Uncertainty quantification of aerodynamic characteristics considering low Reynolds and high Mach number flows

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Abstract

Research on unmanned aerial vehicles flying in the Martian atmosphere and at high altitudes on Earth has been conducted actively. The atmospheric density near the ground on Mars is a hundredth of that on Earth, and the atmospheric temperature is also lower, resulting in a lower speed of sound. A similar situation would be expected for unmanned aerial vehicles flying at high altitudes. These flight conditions are low Reynolds numbers and high Mach numbers, which differ from those of conventional aircraft. Therefore, the aerodynamic data required for their design is insufficient. In addition, there are many uncertainties during flight, such as the effects of disturbances caused by aerial currents and atmospheric temperatures, which require stable and high-performance aerodynamic design. This study quantifies these uncertainties and aims at an aerodynamic design with highly robust performance based on the quantified results.

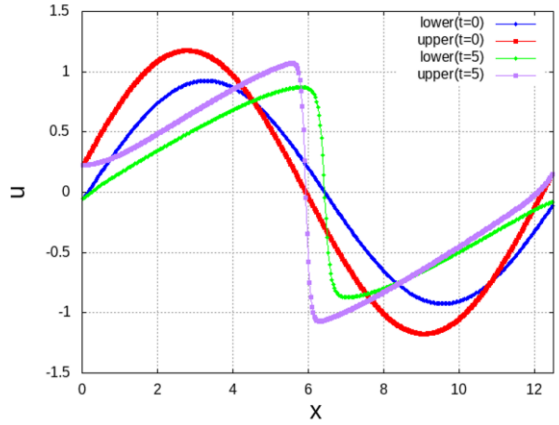
Reasons and benefits of using JAXA Supercomputer System

The computational cost of a parametric CFD study such as uncertainty quantification is very high. Therefore, the use of JSS3 is indispensable for the computation on large memory and CPUs such as supercomputers.

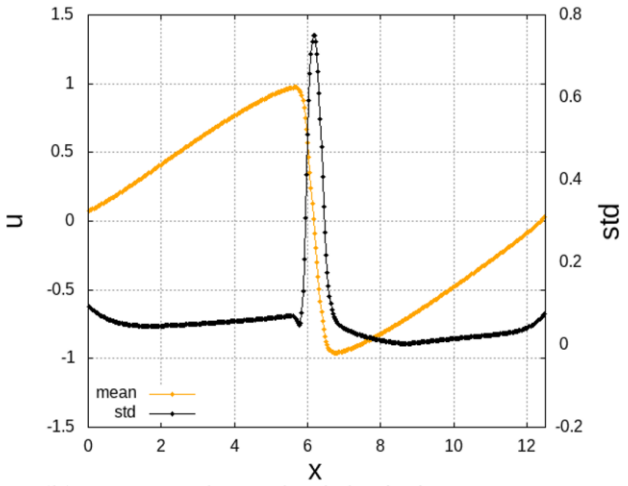
Achievements of the Year

This year, Non-Intrusive Polynomial Chaos (NIPC) was applied to the Burgers equation to evaluate uncertainties in the generation and propagation of shock waves when considering a stochastic-velocity perturbation. Figure 1 shows an example of the results obtained by perturbing the amplitude and phase of a single-wavelength sinusoid. In addition, Fig. 1(a) shows the computation results for the given initial conditions and t = 5. The upper side shows when the given uncertainty is the maximum and the lower side shows when the given uncertainty is the minimum. Figure 1(b) shows the mean and standard deviation of the computation results at t=5 as shown in Fig. 1(a). As a result, an asymmetric standard deviation distribution is observed in Fig. 1 (b), with an upward curvature of the

distribution around x = 0 and 12. The result seems to relate to the distributions around x = 0 and 12 in the computation results at t = 5 in Fig. 4(a). In the future, these analyses will be carried out and the NIPC will be applied to the Navier-Stokes equations to quantify the uncertainty of the separation vortex on the wing surface under high Mach number and low Reynolds number conditions and its effect on the lift and pressure distribution.



(a) Initial conditions and computation results (t=5).



(b) Mean and standard deviation at *t* =5.

Fig. 1 Results with uncertainties in amplitude and phase.

Publications

- Poster Presentations

N. Gima and S. Morizawa, "Uncertainty Quantification in Compressible Flow Fields with Different Initial Conditions," Twenty-first International Conference on Flow Dynamics (ICFD2024), OS23-27, Sendai, Japan, November 18-20, 2024.

Usage of JSS

Computational Information

Process Parallelization Methods	N/A
Thread Parallelization Methods	Automatic Parallelization
Number of Processes	1
Elapsed Time per Case	300 Minute(s)

JSS3 Resources Used

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

Details

Computational Resources		
System Name	CPU Resources Used (core x hours)	Fraction of Usage[*2](%)
TOKI-SORA	0.00	0.00
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	163.33	0.11
/data and /data2	3,380.00	0.02
/ssd	0.00	0.00

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.

- **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.