Performance Evaluation of Internal Flow in a Y-duct Intake at High Subsonic Mach Number

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Introduction - Inlets

- Air intakes (or inlets);
- Curved S-duct with bends and offset for embedded engine;
- Separation and pressure losses
  - due to bends and diffusion;
- Aerodynamic Performance
  - Affects compressor performance and stability margin;
- Also useful for suppressing the radar signature of the compressor/fan.

https://www.pinterest.ca/pin/598626975457408215/
Introduction – Y-ducts

• Y-duct intakes on single engine aircraft:
  • Two inlets,
  • Offset could be in two planes;
• Configuration varies with aircraft design;
• Investigation needed for each design;
• Flow mechanism similar to S-duct with added complexity.

https://wiki.flightgear.org/User:Owenpsmith/Preparing_drawings_for_modelling
Introduction – Geometry & Performance

Important geometric parameters:

• Diffusion ratio,
• Centreline curvature,
• Offset,
• Length,
• Entrance aspect ratio.
Goal and Objectives

Goal
• Investigate the aerodynamic performance of a generic Y-duct at higher subsonic Mach number.

Objectives:
• Design an experimental setup for Y-duct testing,
• Determine static pressure recovery, total pressure recovery, velocity and flow direction at the AIP.
Methodology – Experimental Setup

- RMC transonic wind tunnel;
- Bell-mouth inlet and vacuum exhaust;
- Mach number 0.63, set using iris valve;
- Run time 3 to 5 seconds;
- Rotatable instrumentation housing.
Methodology – Y-duct Test-Section

• Trapezoidal inlet with rounded corners and edges;
• Additively manufactured;
• High-density *Clearvue* plastic;
• Exit diameter 4 inch;
• Diffusion ratio 1.64;
• Offset/length 0.14 (vertical) and 0.29 (horizontal);
• 4 rows of longitudinal pressure taps (112 total).
Methodology – Measurement

Total pressure, velocity, and flow direction at the AIP:

- Aeroprobe 5-hole fast-response pressure probe;
- Radially traversed;
- 30-deg circumferential increments using rotatable housing.
Methodology – CFD

CFD:

• Limited numerical study;
• But at slightly higher Mach number of 0.8;
• Reynolds-averaged Navier-Stokes calculations;
• ANSYS Fluent;
• RKE turbulence model.

Hancock and Ingram (2021)
Results

Results will include:

- Static pressure distribution;
- Total pressure at AIP;
- Flow distortion;
- Swirl.
Results – Longitudinal Static Pressure

Static pressure along 90-deg (□) and 270-deg (○)
Results – Longitudinal Static Pressure

Comparison with computed static pressure at Mach 0.8
Results – Total Pressure Ratio at AIP

Total pressure ratio in perspective with Y-duct
Results – Total Pressure Ratio at AIP

Comparison with computed total pressure at Mach 0.8
Results – Total Pressure Recovery

\[ \bar{\pi} = \left[ \frac{p_{0,2}}{p_{0,1}} \right] \]

<table>
<thead>
<tr>
<th></th>
<th>( Ma )</th>
<th>( \bar{\pi} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exp. Y-duct</td>
<td>0.63</td>
<td>0.9315</td>
</tr>
<tr>
<td>CFD Y-duct</td>
<td>0.80</td>
<td>0.887</td>
</tr>
<tr>
<td>Exp. S-duct</td>
<td>0.80</td>
<td>0.98</td>
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Y-duct total pressure recovery coefficient
Results – Swirl Angle at AIP

\[ \alpha = \arctan \left( \frac{V_{\theta}}{u} \right) \]

Looking downstream
Results – Swirl at AIP

Swirl comparison with computed swirl at Mach 0.8
Conclusions

• A generic Y-duct intake was designed and constructed;

• Preliminary measurement and simulation show encouraging results;

• More detail of methodology and results will be presented in CASI-Aero 2021 conference;

• The measurement at moderately high subsonic Mach number will provide database for design of double entrance Y-ducts.