Introduction

Abradables (such as Ni-4Cr-4Al/Bentonite) entail a family of coatings which are used throughout jet engines, primarily as sacrificial coatings into which moving components wear. These coatings generally consist a metallic and a non-metallic phase, and contain relatively high porosity levels (up to 40%). The diagram below shows the common areas of application for abradable coatings (yellow highlights) within a jet engine. Typical locations for abradable application include the fan, low pressure compressor, and high pressure compressor sections.

Bentonite abradable coatings are primarily used within the higher operating temperature regions of a gas turbine (up to 815°C / 1500°F). Therefore, this coating is most commonly found on steel and/or titanium components within the compressor section of an engine.

When processing abradable coatings, tight control over spray booth parameters is critical. While bentonite is stable at temperatures commonly seen during thermal spray processing, the non-metallic phases used in other abradable coatings (such as graphite in nickel/graphite or polyester in AlSi/Polyester) can be burned off if too much heat is used during application of the coating. As a result, the coating may be metal-rich, leading to excessive hardness and a loss of the coating’s abradable properties.

Instead of blade tips (or other moving parts) wearing into the coating, the coating hardness will cause the actual component to wear.

TSS Round Robin Laboratories

Buehler Ltd. Chromalloy Gas Turbines
Deloro Stellite Goodrich Power Systems
HEICO Aerospace IMR Test Labs
Praxair Tafa Pratt & Whitney Aircraft
Standard Aero Struers

Figure 1: Cutaway view of a PW2000 engine.
Photo courtesy of Pratt & Whitney
www.pw.utc.com
Metallography

Due to their composite nature, abradable coatings present a number of unique challenges from a metallography standpoint. Abradable coatings are generally quite thick (> 0.040” / 1mm) and very porous. Due to the elevated porosity of these coatings, the nonmetallic phases are often loosely bonded and subject to “pull-out” during metallographic preparation.

Round robin testing was performed on this coating by the member laboratories (see page 2) of the TSS Accepted Practices Committee on Metallography. Each laboratory was provided with a single 1”x3” coupon containing the Metco 312NS coating. Labs were instructed to prepare a minimum of one cold mount and one hot mount sample from this coupon. Preparation recipes were collected from each laboratory, and the findings of each lab are outlined in this document.

Observations

- The majority of the laboratories identified vacuum impregnation of a castable epoxy as a critical step to ensure coating integrity during preparation. These labs indicated that hot mounted samples exhibited elevated porosity relative to their cold mounted counterparts. One laboratory also suggested that the hot mounted sample appeared to be compacted as a result of the heat and pressure associated with hot mounting.

- For those samples which were impregnated by a cold mount epoxy, the coating did not appear to be particularly sensitive to preparation recipe.

- One laboratory did not observe a difference between hot mount and cold mount samples.

Accepted Practice

- Due to thickness and porosity considerations, vacuum impregnation with a low-viscosity cold mount epoxy is the recommended mounting method. To facilitate impregnation with “fast cure” epoxies (which are typically more viscous than “slow cure” epoxies), the resin can be heated (~150°F) prior to mixing with the hardener. Holding the epoxy at elevated temperature for 15-20 minutes should result in a significant improvement in the viscosity of the epoxy.

- As with all thermal spray coatings, sufficient material must be removed during the planar grinding stage to ensure that all sectioning damage has been removed. While all laboratories indicated a planar grinding step, one lab went so far as to specify material removal of 0.060”.
Accepted Practice (continued)

- Preparation recipes supplied by the member laboratories contained a range of recipes ranging from predominately SiC papers (120-4000 grit), to strictly resin bonded diamond discs and polishing cloths. Comparable results were generated in each case. As a result, this coating does not appear to be very sensitive to the preparation recipe employed. Examples of these recipes are provided on the following page.

- See Figures 2-4 for reference optical micrographs of this coating.

Reference


OEM Specifications

- GE B50TF232 Class A
- Honeywell Allied Signal FP 5045AB Type XXV
- Pratt & Whitney PWA 1393
- Rolls-Royce MSRR 9507/45
- Volvo PM 819-54
### Recipe 1

<table>
<thead>
<tr>
<th>Surface</th>
<th>Abrasive &amp; Size</th>
<th>Lubricant</th>
<th>Force (per sample)</th>
<th>Time</th>
<th>Speed (rpm)</th>
<th>Rotation¹</th>
</tr>
</thead>
<tbody>
<tr>
<td>SiC</td>
<td>120 Grit</td>
<td>Water</td>
<td>15N</td>
<td>45 seconds</td>
<td>300</td>
<td>Comp</td>
</tr>
<tr>
<td>SiC</td>
<td>240 Grit</td>
<td>Water</td>
<td>15N</td>
<td>45 seconds</td>
<td>300</td>
<td>Comp</td>
</tr>
<tr>
<td>SiC</td>
<td>400 Grit</td>
<td>Water</td>
<td>15N</td>
<td>45 seconds</td>
<td>300</td>
<td>Comp</td>
</tr>
<tr>
<td>SiC</td>
<td>600 Grit</td>
<td>Water</td>
<td>15N</td>
<td>45 seconds</td>
<td>300</td>
<td>Comp</td>
</tr>
<tr>
<td>SiC</td>
<td>4000 Grit</td>
<td>Water</td>
<td>15N</td>
<td>45 seconds</td>
<td>300</td>
<td>Comp</td>
</tr>
<tr>
<td>Medium-Woven Cotton Cloth</td>
<td>1-micron</td>
<td>Water Soluble Polymer</td>
<td>10N</td>
<td>10 minutes</td>
<td>150</td>
<td>Comp</td>
</tr>
</tbody>
</table>

¹ “Comp” refers to complimentary rotation (sample holder and platen spin in same direction). Contra indicates that the rotations are opposite.

### Recipe 2

<table>
<thead>
<tr>
<th>Surface</th>
<th>Abrasive &amp; Size</th>
<th>Lubricant</th>
<th>Force (per sample)</th>
<th>Time</th>
<th>Speed (rpm)</th>
<th>Rotation¹</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resin Bonded Diamond Disc</td>
<td>70 micron</td>
<td>Water</td>
<td>5 lbs</td>
<td>Continue until 0.060” removal</td>
<td>300</td>
<td>Comp</td>
</tr>
<tr>
<td>Course/Hard Woven Synthetic Silk Cloth²</td>
<td>9-micron diamond</td>
<td>Water Soluble Polymer</td>
<td>5 lbs</td>
<td>5 minutes</td>
<td>150</td>
<td>Comp</td>
</tr>
<tr>
<td>No-nap Cloth³</td>
<td>3-micron diamond</td>
<td>Water Soluble Polymer</td>
<td>5 lbs</td>
<td>3 minutes</td>
<td>150</td>
<td>Comp</td>
</tr>
<tr>
<td>Chem Cloth</td>
<td>0.05-micron alumina</td>
<td>Water</td>
<td>4 lbs</td>
<td>1.5 minutes</td>
<td>120</td>
<td>Comp</td>
</tr>
</tbody>
</table>

² Buehler Ultra-Pol or equivalent course-woven, synthetic silk cloth.
³ Buehler Texmet 1500 or equivalent no-nap cloth.
Optical Micrographs

Figure 2: High magnification (~250X) view of a typical NiCrAl/Bentonite abradable coating with the various phases identified.
Figure 3: Low magnification (~50X) views of a hot mounted (left) and cold mounted (right) NiCrAl/Bentonite coating. This coating also contains a fine nickel-aluminum (Ni-Al) bond coat, which is not discussed in this document. In this case, elevated porosity was observed in the hot mounted sample. Please note that the spray direction is toward the substrate (toward the bottom of these images).
Optical Micrographs

Figure 4: Higher magnification (~200X) views of the same hot mounted (left) and cold mounted (right) specimens. A localized region of pull-out (center of image) can be seen in the hot mounted specimen.