EA-6B HVOF-Coated Landing Gear: Post-Deployment Inspection Results

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Outline

• Background
• HVOF Procedure
• Previous Results
• EA-6B Results
• Future Work
Background

• Electrolytic hard chrome (EHC)
  – Wear resistance
  – Corrosion resistance

• Uses hexavalent chromium (Cr$_{6}^{+}$)
  – Carcinogen, OSHA controlled
  – Expensive to dispose
Background

• IPT’s for chrome alternatives
  – HCAT: Hard Chrome Alternatives Team
  – ESTCP: Environmental Strategic Technology Certification Program
  – JG-PP: Joint Group on Pollution Prevention
• Validation Project: HVOF Thermal Spray
  – Environmentally acceptable
  – Superior performance to EHC
Background

• High Velocity Oxygen Fuel (HVOF)
  – Environmental Coatings
  – Wear Resistant Coatings
• FRCSE Applications
  – F404, F414, J52, TF34
  – Drive shafts, combustor cans
HVOF Procedure

• HVOF Process
  – Combustion of fuel gas and oxidizer (accelerant gas)
  – Feed powder into supersonic gas stream
  – Impact particles onto surface with high temperature and high velocity
HVOF Procedure

• HVOF Advantages
  – Low porosity
  – High hardness
  – High adhesive bond strength
  – Higher density

• Fits into NAVAIR LEAN Processes
  – Increases throughput
  – Decrease turn around time
  – Reduce costs and simplifies work processes
HVOF Procedure

• HVOF Coating
  – METCO DIAMALLOY 2005 NS
    • 83WC-17Co powder mixture
  – Advantages over EHC
    • Hardness
    • Wear Resistance
    • Fatigue Resistance
HVOF Procedure

• Concerns for HVOF
  – Unknown response for:
    • Carrier-based landings
    • Saltwater corrosive environments
    • Coating susceptible to aqueous and gaseous corrosion
  – Require validation and demonstration in actual naval environments
Previous Work

• Timeline
  – 10/1999: EA-6B Landing Strut HVOF coated
    • Spalling issues
    • High strains at large stresses
    • Flight clearance on hold
  – 09/2004: EA-6B successfully landed on USS Carl Vinson
    • HVOF coating successful
    • Major project milestone
EA-6B Landing Gear

• Current Landing Gear Strut Piston
  – AISI 4330 V Mod
    • σ_Y = 180-185 ksi
    • σ_{UTS} = 220-240 ksi
  – Coated
    • METCO DIAMALLOY 2005 NS
  – Ground finished
    • Ra = 8-16 μin
  – Superfinished
    • Ra = 2-4 μin
EA-6B Results

• EA-6B (163395) Tours of Duty
  – 2004-2005 VAQ 138/142
  – 2005-2009 VAQ 209 (Reserve Squad)

• Relatively short time-at-sea
  – 153 Catapult shots
  – 154 Arrested landings

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<tr>
<th>Year</th>
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<td>2008</td>
<td>109</td>
<td>54</td>
</tr>
<tr>
<td>2009</td>
<td>70</td>
<td>38</td>
</tr>
<tr>
<td>Total</td>
<td>1552</td>
<td>571</td>
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</table>
EA-6B Results

• Strut Disassembly
  – Performed due to leak in lower seal

HVOF coated axle and piston during tear down

HVOF coated piston during disassembly
EA-6B Results

• Collar Assembly
  – No indications of wear or other damage
EA-6B Results

• Collar Assembly
  – Roughness check

  HVOF coated area
  Surface finish Ra = 7 μin;  
  Ra = 10-11 μin at outer most edge shown

  Chrome plated area
  Surface finish Ra = 6-7 μin
EA-6B Results

• HVOF Axle

HVOF on Axle Journals, edges in good condition, coating appeared to be in very good condition
EA-6B Results

• Collar Bushing
  – The original item was discarded after disassembly
  – Operators reported part corroded
  – Corrosion typical for this part in service.
EA-6B Results

• Failed Seal
  – Seal wear ("flat spots") at 0° and 180°
  – Possible service in Middle East: sand entrapment / intrusion issues
  – Failure analysis will be performed by Trelleborg Sealing Solutions (POC: John Nash)
EA-6B Results

• Strut Disassembly - Barrel
  – Visual Inspection
    • Roughness Check
  – Clean
  – Vapor Degrease
  – Fluorescent Penetrant Inspection (FPI)
  – Re-superfinish
    • Recheck roughness

Disassembly of collar and seal retainer in location of leak
EA-6B Results

• HVOF Piston Surface
  – Roughness check

Surface finish measured Ra 3-4 μin

Surface finish Ra 8-10 μin in center section

Surface finish measured Ra 11-18 μin in area 2” to 8” from base
EA-6B Results

• HVOF Piston Surface
  – Upper Seal Area

Finish Roughness (Ra) = 2-3 μin
EA-6B Results

• HVOF Piston Surface
  – Lower Seal Area
EA-6B Results

• Corrosion issues
  – FPI initially found no indications
  – After superfinishing, pits found in the coating
  – Co binder highly susceptible to salt corrosion
Future Work

• First/Best option: Keep Current Coating
  – Re-superfinish current pitted HVOF coating

• Goal: Remove pits, establish Ra of 2-4 μin
  – Want coating thickness above minimum tolerance
  – If not, then part is in a state of Functionally Unusable Component Technology
Future Work

• Second/Last option: **Apply New Coating**
  – Grind pitted coating to parent metal
  – Recoat the part to return to service
    • Apply chrome coating -OR-
    • Reapply HVOF coating

• Complications
  – Future HVOF coating choice
    • DIAMALLOY 2005: 83WC-17Co
    • AMDRY 5843 (AMS 2447-9): 86WC-10Co-4Cr
  – FUNDING!?!?
    • “Hubba, hubba, hubba, money, money, money…who do you love?”
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Questions?

Due to NAVAIR restrictions, responses to questions are not authorized.