Open Rotor Research at NASA Glenn

A low-noise open rotor system is being tested in collaboration with General Electric and CFM International, a 50/50 joint company between Snecma and GE. Candidate technologies for lower noise will be investigated as well as installation effects such as pylon integration. The research program in both the low and high-speed wind tunnels is reviewed. Some detailed flowfield and acoustics measurements acquired for an internal NASA program are highlighted. The publically available research data is presented also.
Open Rotor Research at NASA Glenn

Dale Van Zante
Propulsion Sub-Project Engineer
Environmentally Responsible Aviation
Integrated Systems Research Program
• The Open Rotor test program
• Rig and facility details
• Low speed isolated/installed data
• Status

Testing is supported by the Environmentally Responsible Aviation Project
Data analysis efforts are supported by the Subsonic Fixed Wing Project
Facility support is from the Aeronautics Test Program
The NASA/GE Collaboration on Open Rotor Testing

- **Objective:** Explore the design space for lower noise while maintaining the high propulsive efficiency from a counter-rotating open rotor system.

- **Approach:** A low-noise open rotor system is being tested in collaboration with General Electric and CFM International, a 50/50 joint company between Snecma and GE. Candidate technologies for lower noise will be investigated as well as installation effects such as pylon integration.

Historical Baseline Blade Set
12 x 10 blade count
Non-proprietary geometry/data
Export controlled
Test Program Overview

<table>
<thead>
<tr>
<th>NASA/GE 9x15 Low Speed Wind Tunnel</th>
<th>NASA/GE 8x6 High Speed Wind Tunnel</th>
<th>NASA/GE/FAA (CLEEN) 8x6/9x15</th>
</tr>
</thead>
<tbody>
<tr>
<td>Takeoff and Approach Conditions</td>
<td>ERA Diagnostics</td>
<td>Cruise Conditions</td>
</tr>
<tr>
<td>• Aerodynamic performance</td>
<td>• Acoustic phased array</td>
<td>• Aerodynamic performance</td>
</tr>
<tr>
<td>• Acoustics</td>
<td>• Farfield Acoustics with Pylon</td>
<td>• Near field unsteady pressure</td>
</tr>
<tr>
<td>• Hot Film flowfield measurements</td>
<td>• Pressure Sensitive Paint</td>
<td>• Aero and acoustic performance of optimized blade designs at low and high speed.</td>
</tr>
<tr>
<td></td>
<td>• Stereo Particle Image Velocimetry</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Acoustic Shielding</td>
<td></td>
</tr>
</tbody>
</table>
8x6 SWT/9x15 LSWT
Wind Tunnel Complex

Operating mode: Aerodynamic—Closed loop
Propulsion—Open loop

9ft. x 15ft.
Low Speed Test Section
MACH NO.: 0–0.2

8ft. x 6ft.
Supersonic Test Section
MACH NO.: 0.25–2.0
Altitude: Sea level to 35,000 ft.
Tunnel pressure: 2400 to 3700 lb/ft²
Temperature: 80 to 200 °F
Drive motors 87,000 HP

Air Dryer
Compressor
Drive motors
Flexible nozzle
Cooler
Muffler

Glenn Research Center
Cleveland, Ohio
The Open Rotor Propulsion Rig (ORPR)

750 SHP per rotor
Rotating force balance:
  430 Lbf thrust per rotor
  550 ft-lb torque per rotor

1/5 to 1/7 of Full Scale
Independently controlled rotor speeds
Digital telemetry units for and aft
12 strain gage channels per rotor
Adjustable rotor spacing
Tare corrections to force balance data

The downstream rotor force, \( \text{frdf} \), is calculated by multiplying the delta pressure term (delta from the freestream static pressure, \( p_{so} \)) by the particular inter-rotor cavity pressure.
Acoustic Configuration

18° forward to 140° aft angles

60” sideline
**Test Matrix**

<table>
<thead>
<tr>
<th>Test Parameter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Freestream Mach number variation</td>
</tr>
<tr>
<td>Blade pitch angle setting variation</td>
</tr>
<tr>
<td>Series of RPMs at a set pitch</td>
</tr>
<tr>
<td>Model angle of attack</td>
</tr>
</tbody>
</table>

A detailed aerodynamic performance data set was acquired for all blade sets as well as acoustic measurements at 18 axial locations.

Primary NASA researcher: John Gazzaniga
The presence of the CFMI pylon induces distortions into blade rows causing noticeable increase in the levels of the individual rotor harmonics.

NASA Researcher: David Elliott
3 blade pitches: TO Nom, Scaled TO, Approach

Work is going on now to apply the tare corrections to this data.
ERA Diagnostics:
Historical Baseline Acoustic Shielding

Test Matrix

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>2 Barrier wall lengths</td>
<td></td>
</tr>
<tr>
<td>2 Barrier wall positions</td>
<td>Forward and Aft</td>
</tr>
<tr>
<td>2 Rotor speeds</td>
<td></td>
</tr>
<tr>
<td>2 Freestream Mach numbers</td>
<td></td>
</tr>
</tbody>
</table>

Short barrier, Forward position

~34° ~67°

Finite acoustic barrier wall.
Semi-infinite acoustic barrier wall.
Objectives: Aerodynamic performance and near field unsteady pressure measurements at cruise Mach number.

Installation of ORPR into the 8x6 began in December.
• Isolated and pylon installed aero and acoustic data exist for the Historical Baseline Blade Set (F31/A31).
• Tare corrections are being applied to the data now.
• This constitutes that data set needed for system analysis.
Federal Aviation Administration: CLEEN program


The ERA Diagnostics Program

| Acoustic Phased Array | Farfield acoustics with Pylon | Pressure Sensitive Paint | Stereo Particle Image Velocimetry | Acoustic Shielding |

The goal is a comprehensive data set that will identify noise sources and enable improved performance and acoustic modeling of open rotor systems.
ERA Diagnostics: Detailed Historical Baseline flowfield measurements

The 3D PIV measurements provide a wealth of information about the blade wakes and vortex track. NASA Researcher: Mark Wernet

The Pressure Sensitive Paint measurements show phase locked static pressure on the surface of the rotating blade. NASA Researcher: Tim Bencic
ERA Diagnostics:
Historical Baseline Installation effects (1)

The location of peak noise level in the **phased array** map changes in the presence of the CFMI pylon indicating a change in the relative strength of sources.

NASA Researcher: Gary Podboy