Basic research for system integration of silent supersonic airplane

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Abstract

The system integration design technologies for achieving low sonic-boom, low aerodynamic drag, low landing and take-off noise, and light weight simultaneously are the key technologies for future supersonic airplanes. JAXA is promoting the R&D for these technologies based on our experiences of demonstrating the advanced low-drag and low-boom design concepts.

Ref. URL: http://www.aero.jaxa.jp/eng/research/frontier/sst/

Reasons and benefits of using JAXA Supercomputer System

To achieve low sonic-boom, low aerodynamic drag, low landing and take-off noise, and light weight simultaneously, the multi-objective optimization tools are utilized in the design study. The super computer is necessary to obtain the efficient evaluation of multiple evaluation indicators.

Achievements of the Year

Supersonic passenger aircraft which mount engine nacelles on under surface of its main wing is superior to cruise range. Shock-wave caused by a supersonic air-inlet is one of the causes of increasing sonic boom. JSS3 was used for numerical calculation in order to examine effects of compression type and mounting orientation of inlet on sonic boom.

A supersonic aircraft designed for around cruise Mach number 1.6 generally adopts an external compression type inlet. Shock waves caused from this inlet for compressing supersonic airflow propagates to outside of engine nacelle and increases sonic boom. An internal compression type inlet which contains the shock waves within the nacelle has potential for reducing difficulty of low boom design. When utilizing it for lower Mach numbers condition such as 1.6, an operating range with being able to keep the shock waves internal is much narrower than an engine operating range. Bleeding from porous walls of inlet throat was tested in this study for the purpose of expanding the inlet operation range with simple system. CFD analysis by FaSTAR was conducted to the cases of a 2D internal compression type inlet with bleed (a ratio of bleed exit height to inlet capture height is 0.2 and 0.3) and without bleed (the height ratio is 0.0) in several height conditions of 2nd throat as shown in Fig.1. The evaluation indexes are mass flow ratio, MFR, total pressure ratio, PR, of inlet and MFR/PR which corresponds to engine speed. Figure 2 presents the range of MFR/PR which allows the shock waves to stand between the design station and just behind the throat. It was shown that the porous wall bleed functions effectively to expand the operating range of internal compression type inlet designed for low Mach numbers.

Another approach to suppress a sonic boom is to prevent the shock waves from an external compression type inlet propagate towards the ground. Although the inlet is generally mounted on under surface of main wing with orientation that its compression ramp is wing side, and its external cowl is ground side, it was installed inversely in this study as shown in Fig.3. A pressure signature observed on the ground was evaluated from a near field pressure distribution extracted from Euler simulation results by FaSTAR. A multipole analysis modified the near field pressure distribution with consideration of propagating in circumferential direction, and a far-field propagation analysis based on the augmented Burgers equation was conducted in the evaluation process. In Fig.4, although a pressure rise with two stages seen in the front pressure signature of the glider configuration is integrated into one stage inthe case of normal installation, it is maintained in the case of inverse installation. It was shown that the inversed inlet contributes to suppress a sonic boom.

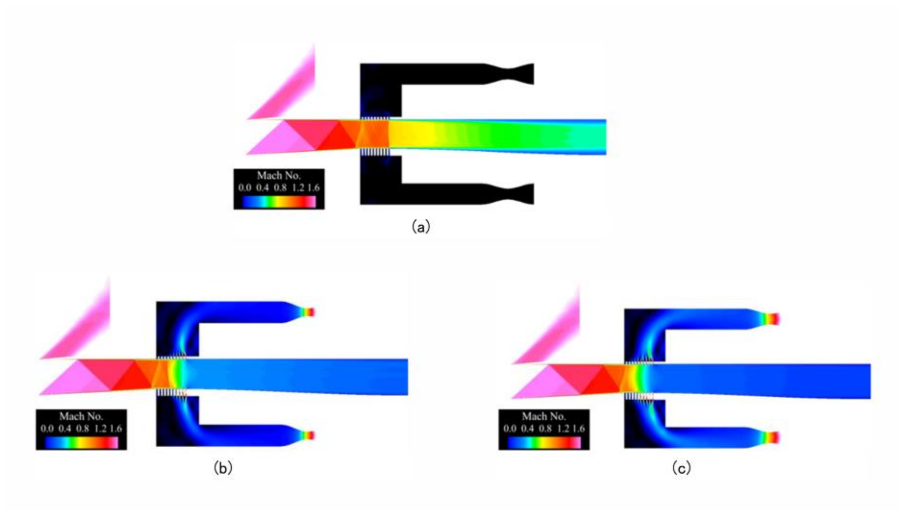
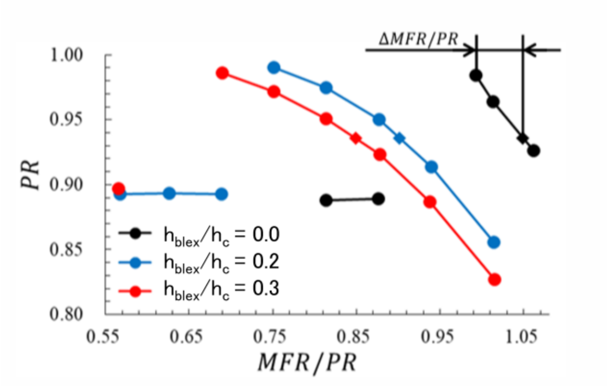


Fig. 1: Shock waves and bleed flow within a internal compression type inlet (a) hblex/hc=0.0, h2ndth/hc= 0.81, (b) hblex/hc=0.2, h2ndth/hc=0.60, (c) hblex/hc=0.3, h2ndth/hc=0.50



h_{blex}/h_c	ΔMFR/PR
0.0	0.057
0.2	0.221
0.3	0.151

Fig. 2: Expantion of inlet operating range by porous wall bleed

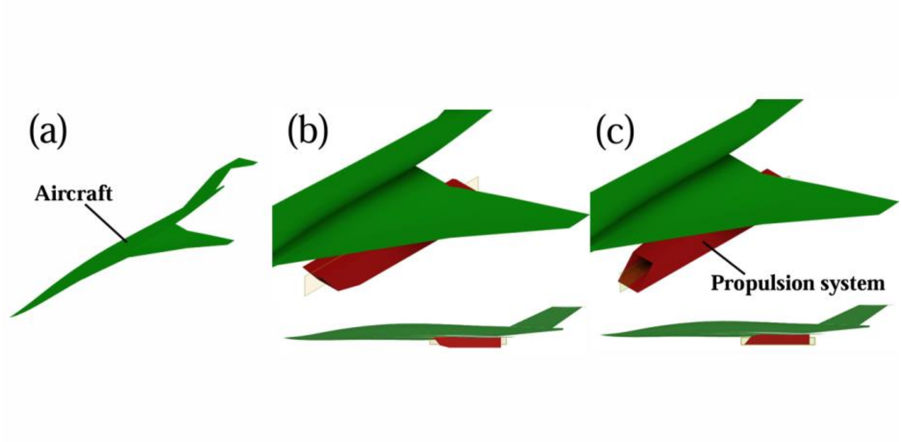


Fig. 3: Reference aircrat and mounting conditions of external compression type inlet on main wing (a) glider, (b) normal, (c) invert

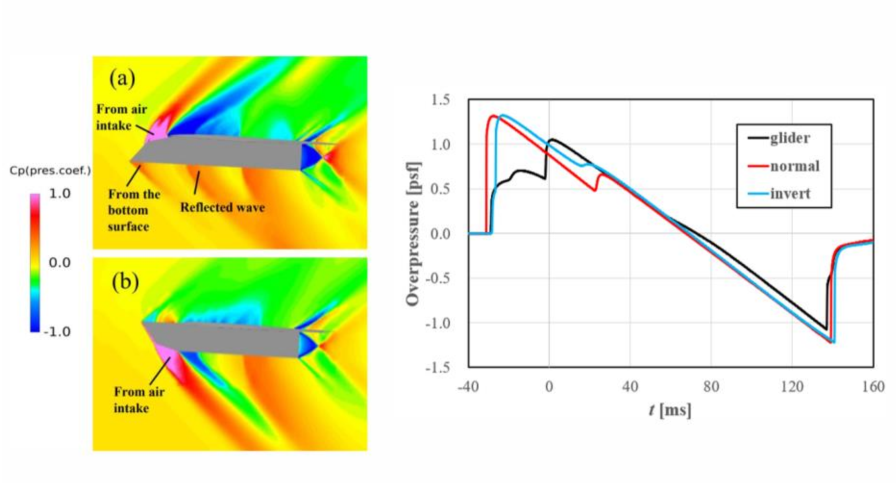


Fig. 4: Left: Propagation of shock waves from nacelle into ground direction (a) normal, (b) invert , Right: Sonic boom signature on ground

Publications

N/A

Usage of JSS

- **Computational Information**

Process Parallelization Methods	MPI
Thread Parallelization Methods	Automatic Parallelization
Number of Processes	144 - 768
Elapsed Time per Case	41 Hour(s)

- **JSS3 Resources Used**

Fraction of Usage in Total Resources*1(%): 0.25

Details

Computational Resources		
System Name	CPU Resources Used (core x hours)	Fraction of Usage*2(%)
TOKI-SORA	4,605,123.88	0.21
TOKI-ST	90,524.67	0.09
TOKI-GP	86,915.63	1.34
TOKI-XM	0.00	0.00
TOKI-LM	9,050.49	0.65
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	1,070.00	0.72
/data and /data2	153,100.00	0.73
/ssd	15,060.00	0.81

Archiver Resources		
Archiver Name	Storage Used (TiB)	Fraction of Usage[*2] (%)
J-SPACE	0.56	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)	2,471.69	1.69

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