Research Goals

• Develop test method to tribologically brush seal materials

• Evaluate materials to identify potential improvements and trends

• Guide seal material development and selection
Turbine Engine Brush Seal

Photograph of typical brush seal
Tuft (lower) and journal (upper) specimens used to simulate brush seal/shaft sliding contact. Note that tuft wears groove into shaft surface.
Brush Seal Tuft Test Rig

Photograph of high temperature (1400°F) tuft test rig showing specimen arrangement for testing.
Comparison of Simulation to Seal

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Brush Seal</th>
<th>Tuft Test</th>
</tr>
</thead>
<tbody>
<tr>
<td>Loads</td>
<td>0-20 psi (variable)</td>
<td>1-20 psi (constant)</td>
</tr>
<tr>
<td>Speeds</td>
<td>≈ 1000 ft/sec</td>
<td>≈ 100 ft/sec</td>
</tr>
<tr>
<td>Temperatures</td>
<td>75 - 1200°F +</td>
<td>75 - 1400°F +</td>
</tr>
<tr>
<td>Tribological</td>
<td>?</td>
<td>Friction Forces Wear Data</td>
</tr>
</tbody>
</table>

The tuft test can simulate most of the sliding conditions encountered by brush seals. In addition, friction and wear can be easily measured.
Schematic of Tuft Test Rig

- Removable Furnace
- Quartz Lamp Heaters
- Normal Load
- Gimbal
- Counter Weight With Fine Adjustment
- Damper
- RPM
- Fiber Optic Speed Probe
- Drive Belt to Electric Motor

Test Bristle Sample
Test Journal
Bearing Housing

CD-98-77936
Tuft sample is made by packing 960 wires into an Inconel collar. The wires are held in place by welding followed by grinding of the tuft surface to a 45° angle.
Brush Specimen Configuration

Chemical Composition of Wire Samples (wt.\%) 

<table>
<thead>
<tr>
<th></th>
<th>Co</th>
<th>Ni</th>
<th>Cr</th>
<th>Fe</th>
<th>W</th>
<th>Mo</th>
<th>OTHERS (&lt; 6 wt.%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>H25</td>
<td>51</td>
<td>10</td>
<td>20</td>
<td>3</td>
<td>15</td>
<td>—</td>
<td>Mn, Si, C</td>
</tr>
<tr>
<td>I718</td>
<td>—</td>
<td>52.5</td>
<td>19</td>
<td>18.5</td>
<td>—</td>
<td>3</td>
<td>Nb, Ti, Al, C, Cu</td>
</tr>
<tr>
<td>H230</td>
<td>5</td>
<td>52.7</td>
<td>22</td>
<td>3</td>
<td>14</td>
<td>2</td>
<td>Si, Mn, C, Al, B, La</td>
</tr>
<tr>
<td>H242</td>
<td>2.5</td>
<td>60</td>
<td>8</td>
<td>2</td>
<td>—</td>
<td>25</td>
<td>Mn, Cu, Al, Si, C, B</td>
</tr>
</tbody>
</table>

CD-98-77938
Operational Issues

• Vibrations
  – Interfere with accurate data collection and results in variable load

• Solution (s)
  – Add dashpot damper
  – Eliminate run-out using in place grinding system
With this set-up, as coated journal specimens are mounted to the test rig shaft. In-place grinding, shown here, eliminates run-out and ensures a vibration free test.
Results Review

Testing of Solid Lubricant Coatings

Coating Compositions by Weight and Percent Volume of PS212, PS300, HVOF300

<table>
<thead>
<tr>
<th>Coating</th>
<th>Constituent, wt.% (vol. %)</th>
<th>Ni-Co-Cr$_2$C$_3$*</th>
<th>NiCr-Cr$_2$O$_3$**</th>
<th>Ag</th>
<th>BaF$_2$/CaF$_2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>PS212</td>
<td></td>
<td>70 (67)</td>
<td>—</td>
<td>15 (9)</td>
<td>15 (24)</td>
</tr>
<tr>
<td>PS300 and HVOF300</td>
<td></td>
<td>—</td>
<td>80 (80)</td>
<td>10 (6)</td>
<td>10 (14)</td>
</tr>
</tbody>
</table>

* By wt.% contains 54 Cr$_2$C$_3$, 28 Ni, 12 Co, 2 Mo, 2 Al, 1 B, and 1 Si

**By wt.% contains 80 Cr$_2$O$_3$, 16 Ni, and 4 Cr
refs. 4, 5, and 6
Note that the surface features observed after tuft testing match those seen in brush seals. This lends confidence in the relevance of the tuft results.
Friction and wear data summary shows that the choice of wire material has a significant effect on friction. Journal coating can have a dramatic effect on both brush and journal wear.
Data Summary

- Friction largely unaffected by coatings

- Wear of "standard" materials better than "lubricated" coatings

- Data may be influenced by coating microstructure
Summary

• Tuft test excellent screening tool

• Wear data suggests an improvement in 2 + orders of magnitude desired for long life of interference fit

• Tester capable of 1400°F + making it ideal for selection of alternate wire materials (e.g. ceramics)
Relevant Publications

“Preliminary Tuft Testing of Metallic Bristles Versus PS212, PS300, and HVOF300”
NASA TM 107522

“High Temperature Brush Seal Tuft Testing of Selected Nickel-Chrome and Colbalt Superalloys”
NASA TM 107497

“A New Tribological Test for Candidate Brush Seal Materials Evaluation”
NASA TM 106753