Direct numerical simulation for understanding on flow over vortex generators

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Abstract

In the present study, we investigated the fundamental characteristics of the supersonic vortex generator implemented on the slip wall by the direct numerical simulation of the Navier-Stokes equation. The characteristics of the flow over vortex generators at subsonic and transonic conditions have been investigated by numerous researchers. However, there are few studies at supersonic conditions, so that we investigated the flow characteristics in quite simplified conditions and proceed with the understanding of the flow physics.

Reasons and benefits of using JAXA Supercomputer System

In this project, direct numerical simulations of the three-dimensional compressible Navier-Stokes equation are conducted, so that large scale computational resources are required even though the low-Reynolds-number conditions. In addition, there are many parameters such as the freestream Mach number, the arrangement and the sphape of the vortex generator.

Achievements of the Year

In this study, flow over a pair of vane-type vortex generator is investigated by solving the Navier-Stokes equation. A pair of the vane-type vortex generator implemented on a slip wall in laminar flow is considered so that the problem setting could be simple. The Reynolds number based on freestream quantities and the height of the vanes is set to be 500. The effect of the arrangement and geometry of vanes on the circulation coefficients, induced flow velocities, and aerodynamic force coefficients of VGs are investigated. In addition, a new circulation coefficient, normalized by freestream velocity and the height of the vortex core was introduced and its effectiveness is examined. This new parameter, C_gamma, include the height of the vortex core, so that appears to be a better measure of VG effectiveness on momentum exchange in near wall region. From the computational results, the wider arrangement can introduce the effective vortices with small drag. Also, the longer vanes can introduce strong and effective vortices with smaller drag coefficient.

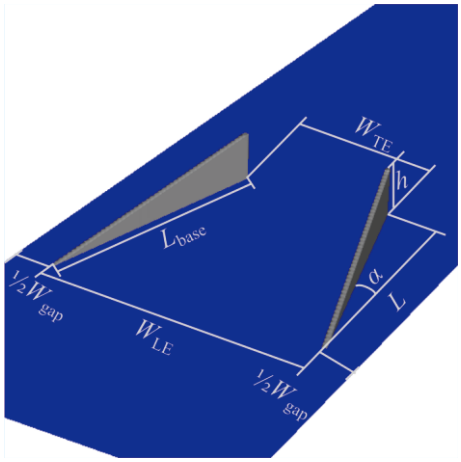

Fig. 1: Problem setting.

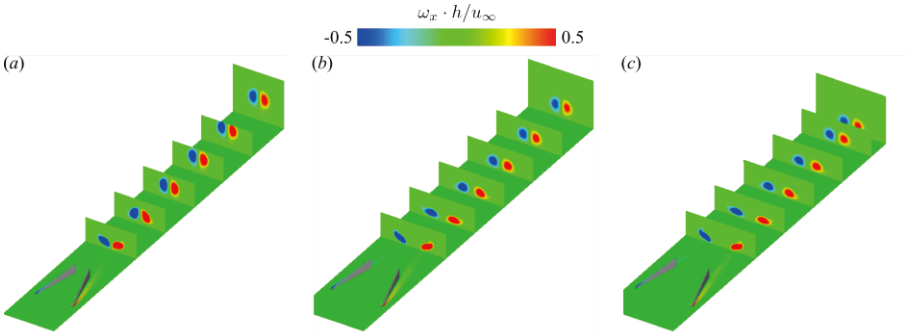

Fig. 2: Effect of L/h on distribution of streamwise vorticity: (a) WTE/h = 1.5; (b) WTE/h = 3.0 (baseline); (c) WTE/h = 3.5. Cross-sectional contours are drawn every 5.0h from trailing edge of VGs.

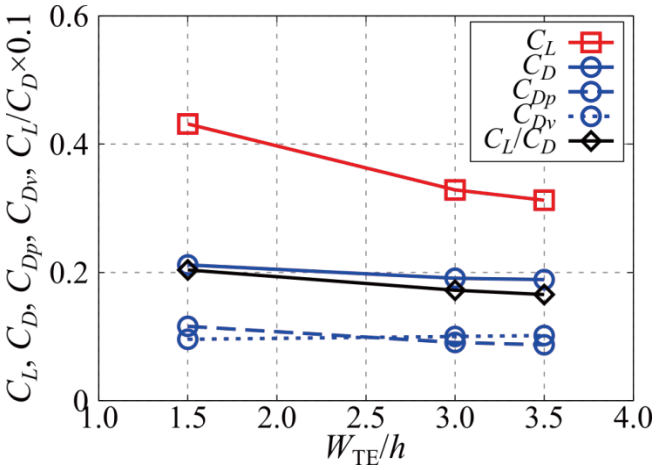

Fig. 3: Effect of WTE/h on aerodynamic force coefficients.

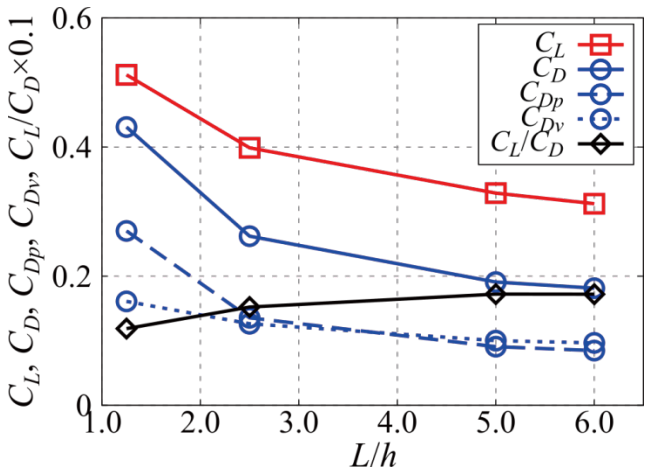

Fig. 4: Effect of L/h on aerodynamic force coefficients.

Publications

- Oral Presentations

Nagata, T., Daspit, J. T., Nonomura, T., and Loth, E., "Direct numerical simulation of supersonic flow over a counter-rotating vane-type vortex generator implemented on slip wall," ASME-JSME-KSME Joint Fluids Engineering Conference 2019, AJKFLUIDS2019-5312, California, USA, July, 2019.

Usage of JSS2

Computational Information

Process Parallelization Methods	MPI
Thread Parallelization Methods	OpenMP
Number of Processes	1 - 289
Elapsed Time per Case	150 Hour(s)

- **Resources Used**

Fraction of Usage in Total Resources[*1](%): 0.18

Details

Computational Resources		
System Name	Amount of Core Time (core x hours)	Fraction of Usage[*2](%)
SORA-MA	1,645,333.92	0.20
SORA-PP	0.00	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	32.82	0.03
/data	5,457.26	0.09
/ltmp	1,091.45	0.09

Archiver Resources		
Archiver Name	Storage Used (TiB)	Fraction of Usage*2(%)
J-SPACE	6.27	0.16

[*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.