Effect of Sidewall Configurations on the Aerodynamic Performance of Supersonic Air-Intake

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Keywords: Air intake, Aerodynamic performance, Buzz, Wind tunnel testing, CFD, Supersonic

1. Introduction
The air-intake plays a key role in propulsion in supersonic flight, being required for high aerodynamic performance. This study focuses on the sidewall configuration of the air-intake to clarify its effect on pressure recovery and flow stability characteristics. Both wind tunnel tests and numerical simulations of the air-intake with two types of sidewalls were performed.

2. Configuration of intake
The supersonic air-intake shown in Fig.1 is a rectangular, external compression air-intake with three-shock system. The design Mach number is 2.0. A shock system is designed to focus on the cowl lip at Mach number 2.3. The first ramp consists of a 3° wedge and a 5° isentropic compression surface. The second ramp and the diffuser ramp have variable geometry, the turning angle of which varies from 0° to 15.6°. The area ratio of the subsonic diffuser varies from 1.4 to 2.2 with the corresponding variable ramp system. The length-to-exit-diameter ratio of the subsonic diffuser is about 3.3. The cross-sectional shape changes from rectangular to circular while the width remains constant along the flow direction.

Two kinds of sidewall configurations (Fig.2) were tested. The larger sidewall “L1” covers most of the supersonic diffuser. The edge line of the smaller sidewall “S1” starts from the corner of the second ramp.

3. Wind tunnel test and CFD analysis
The wind tunnel tests were performed at the NAL 1m×1m Supersonic Wind Tunnel. Measurement of the total pressure distribution at the air-intake exit was performed by means of rotatory pitot rakes. Unsteady pressure measurement was also performed at the air-intake exit.

The steady, compressible, Reynolds-averaged Navier-Stokes equations were solved for the flow through the air-intake. The turbulence viscosity was evaluated with the low-Reynolds-number k-epsilon model. Spatial difference was evaluated by a third order upwind biased Roe scheme with a TVD limiter of Chakravaty and Osher type. For time advancement, an implicit method was adopted.

4. Results and discussion
Figure 3 shows the variation of pressure recovery with the mass flow ratio obtained both in the CFD analysis and in the wind tunnel test. The pressure recovery for the L1 intake is much lower than that for the S1 intake at nearly critical condition. It was found by the CFD analysis that the shape factor of the boundary layer on the sidewall L1 became large, due to the shock boundary layer interaction, resulting in a large boundary layer separation (fig.4). Consequently, it reduces pressure recovery. The time distortion was also affected by the flow structure in the subsonic diffuser, the root-mean-square value of the pressure...
fluctuation for the L1 intake became higher by
the boundary layer separation at nearly critical
condition as shown in fig.5.

In subcritical conditions, the pressure recovery
decreased as the mass flow ratio was reduced,
which was caused by the buzz when the shear
layer from the intersection point of second and
terminal shocks was ingested into the subsonic
diffuser. The mass flow ratio at the onset of buzz
for the L1 intake is lower than that for the S1 in-
take (figs. 3, 5, 6). Assuming the same mass flow
ratio, the width of the capture stream tube for the
S1 intake is smaller than that for the L1 intake
due to the sideways spillage, which indicates that
the height of the stream tube for the S1 intake is
relatively greater. The intersection point, which
is the origin of the shear layer, is easily included
inside the capture stream tube in the case of rela-
tively higher stream tube, S1 intake.

5. Concluding remarks
A large sidewall has the advantage that it
retards buzz onset as the mass flow decreases,
while a smaller sidewall has the advantage that
it suppresses the boundary layer separation in
the subsonic diffuser.

Reference
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