

Investigation on the structure of rotating detonation wave

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● Abstract

In this study, combustion analysis by large eddy simulation (Large-Eddy Simulation, LES) was carried out in order to clarify propagation characteristics and detailed structure of rotating detonation wave. Two-dimensional and three-dimensional simulations were carried out for stable operating conditions in the combustion test of the rotating detonation combustor conducted at the Kakuda Space Center from the equivalence ratio of 0.6 to 1.6 to reproduce the rotating detonation wave propagating in the combustor.

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● Reasons and benefits of using JAXA Supercomputer System

To perform a combustion LES considering more than 20 chemical species generated by the combustion of methane fuel is very expensive, so that it is impossible to carry out it on usual workstations. In addition, the use of a supercomputer is indispensable in order to execute a large number of parametric analyses for a plurality of injection conditions in a realistic computing time.

● Achievements of the Year

LES of non-premixed rotating detonation of CH₄ and O₂ was carried out assuming an annular combustor with 101 mm diameter. It was shown that the propagation velocity of the rotating detonation wave obtained by two dimensional (Fig. 1) and three dimensional (Fig. 2) LES with the equivalence ratio of 0.6 to 1.6 was about 70% against the Chapman-Jouguet velocity. The propagation velocity obtained by the simulation was slightly higher than that obtained by the combustion test, but the approximate tendency was successfully reproduced.

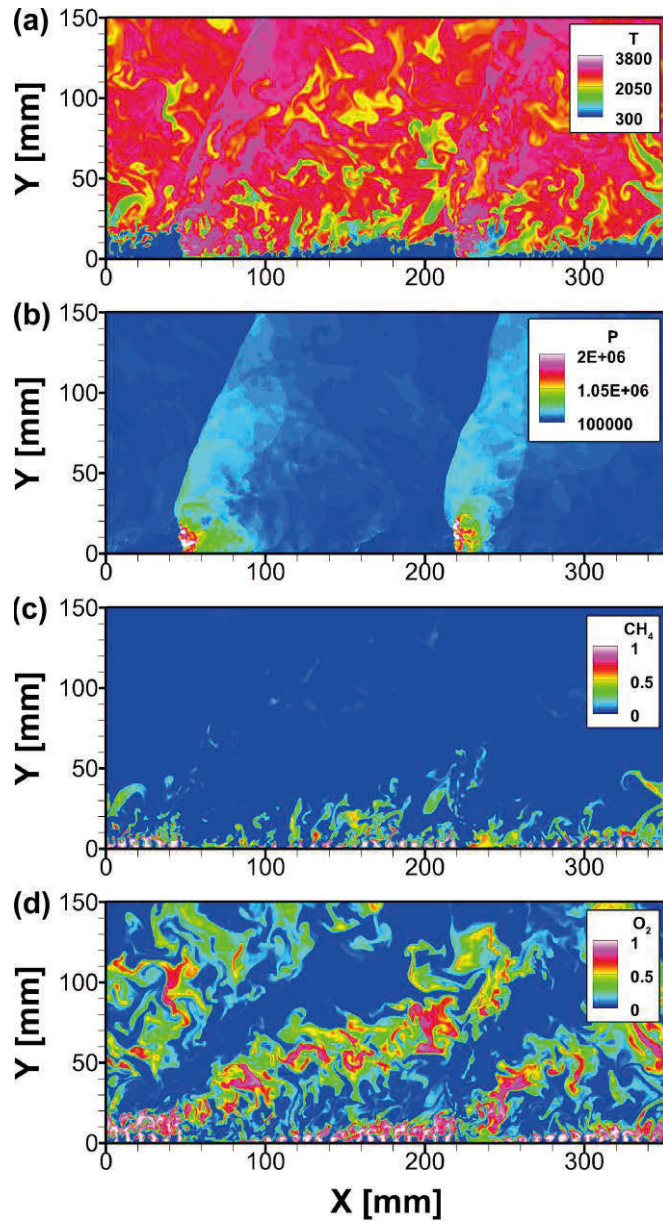


Fig. 1: Instantaneous contours of (a) temperature, (b) pressure, and mole fractions of (c) CH₄ and (d) O₂ by the two-dimensional LES at ER = 1.0.

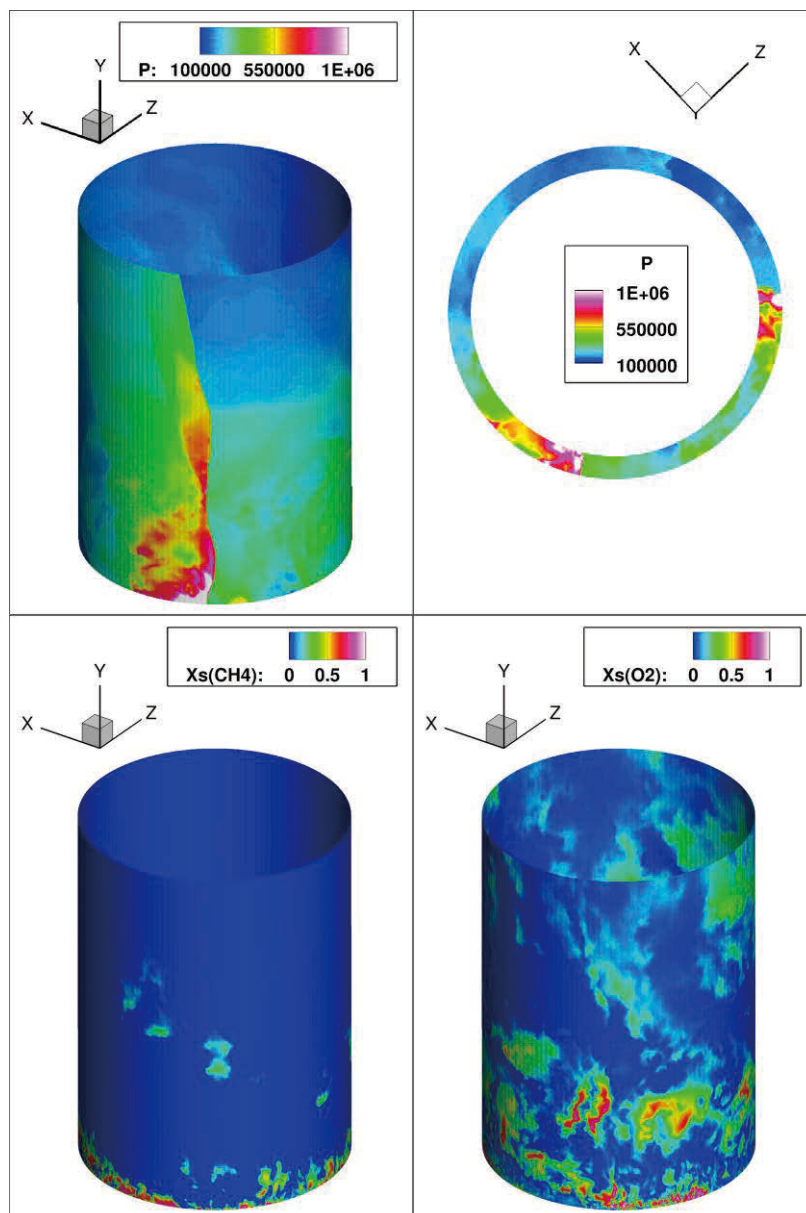


Fig. 2: Instantaneous contours of pressure (upper) and mole fractions of CH₄ and O₂ (lower) at $t = 1.0$ ms by the three-dimensional LES at $ER = 1.0$.

● Publications

- Non peer-reviewed papers

1) Shingo Matsuyama, Kazuya Iwata, Makoto Kojima, Yoshio Nunome, Hideyuki Tanno, Hideto Kawashima, and Toshiharu Mizukaki, "Combustion Simulation of Rotating Detonation with a Non-premixed CH₄/O₂ Injection", Proceedings of the 57th Symposium (Japanese) on Combustion, B215, 2019.

2) Shingo Matsuyama, Kazuya Iwata, Yoshio Nunome, Hideyuki Tanno, Toshiharu Mizukaki, Makoto Kojima, and Hideto Kawashima, "Large-Eddy Simulation of Rotating Detonation with a Non-premixed CH₄/O₂ Injection", AIAA Paper 2020-1174, 2020.

3) Shingo Matsuyama, Kazuya Iwata, Makoto Kojima, Yoshio Nunome, Hideyuki Tanno, Hideto Kawashima, and Toshiharu Mizukaki, "LES of Rotating Detonation with a Non-premixed CH₄/O₂ Injection", Proceedings of the Symposium on Shock Waves in Japan, 1C1-2, 2020.

4) Kazuya Iwata, Shingo Matsuyama, Makoto Kojima, Yoshio Nunome, Hideto Kawashima, Hideyuki Tanno, and Toshiharu Mizukaki, "Research Progress at JAXA on Fundamental Understanding of Wave Dynamics and Performance Evaluation of Rotating Detonation Rocket Engine", Journal of the Combustion Society of Japan, Vol.62 Issue 200, 2020.

- Oral Presentations

1) Shingo Matsuyama, Kazuya Iwata, Makoto Kojima, Yoshio Nunome, Hideyuki Tanno, Hideto Kawashima, and Toshiharu Mizukaki, "Combustion Simulation of Rotating Detonation with a Non-premixed CH₄/O₂ Injection", the 57th Symposium (Japanese) on Combustion, 2019.

2) Shingo Matsuyama, Kazuya Iwata, Yoshio Nunome, Hideyuki Tanno, Toshiharu Mizukaki, Makoto Kojima, and Hideto Kawashima, "Large-Eddy Simulation of Rotating Detonation with a Non-premixed CH₄/O₂ Injection", AIAA Scitech 2020 Forum, 2020.

● Usage of JSS2

● Computational Information

Process Parallelization Methods	MPI
Thread Parallelization Methods	OpenMP
Number of Processes	220 - 1920
Elapsed Time per Case	360 Hour(s)

- **Resources Used**

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

Details

Computational Resources		
System Name	Amount of Core Time (core x hours)	Fraction of Usage* ² (%)
SORA-MA	0.00	0.00
SORA-PP	2.49	0.00
SORA-LM	0.00	0.00
SORA-TPP	0.00	0.00

File System Resources		
File System Name	Storage Assigned (GiB)	Fraction of Usage* ² (%)
/home	342.25	0.29
/data	1,628.02	0.03
/tmp	279.02	0.02

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.