Study on calculation method for chemical reactions in turbulent combustion

Report Number: R19ETET25
Subject Category: Skills Acquisition System
URL: https://www.jss.jaxa.jp/en/ar/e2019/11641/

Responsible Representative

AOYAMA Takashi, Director, Aeronautical Technology Directorate, Numerical Simulation Research Unit

Contact Information

KOMATSU Yusuke(ksw.koma2@asagi.waseda.jp)

Members

KOMATSU Yusuke

Abstract

Japan Aerospace Exploration Agency (JAXA) has been promoting research and development to establish hypersonic aircrafts which can cruise at Mach 5. High-Mach Integrated Control Experiment (HIMICO), which is a flight experiment under hypersonic conditions using the S-520 sounding rocket, has been planned in the first stage. Up to the present time, the supersonic wind tunnel tests and the combustion tests of the engine have been conducted. Then, it has been confirmed that the fuel self-ignites under certain experimental conditions in the combustion tests. However, the quantitative evaluation of the self-ignition condition and the data necessary for the performance evaluation of the engine are insufficient. Therefore, CFD analysis is used to interpolate the experimental data and to clarify the condition for self-ignition of the fuel.

Reasons and benefits of using JAXA Supercomputer System

When numerical simulation including chemical reactions is performed on the actual combustor scale, the calculation cost becomes very large. Therefore, in order to perform numerical simulation within a reasonable time, we used JSS 2 which can parallelize.

Achievements of the Year

We developed a chemically reacting flow solver to elucidate the self-ignition phenomenon in the ram combustor for High-Mach Integrated Control Experiment and predict the self-ignition limit. Large-eddy simulations of the real scale combustor were performed using a detailed hydrogen-air reaction mechanism which consists of 9 species and 23 reactions. As a result, some of the mechanism of self-ignition, which had not been able to be clarified by test results, was clarified. For instance, self-ignition occurred in a lean, high-temperature region (Fig. 1), and the time to self-ignition had a strong correlation with the ignition delay time (Fig. 2). Although there is still a problem in predicting the self-ignition limit by numerical simulations, qualitative prediction is possible.

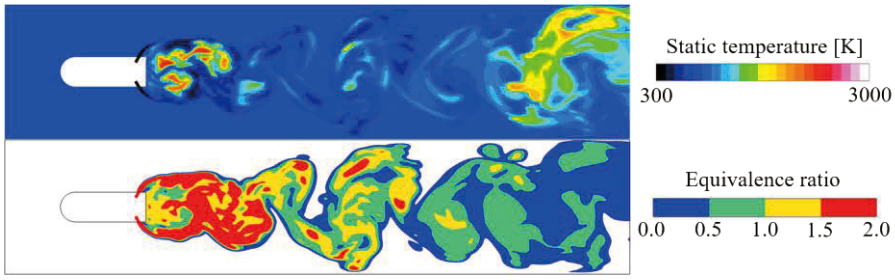

Fig. 1: Static temperature and equivalence ratio distribution

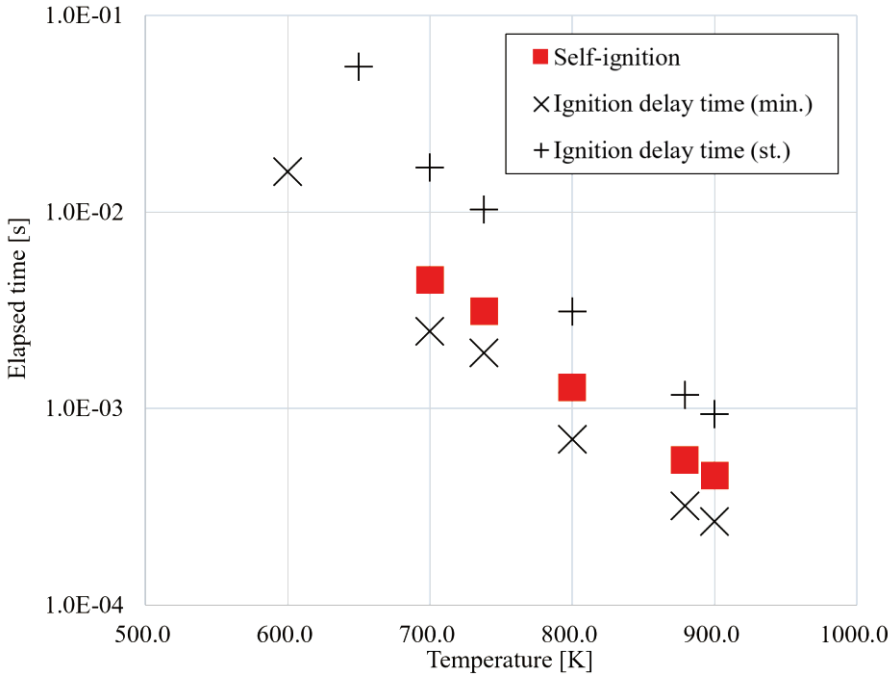

Fig. 2: Ignition delay time and time to self-ignition

Publications

- Oral Presentations

1) Komatsu, Y., Yamamoto, H., Sato, T., and Taguchi, H., Numerical Simulation of the Ram Combustor for High-Mach Integrated Control Experiment (HIMICO), 32nd International Symposium on Space Technology and Science, Fukui, Japan, 2019-a-33, Jun. 2019.

2) Komatsu, Y., Yamamoto, H., Sato, T., Mizobuchi, Y., Nambu, T. and Taguchi, H., Numerical Simulation of Self ignition in Ram Combustor for High Mach Integrated Control Experiment (HIMICO), 47th Annual Conference of GTSJ, C-20, Hakodate, Sep. 2019.

3) Komatsu, Y., Sato, T., Mizobuchi, Y., Nambu, T. and Taguchi, H., Numerical Simulation of Self-ignition with Detailed Chemical Kinetics in Ram Combustor for High Mach Integrated Control Experiment (HIMICO), Space Transportation Symposium FY2019, STCP-2019-021, Sagamihara, Jan. 2020.

Usage of JSS2

Computational Information

Process Parallelization Methods	MPI
Thread Parallelization Methods	N/A
Number of Processes	1024
Elapsed Time per Case	180 Hour(s)

Resources Used

Fraction of Usage in Total Resources[*1](%): 0.66

Details

Computational Resources		
System Name	Amount of Core Time (core x hours)	Fraction of Usage[*2](%)
SORA-MA	5,869,603.13	0.71
SORA-PP	19,863.22	0.13
SORA-LM	206.23	0.09
SORA-TPP	0.00	0.00

File System Resources		
File System Name	Storage Assigned (GiB)	Fraction of Usage*2(%)
/home	476.84	0.40
/data	9,765.63	0.17
/ltmp	1,953.13	0.17

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.