

## Development of combustor simulation system based on physics understanding and modelling.

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### ● Abstract

Development of simulation technology applicable to combustor design based on physics understanding and modelling by detailed and high-fidelity simulations.

### ● Reasons and benefits of using JAXA Supercomputer System

World-level research in this field requires massively parallel huge computational resource and only so-called supercomputer system can provide it.

### ● Achievements of the Year

In the AMM model, the turbulent kinetic energy increases proportional to the square of the mean strain so that the turbulent eddy viscosity tends to be overestimated in the region where the acceleration and deceleration of the mean flow are involved. In this context, we have modified the characteristic time scale in the turbulent eddy viscosity by introducing a parameter  $S^2\text{-}\Omega^2$ , representing the acceleration and deceleration of the mean flow. Figure 1 shows the prediction of the corner separation in the NASA Junction Flow with an attack of angle of 5.0 degrees, using the AMM-QCRcorner model (note that QCRcorner denotes a quadratic constitutive relation to reproduce the secondary flow near a corner). Indeed, the AMM-QCRcorner model with the corrected turbulent eddy viscosity expression improves the overprediction of the turbulent eddy viscosity in the trailing edge near a corner (see Fig. 1) where the size of the separation bubble agrees with the experimental data within a 10 percent difference. In particular, AMM-QCRcorner predicts the length for the corner

separation more accurately than SA-QCR2000, the latter model being widely used in aeronautics.

Using the large-scale analysis result of the droplet group evaporation by a detailed analysis solver for gas-liquid two-phase flow, the effect on evaporation rate by the mutual interference of droplets was modeled. The analysis solver was modified to include the combustion model, and combustion of multiple droplets was analyzed.

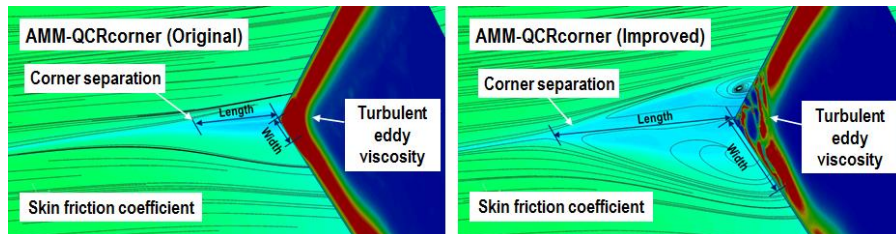


Fig. 1: Prediction for corner separation in the NASA Juncture flow using the AMM-QCRcorner model (contours of the skin friction coefficient and turbulent eddy viscosity).

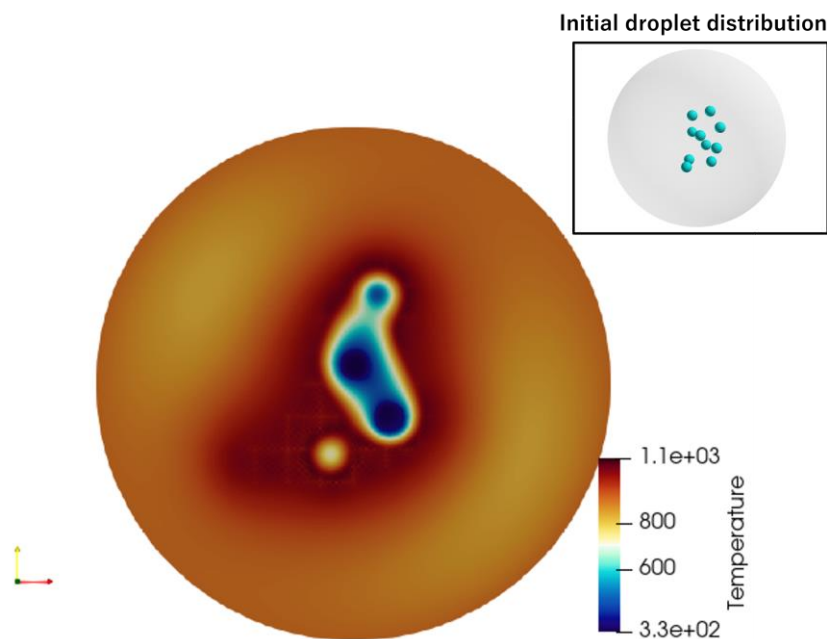


Fig. 2: Evaporation and combustion analysis with multiple droplets: temperature distribution.

## ● Publications

- Peer-reviewed papers

S. Shima, K. Nakamura, H. Gotoda, Y. Ohmichi, and S. Matsuyama, "Formation mechanism of high-frequency combustion oscillations in a model rocket engine combustor," *Physics of Fluids* 33, 064108 (2021).

Y. Mizobuchi, "Large deformation effects on the combustion structure of a hydrogen/air rich premixed flame," *Combustion and Flame* 239 (2022).

- Oral Presentations

Taisuke Nambu and Yasuhiro Mizobuchi, "Large-scale analysis of group droplet evaporation," 53rd Fluid Dynamics Conference / 39th Aerospace Numerical Simulation Symposium.

Hiroyuki Abe, Hirofumi Ohkawa, Yukimasa Konishi, Yasuhiro Mizobuchi, Naoyuki Fujita, Keiichi Murakami and Takashi Aoyama, "Establishment of turbulence DNS database at the JAXA Aeronautical Technology Directorate," 53rd Fluid Dynamics Conference / 39th Aerospace Numerical Simulation Symposium.

Hiroyuki Abe, "DNS analysis of a skewed turbulent boundary layer," Annual meeting of the Japan Society of Fluid Mechanics 2021.

Philippe, R. Spalart and Hiroyuki Abe, "Theory and modeling for Reynolds-number effects in wall-bounded turbulent flow," Annual meeting of the Japan Society of Fluid Mechanics 2021.

Taisuke Nambu and Yasuhiro Mizobuchi, "Large-scale numerical analysis and modeling of droplet group evaporation," The 59th Symposium (Japanese) on Combustion.

Hiroyuki Abe, "DNS analysis on turbulence structure of a skewed turbulent boundary layer," The 99th Fluids Engineering Division meeting of Japan Society of Mechanical Engineering.

Hiroyuki Abe, Taisuke Nambu and Yasuhiro Mizobuchi, "Prediction of corner separation in a wing-body juncture using a nonlinear AMM model," The 35th Computational Fluid Dynamics Symposium.

● Usage of JSS

● Computational Information

Process Parallelization Methods	MPI
Thread Parallelization Methods	N/A
Number of Processes	48 - 2632
Elapsed Time per Case	168 Hour(s)

● **JSS3 Resources Used**

Fraction of Usage in Total Resources<sup>\*1</sup>(%): 2.92

Details

Computational Resources		
System Name	CPU Resources Used (core x hours)	Fraction of Usage <sup>*2</sup> (%)
TOKI-SORA	68,977,611.00	3.36
TOKI-ST	128,416.93	0.16
TOKI-GP	0.00	0.00
TOKI-XM	0.00	0.00
TOKI-LM	7,640.72	0.57
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 <sup>*2</sup> (%)
/home	1,119.16	1.11
/data and /data2	86,192.00	0.92
/ssd	8,216.06	2.12

Archiver Resources		
Archiver Name	Storage Used (TiB)	Fraction of Usage <sup>*2</sup> (%)
J-SPACE	67.21	0.45

<sup>\*1</sup>: Fraction of Usage in Total Resources: Weighted average of three resource types (Computing, File System, and Archiver).

<sup>\*2</sup>: 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 <sup>*2</sup> (%)
ISV Software Licenses (Total)	1,035.88	0.73

<sup>\*2</sup>: Fraction of Usage : Percentage of usage relative to each resource used in one year.