Wall-resolved LES for low Reynolds number compressible flows around a symmetric airfoil

Report Number: R24EACA49
Subject Category: JSS Inter-University Research
URL: https://www.jss.jaxa.jp/en/ar/e2024/27482/

Responsible Representative

Taku Nonomura, Professor, Nagoya University

Contact Information

Taku Nonomura (Professor at Nagoya University)(nonomura@nagoya-u.jp)

Members

Taku Nonomura, Takayuki Nagata

Abstract

Large-eddy simulations (LES) are performed under compressible conditions of flow around symmetric airfoils, including flat plates with Reynolds numbers of O(10^3)-O(10^4), to elucidate the effects of compressibility on laminar separation bubbles and turbulent transition. In the low Reynolds number region investigated in this study, important phenomena for low Reynolds number aerodynamics are pronounced, such as the formation of laminar separation bubbles and turbulent transition. By precisely investigating the effects of compressibility on these phenomena, knowledge will be gained that will contribute to improving the performance of fluid machinery operated under high-speed and low-pressure conditions, such as the Mars aircraft.

Reasons and benefits of using JAXA Supercomputer System

In the present study, a parametric study by large-eddy simulations is conducted, and thus, a large-scale parallel calculation is required.

Achievements of the Year

We performed the DNS around NACA0006 and NACA0012 airfoils at a Reynolds number of 2.3 x 10^4 and investigated the effect of Mach number, the airfoil thickness, and the angle of attack on the flow field and the aerodynamic characteristics. For the higher Mach number, the formation position of the vortex structure and the separation point are located closer to the leading edge at the condition of AoA = 3.0 deg. However, they are located closer to the trailing edge for AoA = 6.0 deg and AoA = 9.0 deg for higher Mach numbers. In addition, the size of the vortex structure increases due to the increase in Mach number (figs. 1 and 2). For all airfoils investigated, the lift coefficient decreases with increasing Mach number, but performance is relatively maintained for thiner airfoils (figs. 3 and 4).

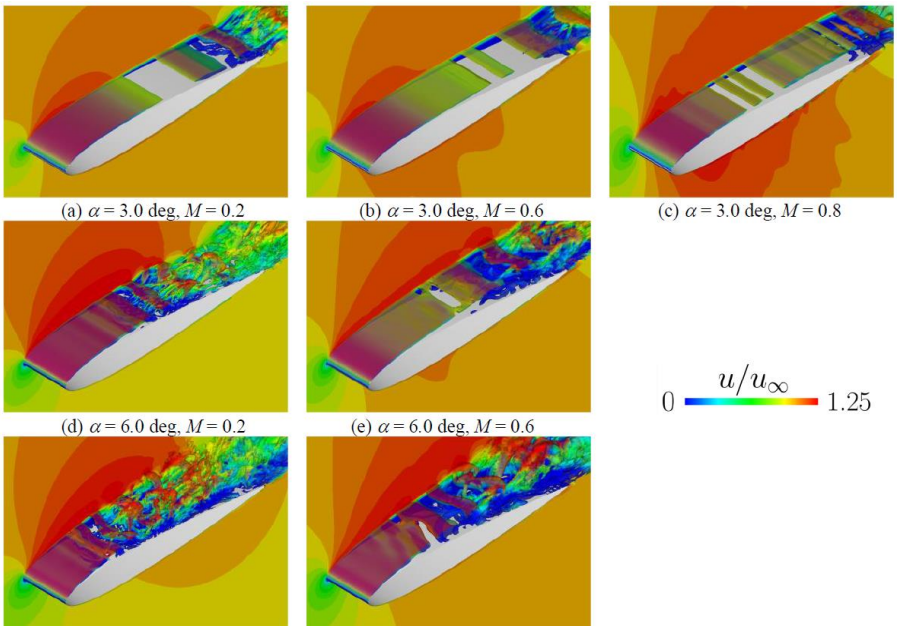

Fig. 1: Instantaneous velocity fields and vortical structure of flow around NACA0012 airfoil visualized by the second invariant of the velocity gradient tensor (perspective view). The threshold of the isosurface is Q/u_inf^2 = 5.

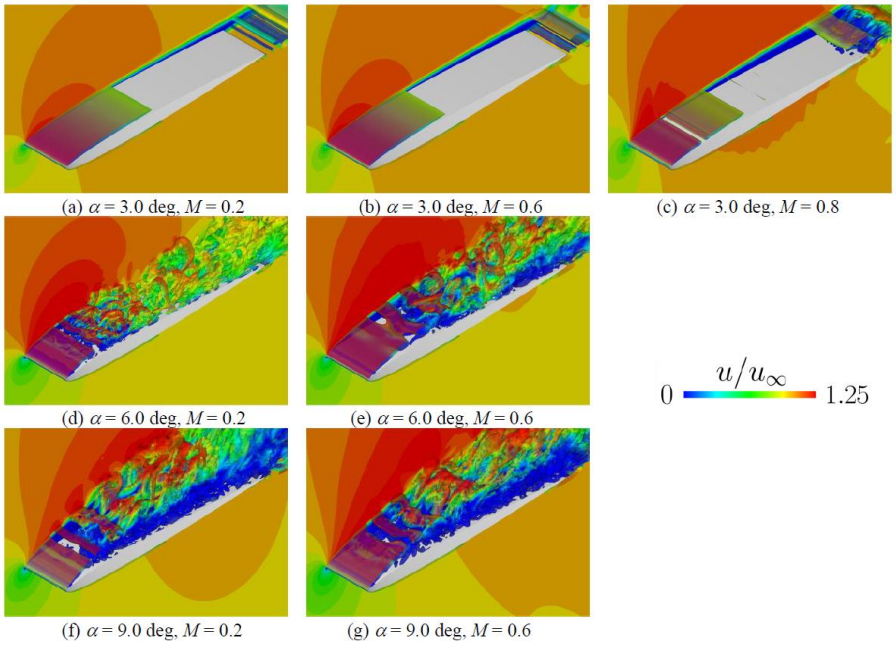

Fig. 2: Instantaneous velocity fields and vortical structure of flow around NACA0006 airfoil visualized by the second invariant of the velocity gradient tensor (perspective view). The threshold of the isosurface is Q/u_inf^2 = 5.

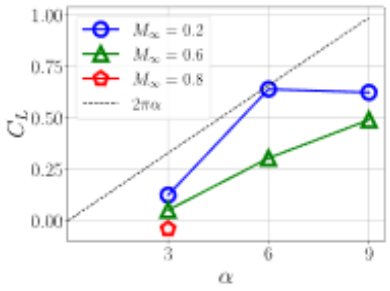

Fig. 3: CL curve of NACA0012

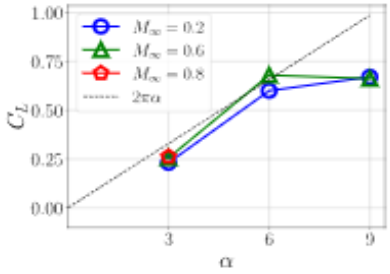

Fig. 4: CL curve of NACA0006

- **Publications**

  N/A

- **Usage of JSS**

- **Computational Information**

Process Parallelization Methods	MPI
Thread Parallelization Methods	OpenMP
Number of Processes	44
Elapsed Time per Case	150 Hour(s)

- **JSS3 Resources Used**

Fraction of Usage in Total Resources[*1](%): 0.04

Details

Computational Resources		
System Name	CPU Resources Used (core x hours)	Fraction of Usage[*2](%)
TOKI-SORA	624,174.20	0.03
TOKI-ST	0.00	0.00
TOKI-GP	0.00	0.00
TOKI-XM	0.00	0.00
TOKI-LM	0.00	0.00
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[*2] (%)
/home	54.45	0.04
/data and /data2	111,926.22	0.54
/ssd	0.00	0.00

Archiver Resources		
Archiver Name	Storage Used (TiB)	Fraction of Usage[*2] (%)
J-SPACE	17.95	0.06

[*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)	0.00	0.00

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