Advanced Seal Sessions I & II

Dr. Bruce M. Steinetz, General Chair
Mr. Patrick H. Dunlap, Structural Seals Co-Chair
NASA Glenn Research Center

Dr. Neelesh Sarawate
Turbine Seals Co-Chair
GE Global Research Center

49th AIAA/ASME/SAE/ASEE
Joint Propulsion Conference, San Jose, CA
July 16, 2013
Outline

Turbine Seals

• Why work advanced seals?
  – NASA engine/propulsion technologies NASA N+3 Studies
  – Challenges

• Advanced concepts under development
  – NASA Glenn
  – GE Global Research

Spacecraft Seals

• Habitable volume seals
• Thermal Barrier seals
Turbine Seals

Aircraft Timeline

1903
1930s
1950s
2000s

DC-3
B-707
B-787
System improvements require advances in propulsor and core technologies

- Core technologies:
  - improved internal aerodynamic
  - higher operating temperature
  - control of parasitic losses
Why Seals?

- Seals provide high return on technology $ investment
- Same performance goals possible through modest investment in the technology development
  - Example: 1/5th to 1/4th cost of obtaining same performance improvements of re-designing/re-qualifying the compressor

### NASA Subsonic Transport System Goals

**Baseline:** 2005

<table>
<thead>
<tr>
<th>Target</th>
<th>Fuel Burn</th>
<th>Cruise NOx Emissions</th>
</tr>
</thead>
<tbody>
<tr>
<td>N+1: 2015</td>
<td>-33%</td>
<td>-55%</td>
</tr>
<tr>
<td>N+2: 2020</td>
<td>-50%</td>
<td>-70%</td>
</tr>
<tr>
<td>N+3: 2025</td>
<td>-60%</td>
<td>-80%</td>
</tr>
</tbody>
</table>

### NASA Study Results: Expected Seal Technology Payoffs

<table>
<thead>
<tr>
<th>Seal Technology</th>
<th>Study Engine/Co.</th>
<th>System Benefits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Large diameter aspirating seals (mult. locations)</td>
<td>GE90-Transport/GE</td>
<td>-1.86% SFC, -0.69% DOC + I</td>
</tr>
<tr>
<td>Interstage seals (mult. locations)</td>
<td>GE90-Transport/GE</td>
<td>-1.25% SFC, -0.36% DOC + I</td>
</tr>
<tr>
<td>Film riding seals (Turbine inter-stage seals, mult. locations)</td>
<td>Regional-AE3007/Allison-RR</td>
<td>&gt; -0.9% SFC, &gt; -0.89% DOC + I</td>
</tr>
<tr>
<td>Advanced finger seals (mult. locations)</td>
<td>Regional/Honeywell</td>
<td>-1.4% SFC, -0.7% DOC + I</td>
</tr>
</tbody>
</table>

**Advanced Seal Technology: An Important Player**
Engine/Propulsion Technologies from NASA N+3 Studies

- High OPR, high T4 cycle
  - CMC Turbine Blades/Vanes
  - high temp disk material
  - **improved seal design**
  - intercooled compressor

- High Efficiency Small Cores
  - mitigate efficiency decrement
  - active clearance control
  - flow control

<table>
<thead>
<tr>
<th>Goals</th>
<th>Noise</th>
<th>Emissions (LTO)</th>
<th>Emissions (cruise)</th>
<th>Energy Consumption</th>
</tr>
</thead>
<tbody>
<tr>
<td>Metrics (N+3)</td>
<td>Stage 4 – 52 dB cum</td>
<td>CAEP6 – 80%</td>
<td>2005 best – 80%</td>
<td>2005 best – 60%</td>
</tr>
</tbody>
</table>

**Goal-Driven Advanced Concepts (N+3)**
Turbine Seals: Challenges

- Minimize leakage to enable: reduced fuel consumption and emissions
- High temperatures: 1200 to 1500°F
- Minimize heat generation
- High speeds 1000 to 1500 fps
- Moderate pressure 250 psi
- Operate with little or no wear for long life >20,000 hrs
- Occupy small “footprint”
GRC Non-contacting Finger Seals

Key benefits are …

• **Avoids wearing out parts**: No contact avoids wear found in brush seals and labyrinth seals

• **Reduced flow**: <1/3 the flow of a straight tooth labyrinth seal and <1/2 the flow of a contacting brush seal

• **Comparable power loss**: Power loss is the same order of magnitude as brush and finger seals
GE Global Research

Neelesh Sarawate
GE Global Research
GE Global Research: Advanced Sealing Synergy

GE Global Research Center
• First industrial R&D lab
• Established in 1900
• Nearly 180 research labs
• ~2,000 technologists, 2/3rd hold PhDs

Aircraft engines
• High temp & creep
• Limited space
• High speed, swirl ratio
• Seal stability

GE Global Research
• Fundamental research
• Seal design & analysis
• Validation tests in custom rigs

Gas turbines
• Longer life
• Field installation, assembly
• Large interference

Steam turbines
• Rotor dynamics
• Short cycles
• Low-cost
• Rub tolerant
GE Sealing & Performance Technologies

- Brush seals
- Cloth seals
- Aspirating seals
- Abradable coatings
- Non-metallic brush seals
- Retractable seals
- Compliant plate seals

ST Brush seals
1990s-2000

Cloth Seals
AIAA 2001

Aspirating seals
JPP 2006

Shroud coated with abradable

Abradable coatings
GT2004-53029

Non-metallic brush seals
AIAA-2010
GT2012-69329

Retractable seals
GT2011-45756

Compliant plate seals
GT2011-45756

2013 AIAA Joint Propulsion Conference, San Jose, CA
7/16/2013
Spacecraft Seals

Pat Dunlap
NASA Glenn Research Center
Types of Seals

- **Habitable volume seals**
  - Seals for hatches, windows, docking interfaces, penetrations/feed-throughs
  - Require extremely low leak rates to ensure that astronauts have sufficient breathable air for extended missions
  - Typically made of elastomer materials

- **Thermal barrier seals**
  - Seals for interfaces in vehicle thermal protection systems (TPS)
  - Must withstand extreme heating during re-entry
  - Typically made of high temperature fibers, wires, or insulating materials
Potential Missions

- Asteroid retrieval mission
- Future space station (e.g., cislunar)
- Lunar/Mars outpost
Habitable Volume Seals
# Habitable Volume Seal Challenges

<table>
<thead>
<tr>
<th>Feature</th>
<th>Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low leakage</td>
<td>Near hermetic levels (~0.002 lb\textsubscript{m} air/day)</td>
</tr>
<tr>
<td>Space environments</td>
<td>Resist damaging effects of atomic oxygen, UV radiation, ionizing radiation, MMOD</td>
</tr>
<tr>
<td>Resiliency</td>
<td>Exhibit acceptable compression set vs. cycling and re-mate after long term holds</td>
</tr>
<tr>
<td>Temperature</td>
<td>Survival: -65 to +100°C (-85 to +212°F)</td>
</tr>
<tr>
<td></td>
<td>Operational: -50 to +75°C (-58 to +167°F)</td>
</tr>
<tr>
<td>Loads</td>
<td>Low compression and adhesion loads</td>
</tr>
<tr>
<td>Androgynous docking</td>
<td>Design for seal-on-seal operation for vehicle-to-vehicle craft emergency rescue</td>
</tr>
<tr>
<td>Fault tolerance</td>
<td>Include multiple seals/bulbs for redundancy</td>
</tr>
<tr>
<td>Surface operations</td>
<td>Exhibit robust operation in presence of dust, FOD, etc.</td>
</tr>
</tbody>
</table>
NASA Docking System

- NASA implementation of the International Docking System Standard (IDSS)
- Under development as a common docking system for a variety of host vehicles
- Requires a large (~51” diameter) near hermetic seal to prevent loss of cabin air
- Operate in either of following modes:
  - Seal-on-Flange
  - Seal-on-Seal (androgynous)
Potential NDS Applications

MPCV/Orion

Space-X Dragon

Boeing CST + Bigelow BA330

Sierra-Nevada Dream Chaser
Advanced Habitat + Rover Seals

- Rover Docking Interface/Seal
- Hatch/Seal
- Suit Port Seal
Advanced Habitable Volume Seals for Space Environments

- Seals with UV-resistant coatings
- Seals with additives for UV resistance
- Seals with retractable “shrouds”
Thermal Barrier Seals
<table>
<thead>
<tr>
<th><strong>Thermal Barrier Seal Challenges</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Temperature</strong></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td><strong>Leakage</strong></td>
</tr>
<tr>
<td><strong>Space environments</strong></td>
</tr>
<tr>
<td><strong>Resiliency</strong></td>
</tr>
<tr>
<td><strong>Loads</strong></td>
</tr>
<tr>
<td><strong>Durability</strong></td>
</tr>
</tbody>
</table>
Advanced Thermal Barrier Seals

Use of advanced high temperature fibers

Advanced seal preloaders for improved resiliency at high temperatures
Agenda Information
Advanced Seal Technology I
2013 AIAA Joint Propulsion Conf. – Session: SCP-03 Tuesday Morning, July 16, Room 210 G
Co-Chairmen: Bruce M. Steinetz and Patrick H. Dunlap, NASA Glenn; Neelesh Sarawate, GE Global Research

10:00 am Oral Presentation: Overview of Advanced Seals Challenges and Opportunities
Bruce M. Steinetz and Patrick H. Dunlap, NASA Glenn Research Center; Neelesh Sarawate, GE Global Research Center

10:30 am Oral Presentation: Turbomachinery Sealing Technology- Survey of Past Success and Strategy for Future Development
Joel Kirk, GE Aviation

11:00 am: Design, Manufacture and Testing of Variable Bristle Diameter Brush Seals (AIAA- 2013-3859)

11:30 am: A Novel Air/Oil Separator and Its Integration to a Prototype Miniature Jet Engine (AIAA- 2013-3860)
Emre Tan Topal, TUSAS Engine Industries Inc; Sercan Acarer, TEI TUSAS Engine Industries Inc. /Izmir Institute of Technology; Tuna Kirgiz, TEI TUSAS Engine Industries Inc.
1:00 pm Oral Presentation: Characterizing Multi-Scale Viscoelasticity of Polymers: A Transient Sealing Perspective
   Azam Thatte, GE Global Research

1:30 pm: Transient Simulations of Rotordynamic Problems with Whirling Motion (AIAA-2013-3914)
   Chandrasekhar Kannepalli, Vineet Ahuja, and Ashvin Hosangadi, Combustion Research and Flow Technology, Inc. (CRAFT Tech)

2:00 pm: Use of VUV Radiation to Control Elastomer Seal Adhesion (AIAA-2013-3915)
   Henry C. de Groh III, Bernadette J. (“Sue”) Puleo, and Deborah L. Waters, NASA Glenn Research; Presented by Sue Puleo