Numerical investigation of the supersonic intake and wings

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Abstract

JAXA and universities have been advancing research to realize a hypersonic passenger airplane. This plan is divided into 4 stages and the 1st stage is called High-Mach Integrated Control Experiment (HIMICO). This is a hypersonic flight experiment aiming at establishing the integrated control technologies of the airframe and the engine. It is known that the supersonic intake performance can be enhanced by increasing the intake back pressure. However, the excessively high back pressure is known to induce a buzz, which is a self-excited oscillation of the shock wave. The buzz causes a severe vibration of the pressure inside the engine and can result in a misfire or a breakdown of the engine. Therefore, finding out the mechanism of the buzz and establishing the methods to suppress the occurrence are necessary. In this study, the characteristics of the buzz occurring on the intake for HIMICO is investigated numerically.

Reasons and benefits of using JAXA Supercomputer System

The inner flow of the supersonic intake is so complex that the calculation cost is large. However, it became possible to carry out the unsteady simulation of the intake with several turbulence models by using JSS3.

Achievements of the Year

The numerical simulation is carried out to reveal the buzz characteristics occurring on the supersonic intake for HIMICO. The several calculations are conducted using some turbulence models in order to match the results of simulation with the experimental results. The buzz frequency gained by DDES (SST-2003sust) and RANS(SST-2003) simulations are 62.1 Hz and 92.6 Hz, respectively, and the results with DDES simulation corresponds well with the experimental results

(66.8 Hz). The time variation of the static pressure inside the engine is shown in fig.1. As shown in fig.1, the cause of the error in buzz frequency with RANS simulation is the shorter pressure increasing period. It is found that the rapid rise of the static pressure is caused by the separation region on the ramp generated with RANS simulation shown in fig.2. This separation region changes the Mach number distribution inside the engine and results in the rapid rise of the static pressure. Therefore, it is revealed that the type of the turbulence model greatly affects the existence of the separation region, which make large impact on the buzz characteristics, so the calculation methods must be chosen carefully.

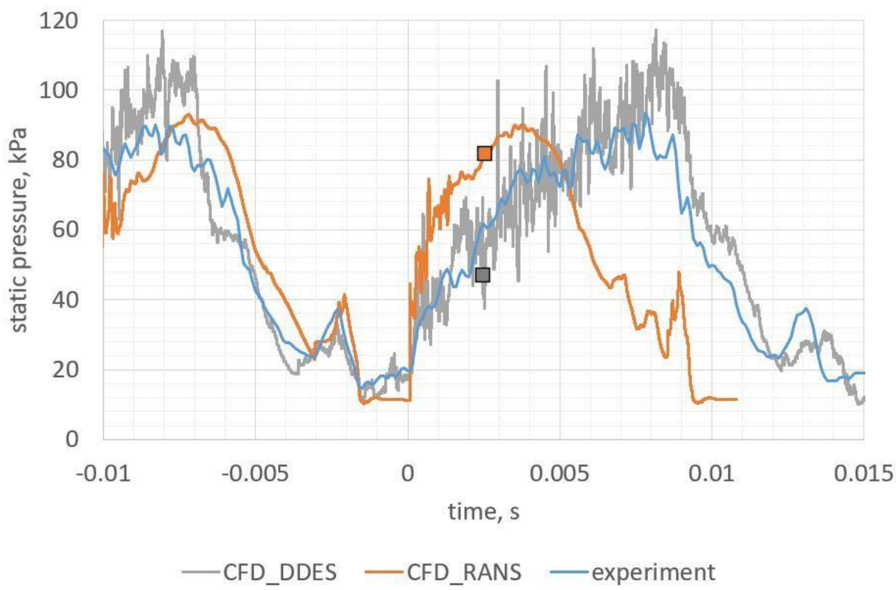

Fig. 1: Time variation of the static pressure inside the intake

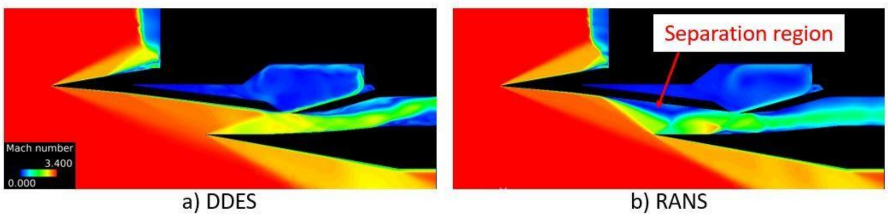

Fig. 2: Mach number distribution inside the intake (0.0025 s)

Publications

- Oral Presentations

1) Fujii, M., Hoshiya, Y., Fujimori, Y., Sato, T., Hashimoto, A., Takahashi, T., and Taguchi, H., Effect of the Turbulence Model on the Buzz Characteristics Occurring on the Air Intake for High-Mach Integrated Control Experiment (HIMICO), AIAA ASCEND, online, AIAA-2021-4164, Nov. 2021.

2)Fujii, M., Sato, T., Hashimoto, A., Taguchi, H., Numerical Investigation on the Effect of the Airframe Angle of Attack on the Intake Performance for High Mach Integrated Control Experiment (HIMICO), The 61th Conference on Aerospace Propulsion and Power, Yonago, 3A07, Mar. 2022 (planned).

Usage of JSS

- **Computational Information**

Process Parallelization Methods	MPI
Thread Parallelization Methods	N/A
Number of Processes	512 - 1024
Elapsed Time per Case	90 Hour(s)

- **JSS3 Resources Used**

Fraction of Usage in Total Resources*1(%): 0.66

Details

Computational Resources		
System Name	CPU Resources Used (core x hours)	Fraction of Usage*2(%)
TOKI-SORA	11,592,905.56	0.56
TOKI-ST	989,532.21	1.22
TOKI-GP	0.00	0.00
TOKI-XM	233.20	0.17
TOKI-LM	21,411.81	1.60
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	1,250.00	1.24
/data and /data2	76,440.00	0.82
/ssd	10,290.00	2.66

Archiver Resources		
Archiver Name	Storage Used (TiB)	Fraction of Usage[*2](%)
J-SPACE	0.07	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)	4,131.21	2.89

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