AN UPDATE ON STRUCTURAL SEAL DEVELOPMENT AT NASA GRC

Pat Dunlap, Bruce Steinetz, and Josh Finkbeiner
National Aeronautics and Space Administration
Glenn Research Center
Cleveland, Ohio

Jeff DeMange and Shawn Taylor
University of Toledo
Toledo, Ohio

Chris Daniels
University of Akron
Akron, Ohio

Jay Oswald
J&J Technical Solutions, Inc.
Cleveland, Ohio

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NASA Glenn Research Center, Cleveland, OH

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November 8-9, 2005
Introduction & Background

- Advanced structural seals are required on future hypersonic vehicles and on vehicles and systems for NASA's Exploration Initiative
  - Dynamic seals:
    - Control surfaces
    - Landing gear doors
    - Access panels and doors
    - Hypersonic engine ramps and panels
  - Static seals:
    - Docking/berthing system seals
    - Leading edge panel joints
    - Acreage thermal protection system (TPS) joints
    - Heatshield joints and interfaces
GRC Structural Seals Team Research Areas

- Advanced Docking/Berthing System (ADBS) for CEV (JSC)
- CEV TPS Advanced Development (LaRC, Ames)
- Aerocapture Technology Development (MSFC)
- Deployable Skirt System (Northrop Grumman)

Trailing ballute for aerocapture

Sealing interface

Crew Exploration Vehicle (CEV)

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Research Areas & Objective

- GRC Structural Seals Team also developing seals for hypersonics programs:
  - Falcon program (Lockheed Martin, DARPA, JSC)
  - X-43C Direct Connect Combustor Rig (ATK GASL, LaRC)

**Objective:** Develop sealing systems that meet vehicle/system requirements and demonstrate performance in relevant environments
Presentation Outline

- Wafer seals
- Spring tube seals
- High temperature seal preloaders: TZM canted coil springs
- Arc jet test rig
Previous tests revealed that wafer seal installation factors influenced flow rates

**Objective:** Improve understanding of wafer sealing system

**Approach:** Parametric studies of performance (flow tests)
- Design of experiments (DOE) study to evaluate variables that affect seal installation
- Wafer seal geometry study
Wafer Seal Installation DOE Study

- Wafer geometry: 0.5 in. wide x 0.92 in. long x 0.125 in. thick
- Five factors evaluated at two levels
  - Wafer height tolerance: 0.0003 and 0.0020 in.
  - Preload: 1.8 and 4.3 lbf per inch of seal
  - Bridge element thickness: 0.015 and 0.060 in.
  - Groove width clearance: 0.001 and 0.007 in.
  - Groove length clearance: 0.001 and 0.005 in.
- Test matrix:
  - 16 trials
  - Fractional factorial design (Resolution V)
  - Tests performed in random order to minimize biases
Results of Wafer Seal Installation DOE Study

**Key**
- **WHT** = Wafer height tolerance, in.
- **Preload** = Preload per inch of seal, lbf/in.
- **BET** = Bridge element thickness, in.
- **GWC** = Groove width clearance, in.
- **GLC** = Groove length clearance, in.
- Leakage metric = Area under flow vs. pressure curve from 0 to 100 psig

**Graph**
- **Mean of 0-100 psi leakage metric, SCFM-psi/in.**
  - **WHT**
  - **Preload**
  - **BET**
  - **GWC**
  - **GLC**

- **Tight** vs. **Looser**
- **Higher** vs. **Lower**
- **Thicker** vs. **Thinner**

**Legend**
- Tighter wafer height tolerance
- Higher seal preload
- Thicker bridge element
- Looser groove length clearance
- Tighter groove width clearance
Motivation: Thicker wafers have lower part count, lower leakage rates?

Comparable leakage rates for 1/8-in. and 1/4-in. thick wafers: can reduce part count 2X by using 1/4-in. thick wafers

Higher flow rates for 1-in. and 2-in. thick wafers, less able to conform to wafer misalignments and sealing surface distortions
Wafer Geometry Study: Full-Size vs. Half-Size Wafers

- Motivation: Smaller wafers occupy less space, weigh less, fit in tighter locations
- Flow rates for half-size wafers ~3X those for full-size wafers (1/8-in. thick)
- Can reduce part count 4X for half-size wafers by using 1/2-in. thick wafers vs. 1/8-in. thick (similar flow rates)
Spring Tube Seal Development

- **Objective:** Improve resiliency of spring tube seals at high temperatures
- **Approach:** Substitute Rene 41 as material for knitted spring tube vs. Inconel X-750 in baseline design
Resiliency Improvement for Rene 41 Spring Tube

20% Compression Tests on IN X-750 Spring Tube

<table>
<thead>
<tr>
<th>Pre-test</th>
<th>1200°F</th>
<th>1500°F</th>
<th>1750°F</th>
<th>2000°F</th>
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</thead>
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Permanent set

Significant permanent set for Inconel at 1500°F

20% Compression Tests on Rene 41 Spring Tube

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</table>

No visible permanent set for Rene until 1750°F
Spring Tube Seals: Go-Forward Plan

- Testing to-date has been on spring tubes by themselves
- Work in progress:
  - Fabricating seals with Rene 41 spring tubes for evaluation (Jackson Bond Enterprises, LLC)
- Future work
  - Perform hot compression tests on new seals to evaluate if resiliency improvements translate to full seals
  - Fabricate and evaluate seals with Kanthal A1 wire overbraid instead of Nextel fabric (improved durability)
  - Fabricate and evaluate seals with engineered cores instead of Saffil (improved resiliency and lower flow rates)
High Temperature Seal Preloader Development: TZM Canted Coil Spring

- **Objective:** Develop preload devices that provide/augment seal resiliency at high temperatures

- **Approach:** Pursuing high temperature TZM canted coil springs
  - Unique load vs. displacement curve provides nearly constant force over large range
  - Large working deflection
TZM Canted Coil Spring Development

- **Recent accomplishments**
  - Successfully fabricated split-free 0.025-in. diameter TZM wire with better than expected strength and ductility (Rhenium Alloys, Inc.)
  - Successfully cold-coiled TZM wire into representative spring geometries

- **Work in progress**
  - Wire coating trials using platinum
  - Wire tensile tests at room temperature and 2300°F

- **Future work**
  - Assess platinum coating durability via bend tests at 2300°F in air
  - Coil TZM wire into canted coil configuration and perform compression tests to evaluate resiliency
Arc Jet Test Rig Development

- **Objective**
  - Evaluate seals under simulated reentry heating conditions in JSC arc jet using GRC-developed test fixture

- **Features**
  - Unique GRC design permits testing of different seal and flap designs/materials
  - Modular seal cartridges enable rapid exchange of seal specimens
  - Motor-driven flap moves during testing to simulate flight
  - Adjustable angle-of-attack and yaw angle permit investigation of different flow conditions
  - Instrumentation records temperatures and pressures around seal and flap
  - Cooled subassembly permits time-at-temperature tests

![Typical arc jet test at JSC](image-url)
Arc Jet Test Rig – Status

- Fabrication is underway (Cook Manufacturing Co.)
- Schedule:
  - Complete test fixture fabrication and assembly: 1Q FY06
  - Perform tests at JSC: FY06-07

Cooled copper motor and brake housings

Wax model of sidewall showing cooling channels

Aluminum mockup of leading edge
Summary

- GRC Structural Seals Team developing key seal technologies for NASA’s Exploration Initiative and hypersonics programs
- More details in presentations to follow…