84th Combat Sustainment Wing

Hill AFB HVOF Implementation

HCAT
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**Hill AFB HVOF Implementation**

Surface Finishing and Repair Issues for Sustaining New Military Aircraft Workshop, February 26-28, 2008, Tempe, AZ. Sponsored by SERDP/ESTCP.
Key Personnel in attendance today from Hill AFB

- Ryan Josephson- Landing Gear Lead Engineering PM
- Brian Kemp- HVOF Process Engineer, HAFB
- Ben Smith- HVOF Program Manager, HAFB 309 CMXG
- Preston Miller- Process Engineer- Grinding, HAFB
- Dave Web- HVOF Engineer, ES3
- Richard Vander Straten- HVOF Manager, ES3

Subcontractor support to Hill AFB/ES3

- Metcut
- 3M
- Abbott Machine
AGENDA

- HVOF Implementation – Phase I, II, III
- Qualification Spec
- Diamond Belt Grinding
- Duplex Coating
- Narrow Groove Super Finishing Technique
- C-5 Lower Metering Tube
- B-1 MLG Axle Evaluation
- Questions
Aircraft currently flying with HVOF components

- A-10
- F-16 LW
- F-16 HW
- B-1
- T-38
- F-15 C/D
- F-15E
- KC-135
- C-130
- C-5
- B-52
HVOF IMPLEMENTATION

- HVOF implementation at Hill AFB
  - Program to convert all line of sight chrome plate to HVOF WC-Co coatings on landing gear components
  - Approximately 400 parts with an average of 4 surfaces per part = 1600 surfaces being converted to HVOF coatings

- Combined Effort Between
  - Hill AFB LG Engineering
  - Hill AFB Process Engineering
  - Hill AFB Production
  - ES3 and Support Contractors
HVOF Implementation Program Workflow

- Component selection
- Initiate System Safety Evaluation (SSE)
  - Unique to this program
  - Review part function
  - Review stress level
- 3D Model Part using Pro-E software
- Design and manufacture HVOF application tools/fixtures
- HVOF Prototype Spray
  - Program robot
  - Confirm dimensional attributes are met
  - Document and create HVOF Process Order, route and publish
- Prototype Grind/Super Finish
  - Design/Purchase diamond wheels and super finish equipment, create methods
  - Document and create HVOF Grind Process Orders, route and publish
- Create Tech Order changes, submit for publication
- Production spraying begins (46 parts in production at this time)
HVOF IMPLEMENTATION

- Phase I - Converted 38 components (1-06 to 4-07)
- Phase II - Converting 128 components (1-07 to 6-08)
- Phase III - 238 parts identified, work commencing
HVOF IMPLEMENTATION

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HVOF IMPLEMENTATION
Hill AFB currently has five HVOF booths

- Three additional booths installed in 07
  - Gantry robot, vertical, large swing
  - Gantry robot, horizontal, large swing
  - Gantry robot, multiple turntables, vertical
  - New Booth qualifications began Winter 08
    - Bonds
    - Porosity
    - Hardness
    - Fatigue as required
    - Coating integrity as required

- C-17 Booth installation scheduled for Summer 08
In addition to the implementation program, the following projects were worked in 2007

- Qualification specification
- Diamond Belt Grinding
- Duplex coating development
- Narrow Groove Super Finishing
- C-5 Elimination of scratch induced N₂ leak
Qualification Specification

Qualification specification

- Establish a standard for USAF system qualification
  - Long term goal to qualify vendors for manufacture of spare parts
    - Criteria for HVOF vendors and suppliers to become qualified to spray Air Force LG components
- Air Force specification drawing
  - Process qualification
  - Powder qualification
  - ECD May 08
3M introduced data during the 2007 HCAT meeting indicating a significant reduction in diamond grinding times associated with finishing of HVOF applied WC/Co coatings.

3M and ES3 worked with HAFB personnel to evaluate 3M Trizact™ Diamond Belt grinding of HVOF WC/Co coatings.

- Initial Tests Evaluated:
  - Diamond belt grinding efficiency (Speed)
  - The reduced grinding burn potential on 300M substrates.
  - Ease of surface finish attainment
  - Effectiveness of correcting induced out of round conditions.

Base metal preparation and Hard Chrome stripping, grinding and finishing methods were also evaluated with 3M Trizact™ Ceramic belt technology.
Diamond Belt Grinding

Two condemned parts were diamond belt finished to determine cutting efficiency and quality of surface finish.

B1-B Nose Landing Gear Axle Journal Locations

C-5 Upper Shaft #1 Journal Locations

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Diamond Belt Grinding

Equipment configuration

Abbot Machine Belt Grinding Housing Attachment for 3M Belts
Side View

Standard aluminum oxide wheel
3M diamond belt
WC/Co coated journals, B-1
NMG Axle
Results-

<table>
<thead>
<tr>
<th>Journal #</th>
<th>HAFB Operator Actual Grind Time on Part</th>
<th>Test Diamond Belt Grinding Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>J1</td>
<td>30 min</td>
<td>2 min</td>
</tr>
<tr>
<td>J2</td>
<td>30 min</td>
<td>2 min</td>
</tr>
<tr>
<td>J3</td>
<td>2 hrs</td>
<td>5.4 min</td>
</tr>
<tr>
<td>J3 (center)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Estimated time saved per part is 3.75 hours (actual time on part)
Diamond Belt Grinding

- **Conclusion of results**
  - Dramatic reduction of grinding times with belt compared to standard wheel
  - Surface finishes were very good without great degree of optimization
  - Burns were not found where most aggressive grinding took place
  - Belt change took approximately 2.5 minutes

- **Next steps**
  - Determination of optimized methods to ensure grinding burns will not occur
  - Limited fatigue testing
  - Write specification
  - Install for use
HVOF Duplex Coating

- Duplex coating to be used to replace chrome/nickel repair use in landing gear
  - Phase I showed promising results
    - Briefed in Spring 04 HCAT
    - On HCAT web page
  - Phase II to investigate a variety of powders for the build-up coat
    - Top coat to be WC-Co
    - Initial testing to include
      - Bond plugs
      - Porosity
      - Hardness
    - Qualification testing to include
      - Fatigue
      - Coating integrity
      - Corrosion
      - Stripping
Narrow Groove Super Finishing

Testing to investigate interface wear of landing gear components using different finishing techniques
Super Finishing of Narrow Groove

| Surface Finish Parameters for seal surfaces Per Air Force Drawing 200310642 Rev A |
|---------------------------------|-----------------|
| Ra                             | 4 micro-inch Max |
| Rp                             | 8 micro-inch Max |
| Rz                             | 40 micro-inch Max |
| Tp                             | 10-90% at c=5% and 0.25 Rz |

C-5 Spline Tube Narrow Groove Super Finished
Problem Description

- The C-5 Lower Metering Tube is part of a high pressure nitrogen system which utilizes the C-5 Floating Carrier Piston (P/N 4G13514-101) an anodized aluminum sleeve, which slides up and down the length of the C-5 Lower Metering Tube.

- The C-5 Lower Metering Tube (P/N 4G13518-101) has a history of leaks due to longitudinal scratches. The Lower Metering Tube develops scratches on its working surfaces both during new part assembly and during use in the field.

- The scratches are created by imbedded particles in the seals of the C-5 Floating Carrier Piston and/or anodize defects in the surface of the C-5 Floating Carrier Piston. The Lower Metering Tube is stainless steel or flash chrome and both surfaces have become scratched in service.

- To prevent constant field rework and frequent part condemnation ES3 was asked to determine cause of scratches and to evaluate the use of High Velocity Oxygen Fuel (HVOF) applied coatings to eliminate them. Cost was a consideration so three materials were considered.

Three images (35X) of damage on mating surface, creating fine line scratches
C-5 Lower Metering Tube

HVOF Processing Parameters (JP-8000 System)

<table>
<thead>
<tr>
<th>Powder Composition</th>
<th>WC-Co</th>
<th>CrC-NiCr</th>
<th>NiCr</th>
</tr>
</thead>
<tbody>
<tr>
<td>83%WC-17%Co</td>
<td>83%WC-17%Co</td>
<td>75%Cr-25%NiCr</td>
<td>Ni-Bal, 14.5%Cr, 4.5%Fe, 4.5%Si, 3.2%B</td>
</tr>
<tr>
<td>Spray Rate</td>
<td>10.5 lbs/hr</td>
<td>10 lbs/hr</td>
<td>10 lbs/hr</td>
</tr>
<tr>
<td>Carrier Gas Flow Rate</td>
<td>20 scfh</td>
<td>21 scfh</td>
<td>26 scfh</td>
</tr>
<tr>
<td>Fuel Flow Rate</td>
<td>5.3 gph</td>
<td>6 gph</td>
<td>8.8 gph</td>
</tr>
<tr>
<td>Oxygen Flow Rate</td>
<td>1900 scfh</td>
<td>1850 scfh</td>
<td>1950 scfh</td>
</tr>
<tr>
<td>Oxygen Supply Pressure</td>
<td>128 psi</td>
<td>136 psi</td>
<td>133.4 psi</td>
</tr>
<tr>
<td>Traverse Rate</td>
<td>4 mm/s</td>
<td>4 mm/s</td>
<td>4 mm/s</td>
</tr>
<tr>
<td>Nozzle Length</td>
<td>6 in</td>
<td>6 in</td>
<td>4 in</td>
</tr>
<tr>
<td>Stand off distance</td>
<td>15.5 in</td>
<td>14 in</td>
<td>15 in</td>
</tr>
<tr>
<td>Max Part Temperature</td>
<td>350 °F</td>
<td>350 °F</td>
<td>350 °F</td>
</tr>
<tr>
<td>Total coating thickness</td>
<td>.0092 inch</td>
<td>.0083 inch</td>
<td>.0088 inch</td>
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</tbody>
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C-5 Lower Metering Tube

- Scratch Test WC/Co vs EHC

<table>
<thead>
<tr>
<th>Grit</th>
<th>WC-Co</th>
<th>Chrome</th>
</tr>
</thead>
<tbody>
<tr>
<td>400 Grit</td>
<td>2.4 Ra</td>
<td>.96 Ra</td>
</tr>
<tr>
<td>240 Grit</td>
<td>1.72 Ra</td>
<td>5.8 Ra</td>
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</tbody>
</table>

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Scratch Test CrC/NiCr vs EHC

400 Grit: CrC-NiCr

240 Grit: CrC-NiCr

<table>
<thead>
<tr>
<th></th>
<th>Chrome</th>
<th>CrC-NiCr</th>
</tr>
</thead>
<tbody>
<tr>
<td>Super Finish</td>
<td>1.03 Ra</td>
<td>1.03 Ra</td>
</tr>
<tr>
<td>400 Grit</td>
<td>5.8 Ra</td>
<td>2.04 Ra</td>
</tr>
<tr>
<td>240 Grit</td>
<td>7.18 Ra</td>
<td>3.79 Ra</td>
</tr>
</tbody>
</table>
C-5 Lower Metering Tube

- Scratch Test NiCr vs EHC

400 Grit: NiCr

<table>
<thead>
<tr>
<th></th>
<th>Chrome</th>
<th>NiCr</th>
</tr>
</thead>
<tbody>
<tr>
<td>Super Finish</td>
<td>1.36 Ra</td>
<td></td>
</tr>
<tr>
<td>400 Grit</td>
<td>5.8 Ra</td>
<td>7.47 Ra</td>
</tr>
<tr>
<td>240 Grit</td>
<td>7.18 Ra</td>
<td>14.4 Ra</td>
</tr>
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</table>
Scratch Test conclusions

- The cause of the initial scratches could not be determined. Damage was noted on the mating part, imbedded particles in the seal were not found. As a result both 240 and 400 grit aluminum oxide cloth was used to create a controlled, worst case test.

- As expected, the WC/Co performed better than the CrC/NiCr and NiCr coatings

- The application cost differences between the three coatings was relatively insignificant based on performance levels

- Currently both the Lower Metering Tube and its corresponding part on the C-5 Nose Landing Gear are being converted from Chrome to an HVOF applied WC/Co eliminating the in-service failures.
The axles (P/N 1881B85) were installed in Dec 06. They have performed great while in service, due to the high brake removal costs, the axles have not been removed for further inspection to date.

The axles will be inspected during the next major Phase inspection for AC 134.

The most notable item is the axle beam bushings had to be reseated before the installation of HVOF axles in 06.

In every past case, the axle beam bushings migrate with chrome axles and they re-migrate in service very shortly after being reseated.

The HVOF axles, in service since Dec 06, have not encountered axle beam bushing migration.

When the axle bushings migrate, the brake swivels in a direction it was not designed for and may be cause of failures which may have led to major fire mishaps.

This is very important, and a major reason for switching to HVOF 100% at both Depot and for new axles spare buys.

An Engineering Change Order was recently created, new parts will have HVOF coatings only, no chrome.
Questions??