W-8 Acoustic Casing Treatment Test Overview

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Advanced Air Transport Technology Project
Aircraft Noise Reduction Subproject
Outline

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• W-8 Facility Overview
• SDT/R4 Hardware Overview
• Treatment Configurations
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  – Aerodynamic Performance Instrumentation
  – Casing Treatment
    • Instrumentation
    • Over-the-Rotor Pressure and Temperatures
  – Inlet In-duct Array
    • Array Instrumentation
    • Background Acoustic Results

• Summary
Acoustic Casing Treatment Development

Overall Objective: To improve upon acoustic and aerodynamic performance acoustic casing treatments by further understanding their impact in the over-the-rotor environment and incorporating lessons learned from previous tests.

2015: Normal Incidence Tube (NIT) Test
- Traditional impedance measurements to determine liner performance.
- Liner performance with varying sound levels to understand how they scale to sound levels in the over-the-rotor environment.

2016: Advanced Noise Control Fan (ANCF) Test
- Evaluate the acoustic performance of 4 over-the-rotor liners
- Evaluation of the liners installed in the inlet as well as over-the-rotor.
- Both in-duct and far-field microphones were be used to evaluate the acoustic performance.
- Results will be presented at AIAA Aviation in June.

Same treatment geometries tested in each facility.
Test Objective: to evaluate the potential benefits of acoustic casing treatments installed over a high bypass turbofan rotor at TRL 3.

Test Data Acquired:
- Steady Fan Exit Measurements (pressure/temperature)
- Unsteady Fan Exit measurements (hotfilm)
- Inlet In-duct Acoustic Array Measurements

Data Analysis in Progress
- Overall Acoustic Performance
- Overall Aerodynamic Performance
W-8 Single Stage Axial Compressor Facility

- Internal flow propulsor facility
- Electric drive motor provides up to 7000 hp, 21,240 RPM
- Mass Flows up to 100 lb/sec
- 22” Rotor Alone or Stage Fan Models
- Dual Flow or Bypass only
- Atmospheric or Altitude Exhaust Capability
SDT/R4 Hardware

- The Source Diagnostic Test hardware was tested in a rotor alone configuration in the 9x15 wind tunnel\(^{1}\) and the W-8 Single Stage Axial Compressor Facility\(^{2}\) in the early 2000’s.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of Fan Blades</td>
<td>22</td>
</tr>
<tr>
<td>Fan Tip Diameter</td>
<td>22 in. (0.56m)</td>
</tr>
<tr>
<td>Hub/tip Ratio</td>
<td>0.30</td>
</tr>
<tr>
<td>Corrected Tip Speed</td>
<td>1215 ft/s (370 m/s)</td>
</tr>
<tr>
<td>Fan Design Speed, corrected rpm</td>
<td>12,657</td>
</tr>
<tr>
<td>Fan Design Pressure Ratio</td>
<td>1.50</td>
</tr>
</tbody>
</table>


Fan Case Configurations

1. Hardwall
2. Groove Only
3. Empty Chamber
4. Thick Perforate
5. Foam Metal
6. Expansion Chamber
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Foam Metal:
80 ppi, 8% FeCrAlY
Fan Case Configurations

1. Hardwall
2. Groove Only
3. Empty Chamber
4. Thick Perforate
5. Foam Metal
6. **Expansion Chamber**
Test Summary and Test Conditions

Steady Aerodynamic Measurements
- Fan exit rake measurements on the nominal operating line and speed lines at rating conditions.
- Fan exit pressure-temperature probe surveys at the rating conditions.

Unsteady Aerodynamic Measurements
- Fan exit hofilm surveys at the rating conditions.

Acoustic Measurements
- Fan exit rakes removed to provide a ‘clean’ acoustic configuration.
- Inlet In-duct Array acoustic measurements on the nominal operating line and speed lines at rating conditions.

### Rating Conditions

<table>
<thead>
<tr>
<th>Rating Condition</th>
<th>% Design Speed</th>
<th>Corrected Mass Flow (lbm/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Approach</td>
<td>61.7%</td>
<td>57.8</td>
</tr>
<tr>
<td>Cutback</td>
<td>87.5%</td>
<td>83.7</td>
</tr>
<tr>
<td>Takeoff</td>
<td>100%</td>
<td>97.2</td>
</tr>
</tbody>
</table>
Aerodynamic Performance Instrumentation

Pressure-Temperature Detailed Surveys
Hotfilm Surveys

3x7 element Pressure Rakes
3x7 element Temperature Rakes
Casing Treatment Instrumentation

8-Over-the-Rotor Kulites® in the Baseline and Circumferentially Grooved Fan Cases

6-Surface thermocouples in each axial row of treatment in each of the 4 treated fan cases
Over-the-Rotor Environment

Dynamic Pressure Level at the Fan Leading Edge

- Hardwall
- Groove Only

Fan Tip Mach Number
SPL (dB ref. 20\(\mu\)Pa)

Temperature within the Treatment at the Fan Leading Edge

- Empty Chamber
- Thick Perforate
- Metal Foam
- Expansion Chamber

Fan Tip Mach Number
Temperature Ratio
Inlet In-duct Array Instrumentation

- 22-inch constant area inlet duct
- 85 sensors
  - Kulite® 25PSIA
  - Installed into nylon inserts
- T-Array
  - \( \frac{1}{2} \) Circle
  - Long Axial
  - Staggered Short Axial
W-8 Background Noise

Background Noise Comparison
Sensor 45: 50% Speed

SPL (dB ref. 20 μPa)
Frequency (Hz)

Suspected Collector Rod Noise

50%: $M_{exhaust} = 0.46$
50%: $M_{exhaust} = 1.39$
No fan: Clean Flow
No fan: No Flow
Summary

• In January and February 2017, aerodynamic performance and acoustic measurements were made to evaluate the potential benefits of acoustic casing treatments installed over a high bypass turbofan rotor.

• Data analysis is in progress to determine the impact of the treatments on the fan exit steady and unsteady flow-field and acoustic performance.

• Over-the-Rotor Environment:
  – The 0.5” groove depth reduces the incident pressure field on an acoustic treatment by up to 6dB.
  – Pressures over-the-rotor are significantly higher than simulated in the Normal Incidence Tube (LaRC).
  – Temperatures can be a concern at sonic fan tip Mach numbers.

• W-8 Background Noise:
  – Gearbox/Bearing/Drive Motor noise is not an issue.
  – Flow background noise is potentially an issue under 1kHz.
  – Low frequency exhaust noise is potentially an issue when atmospheric exhaust is used.

• NASA/TM-2017-219489 “Inlet Acoustic Data from a High Bypass Ratio Turbofan Rotor in an Internal Flow Component Test Facility”
  – Contains in-duct array data with the hardwall fan case for the development of array processing techniques and comparison to 9x15 far-field data.