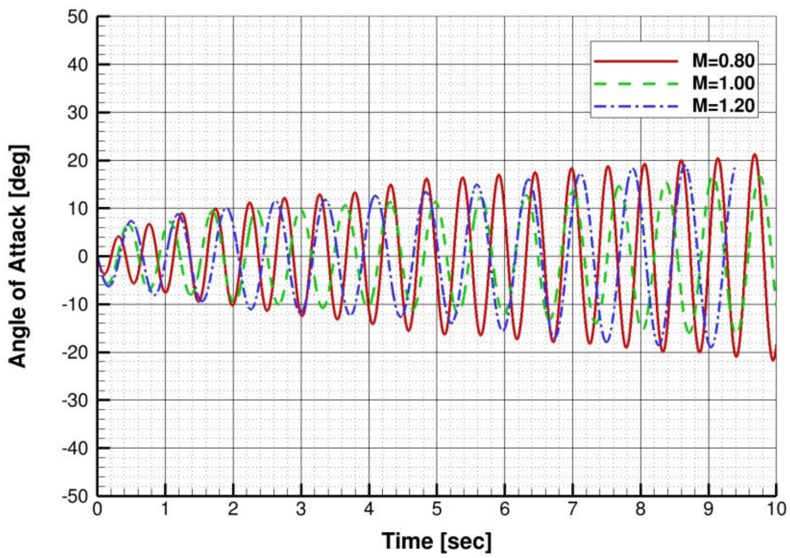

Fig. 4: Comparison of angle of attack history among M=0.8, 1.0 and 1.2 mm with a D=400mm hayabusa-type capsule

Publications

- Oral Presentations

The 34th International Symposium on Space Technology and Science

Proceedings of the Fluid Mechanics Conference:2023

Proceedings of the Space Sciences and Technology Conference: 2023

Symposium on Flight Mechanics and Astrodynamics: 2023

Usage of JSS

- **Computational Information**

Process Parallelization Methods	MPI
Thread Parallelization Methods	OpenMP
Number of Processes	366 - 2928
Elapsed Time per Case	24 Hour(s)

- **JSS3 Resources Used**

Fraction of Usage in Total Resources*1(%): 2.62

Details

Computational Resources		
System Name	CPU Resources Used (core x hours)	Fraction of Usage*2(%)
TOKI-SORA	71,350,306.03	3.22
TOKI-ST	0.00	0.00
TOKI-GP	0.00	0.00
TOKI-XM	0.00	0.00
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	163.33	0.14
/data and /data2	3,380.00	0.02
/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.