Study on combustion instability

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Abstract

In this study, LES analysis was carried out for Continuously Variable Resonant CoContinuously Variable (CVRC), and the contraction model which can predict the occurrence of vibration combustion was developed based on the obtained result, aiming at the prediction of vibration combustion.

Reasons and benefits of using JAXA Supercomputer System

LES analysis and analysis of the results require large computational resources.

Achievements of the Year

Liquid rocket engine combustion instability was studied using Large-Eddy Simulation with the aim of predicting the conditions for the onset of combustion oscillations in advance, using the Continuously Variable Resonance Combustor (CVRC), a widely researched simplified rocket engine combustor model. It was confirmed that adjusting the oxidizer inlet temperature could amplify or dampen the combustion oscillations of the first longitudinal mode (1L mode). For 10 cases with temperatures ranging from 700K to 1300K, phase averaging was applied to analyze pressure fluctuations, velocity fluctuations, and heat release rate fluctuations. In the range of 720K to 1200K, where pressure fluctuations were prominent, shock waves traveled within the oxidizer post and velocity disturbances were generated upon reaching the combustor inlet. These velocity disturbances promoted the mixing of fuel and oxidizer, resulting in localized heat release. In contrast, at 700K and 1300K, where pressure fluctuations were damped, the resulting velocity disturbances were small, so the mixing of fuel and oxidizer was not promoted and the heat release region extended downstream.

The periods for the propagation of traveling waves in the oxidizer post T_post and the reaction-related time (T_react) were evaluated with higher accuracy compared with previous studies, and their relationship with the period of the 1L mode T_comb was analyzed. In the range of 720K to 1200K, the sum of T_post and T_react almost coincided with T_comb, confirming the occurrence of self-excited oscillations. In contrast, at 700K and

1300K, T_comb < T_post + T_react, and a phase discrepancy was observed. Therefore, by modeling these three time scales, a simplified model capable of predicting combustion oscillations was demonstrated. Based on the results obtained, incorporation into a reduced-order model for predicting the onset of combustion instability based on the Matveev and Culick (Combust. Sci. Tech. 175(6) 2003) model is under consideration.

Publications

- Oral Presentations

Seiji Tsutsumi, Noriyasu Omata, Taro Shimizu, Masahito Akamine, and Junya Aono, "Numerical Analysis of Amplifying Longitudinal Combustion Instability in a Self-Excited Combustor," 19th International Conference on Numerical Combustion, 2024.

Masahito Akamine, Seiji Tsutsumi, Taro Shimizu, Noriyasu Omata, Junya Aono, "Application of Matveev-Culick Model to Combustion Instability in a Self-Excited Combustor," 19th International Conference on Numerical Combustion, 2024.

Usage of JSS

Computational Information

Process Parallelization Methods	MPI
Thread Parallelization Methods	N/A
Number of Processes	1600
Elapsed Time per Case	10 Hour(s)

JSS3 Resources Used

Fraction of Usage in Total Resources[*1](%): 0.00

Details

Computational Resources		
System Name	CPU Resources Used (core x hours)	Fraction of Usage[*2](%)
TOKI-SORA	0.00	0.00
TOKI-ST	662.66	0.00
TOKI-GP	0.00	0.00
TOKI-XM	0.00	0.00
TOKI-LM	0.00	0.00
TOKI-TST	2.73	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	75.35	0.05
/data and /data2	13,395.99	0.06
/ssd	51.33	0.00

Archiver Resources		
Archiver Name	Storage Used (TiB)	Fraction of Usage*2 (%)
J-SPACE	96.86	0.32

*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)	11.63	0.01

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