Development of combustor simulation system based on physics understanding and modelling

Report Number: R19EDA201N06
Subject Category: Aeronautical Technology
URL: https://www.jss.jaxa.jp/en/ar/e2019/11589/

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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

Ref. URL: http://www.aero.jaxa.jp/eng/research/basic/numerical/comb/index.html

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

A skewed turbulent boundary layer is one of the key phenomena in aeronautical applications such as combustors and airfoils. In the present study, we have performed a series of direct numerical simulations (DNSs) of a shear-driven three-dimensional turbulent boundary layer up to the momentum thickness Reynolds number Re_θ=900. The latter $Re_\theta$is the largest Reynolds number ever performed in this configuration. Number of grid points used for Re_θ=900 are 1.5 billion to resolve the essential motions. Figure 1 shows visualization of tubulence structures for Re_θ= 900, which highlights that hierarchical turbulence structures appear clearly when the large spanwise surface veclotiy is imposed.

Under gas turbine engine conditions, an analysis of cross-flow type primary atomization was conducted using a sufficient grid density that can resolve even droplets after atomization(Fig.2). Details of the breakup mechanism from a liquid column to liquid droplets, which has been difficult to measure experimentally, were confirmed.

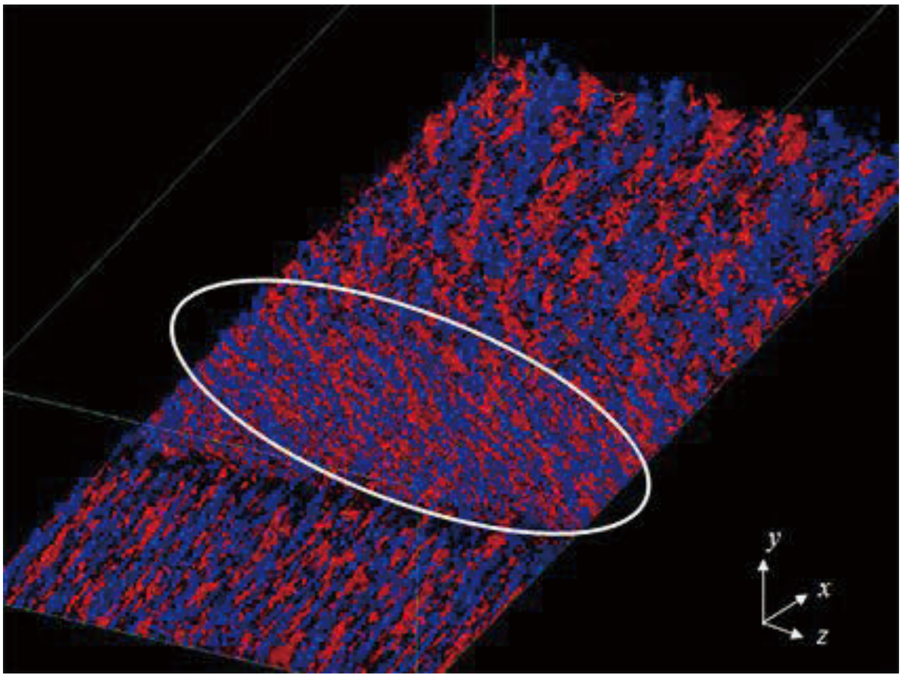

Fig. 1: Turbulence structures observed in the DNS for Re_θ=900 (blue: negative streamwise velocity fluctuation; red: positive streamwise velocity fluctuation).

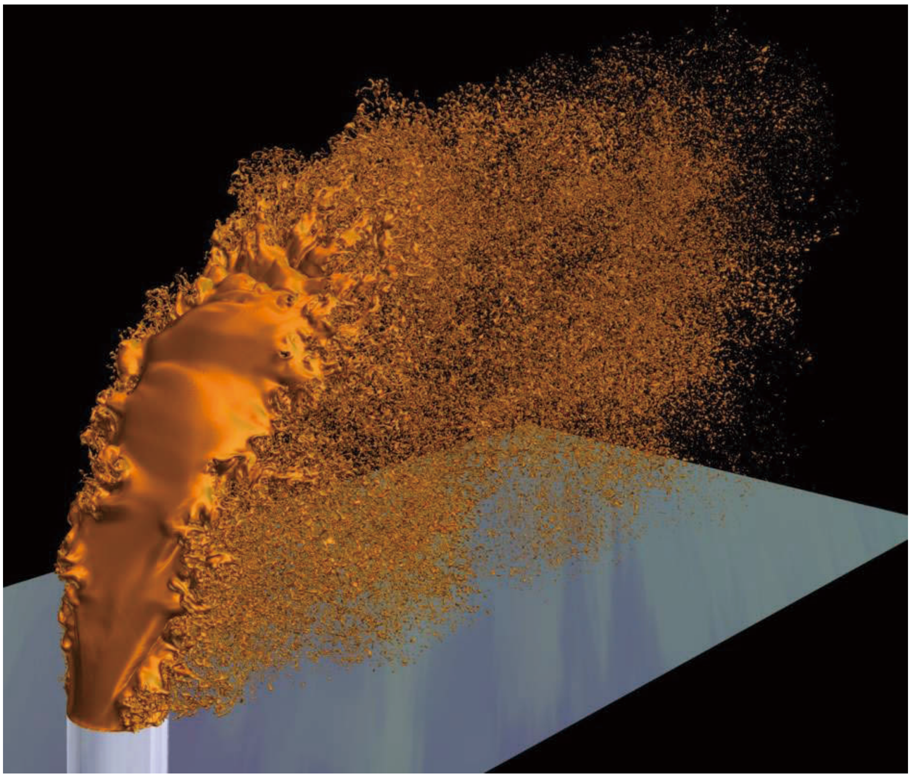

Fig. 2: Distribution of the liquid-gas interface.

Publications

- Invited Presentations

Hiroyuki Abe, "DNS study of a turbulent separation bubble with emphasis on low-frequency unsteadiness," AIAA SciTech (Orlando, FL, USA, Jan. 6-10, 2020).

- Oral Presentations

Hiroyuki Abe, Yasuhiro Mizobuchi and Yuichi Matsuo, "Prediction of turbulent flow around an airfoil with a nonlinear k-ε model," 51th FDC/37th ANSS, July, 2019.

Hiroyuki Abe, Yasuhiro Mizobuchi and Yuichi Matsuo, "DNS and RANS modeling of a turbulent boundary layer with separation and reattachment," AIAA Aviation Turbulence Model Benchmarking Working Group meeting (Dallas, USA, June 17, 2019).

Hiroyuki Abe, "DNS study on Reynolds stress anisotropy in a turbulent boundary layer with separation and reattachment," Proc. of 17th European Turbulence Conference (Turin, Italy, Sept. 3-6, 2019).

Hiroyuki Abe, "A DNS study of a shear-driven three-dimensional turbulent boundary layer with emphasis on momentum transport," American Physical Society 72nd Annual Meeting of the APS Division of Fluid Dynamics (Seattle, WA, USA, Nov. 23-26, 2019).

Taisuke Nambu, Yasuhiro Mizobuchi, "Detailed numerical simulation of primary atomization by crossflow in a flow condition of gas turbine combustor," The Fifty-Seventh Symposium (Japanese) on Combustion

Taisuke Nambu, Yasuhiro Mizobuchi, "Investigation of the Grid Density Effect on a VoF-based Numerical Analysis of Primary Atomization by Crossflow," ILASS-Asia 2019.

- Poster Presentations

Hiroyuki Abe, Yasuhiro Mizobuchi and Yuichi Matsuo, Prediction of turbulent flow around NASA CRM with a nonlinear k-ε model, JSME Fluids Engineering Conference, November, 2019.

Usage of JSS2

Computational Information

Process Parallelization Methods	MPI
Thread Parallelization Methods	OpenMP
Number of Processes	256 - 7712
Elapsed Time per Case	2000 Hour(s)

- **Resources Used**

Fraction of Usage in Total Resources*1(%): 8.88

Details

Computational Resources		
System Name	Amount of Core Time (core x hours)	Fraction of Usage*2(%)
SORA-MA	79,926,448.43	9.71
SORA-PP	20,652.48	0.13
SORA-LM	34,526.54	14.42
SORA-TPP	0.00	0.00

File System Resources		
File System Name	Storage Assigned (GiB)	Fraction of Usage*2(%)
/home	1,660.61	1.38
/data	35,053.45	0.60
/ltmp	5,504.79	0.47

Archiver Resources		
Archiver Name	Storage Used (TiB)	Fraction of Usage*2(%)
J-SPACE	45.27	1.14

*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.