84th Combat Sustainment Wing

Hill AFB HVOF Implementation

HCAT
23 Jan 07

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Teamwork - Integrity - Excellence
Report Documentation Page

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29

19a. NAME OF RESPONSIBLE PERSON

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18
Key Personnel in attendance today from Hill AFB

- Ron Montgomery - HW Landing Gear Supervisor (not Chad’s)
- Chad Hogan - Landing Gear Lead Engineering PM
- Brian Kemp - Process Engineer, HVOF Project
- Clint Forrest - ES3 Landing Gear Engineer
- Craig Edwards - ES3 Landing Gear Engineer
- Richard Vander Straten - ES3 HVOF Program Manager

Subcontractor support to Hill AFB/ES3

- Metcut
- Kamatics
- Keeley Aerospace
- HerouxDevtek
AGENDA

- HVOF Implementation
- Qualification Spec
- Diamond Grinding
- Duplex Coating
- Bearing Wear Test
- Questions
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

HVOF Program Workflow

- Component selection
- Initiate System Safety Evaluation (SSE)
  - Unique to this program
  - Review part function
  - Review stress level
- Design and manufacture tools/fixtures
- Prototype Spraying
  - Adjustments made as needed
- Final Spray off and acceptance
- Initiate tech order changes
- Production spraying begins
Field Service Evaluations (FSE) underway on B-1 MLG Axles

- Working on FSE for full ship-set on F-16
HVOF IMPLEMENTATION

- Approximately 40 components converted at this time
  - Approximately 300 components flying with HVOF coating
- Aircraft currently flying with HVOF components
  - A-10
  - B-1
  - B-52
  - C-5
  - C-130
  - F-15 C/D
  - F-16 HW
  - F-16 LW
  - KC-135
  - T-38
Prioritized Parts Examples Cargo Bomber
Prioritized Parts Examples Fighter Trainer
Hill AFB currently has two HVOF production booths

- Three additional booths on order
  - Installation June 07
  - Booth qualification begin summer 07
    - Bonds
    - Porosity
    - Hardness
    - Fatigue as required
    - Coating integrity as required
- One additional booth thereafter per year to 2012
In addition to implementation program following projects being worked

- Qualification specification
- Diamond Grinding of 300M steel substrate
- Duplex coating development
- Bearing wear testing
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 Spring 07
Diamond Grinding

- **Diamond grinding**
  - Investigating grinding 300M steel with same diamond wheel used on HVOF coatings
  - Currently aluminum oxide wheels used for base metal and chrome plate, diamond wheels used for HVOF WC-Co coating
    - Using one type of wheel will prevent wheel change-out for grinding HVOF coatings
    - 180, 220 and 320 grit wheel investigated

- **MIL-STD-866, Grinding of High Strength Steels used as baseline**
  - Typical process flow
    - Surface finish measurement
    - Conduct grind operation
    - Surface finish measurement
    - Conduct temper etch
    - Conduct Barkhausen Noise Inspection (BNI)
Diamond Grinding

Table 1: Grinding Specimens

<table>
<thead>
<tr>
<th>Description</th>
<th>P/N</th>
<th>Material</th>
<th>Dimensions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cylindrical</td>
<td>SK0425</td>
<td>300M</td>
<td>2&quot;OD x 1.375&quot;ID x 8&quot;L</td>
</tr>
<tr>
<td>Stepped</td>
<td>SK0426</td>
<td>300M</td>
<td>2&quot;OD x 1.375&quot;ID x 4&quot;L to 3&quot;OD x 1.375&quot;ID x 4&quot;L (0.090&quot;/0.125&quot;transition radius)</td>
</tr>
<tr>
<td>Flat</td>
<td>SK0427</td>
<td>300M</td>
<td>3&quot;W x 5&quot;L x 0.125&quot;/0.200&quot;T</td>
</tr>
</tbody>
</table>
Diamond Grinding

- Initial results look very promising
- More work needs to be done
  - Contour grinding
- Draft copy of Air Force specification for Diamond Grinding of 300M steel is complete
  - Contour grinding not included
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
Bearing Wear Testing

- Testing to investigate interface wear of landing gear components using different finishing techniques
  - HVOF and Chrome tested
  - Standard landing gear joint
    - Standard Al-Ni-Bronze bushing (AMS 4640)
      - Greased
      - Un-greased
    - KAron B
      - Greased
      - Un-greased
  - Shock Strut bearing
    - KAron VS
      - Lubricated with hydraulic fluid
    - Al-Ni-Bronze (AMS 4640)
      - Lubricated with hydraulic fluid
Bearing Wear Testing

- **Bearing Material**
  - AMS 4640 (15 ea 10KSI & 15 ea 30 KSI)
  - Liner KAron B (30 KSI Journal Bearing 30 ea)
  - Liner KAron VS (10 KSI Shock Strut Bearing 15 ea)

- **Pin Wear Coating**
  - Chrome (15 ea)
  - HVOF (60 ea)

- **Lubrication**
  - MIL-PRF-81322 (Journal Bearing)
  - Hydraulic Fluid

- **Finish Requirements**
  - Ra=8 max (Ground Pins)
  - Ra=4 max, Rp=8 max, Rz=40 max, Tp=70-90% @ C=5% & .25Rz (Super-finished/800 Grit Pins)
Bearing Wear Testing

Finishing Techniques
- Chrome 220 Grit Aluminum-Oxide Ground (15 ea)
- HVOF 220 Grit Diamond Ground (15)
- HVOF 220 Grit Diamond Ground- Stone Super-finished (15)
- HVOF 220 Grit Diamond Ground- Belt Super-finished (15)
- HVOF 800 Grit Diamond Ground (15)

Photo Provided by Supfina
Test Set-Up and Loads

- **Journal Bearing Test**
  - Bearing Pressure 30 KSI
  - Oscillatory Motion ± 25°
  - 25,000 Cycles
  - Bearing ID 1.000 inch
  - Bearing Width 0.500 inch

Images Provided by Kamatics
Test Set-Up and Loads

- **Shock Strut Bearing Test**
  - Bearing Pressure 10 KSI
  - Linear Sliding Motion ± 1.0 inch @ 17 cycles/min
  - 25,000 Cycles
  - Bearing ID 1.000 inch
  - Bearing Width 0.500 inch

Images Provided by Kamatics
# Test Results

## Journal Bearings AMS 4640- Lubricated

<table>
<thead>
<tr>
<th>Description</th>
<th>220 Grit Wheel Chrome Finish 1</th>
<th>220 Grit Wheel HVOF Finish 1</th>
<th>Super-Finish Stone HVOF Finish 2</th>
<th>Super-Finish Belt HVOF Finish 2</th>
<th>800 Grit Wheel HVOF Finish 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Serial #</td>
<td>SAMPLE 1</td>
<td>KPD4536-37 / KPD4536-33</td>
<td>KPD4536-11</td>
<td>KPD4536-26</td>
<td>KPD4536-14</td>
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<tr>
<td>Bushing Material</td>
<td>AMS4640 - BARE</td>
<td>AMS4640 - BARE</td>
<td>AMS4640 - BARE</td>
<td>AMS4640 - BARE</td>
<td>AMS4640 - BARE</td>
</tr>
<tr>
<td>Ra (μm.) Before</td>
<td>6.8</td>
<td>3.3 / 3.6</td>
<td>3.6</td>
<td>2.1</td>
<td>2.5</td>
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<tr>
<td>Ra (μm.) After</td>
<td>172.6</td>
<td>68.2 / 13.1</td>
<td>103.8</td>
<td>128.5</td>
<td>7.0000</td>
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<td>Shaft OD Before</td>
<td>0.9996</td>
<td>0.9998 / 1.0004</td>
<td>0.9998</td>
<td>0.9997</td>
<td>0.9999</td>
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<tr>
<td>Shaft OD After</td>
<td>1.0005 Build up</td>
<td>1.0005 BdUp / 1.0005 BdUp</td>
<td>1.0008 Build up</td>
<td>1.0050 Build up</td>
<td>1.0001 Build up</td>
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<tr>
<td>Bushing ID Before</td>
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<td>1.0000 / 1.0000</td>
<td>1.0000</td>
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<td>Bushing ID After</td>
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<td>1.0100 / 1.0200</td>
<td>Destroyed</td>
<td>Destroyed</td>
<td>1.0100</td>
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<tr>
<td>Total Wear</td>
<td>0.035</td>
<td>0.0100 / 0.0200</td>
<td>0.0900</td>
<td>0.0200</td>
<td>0.0100</td>
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<tr>
<td>Total Cycles</td>
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<td>10,200 / 10,200</td>
<td>5,256</td>
<td>8,000</td>
<td>10,200</td>
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</tbody>
</table>
## Test Results

### Journal Bearings KAron B- Lubricated

<table>
<thead>
<tr>
<th>Description</th>
<th>220 Grit Wheel Chrome Finish 1</th>
<th>220 Grit Wheel HVOF Finish 1</th>
<th>Super-Finish Stone HVOF Finish 2</th>
<th>Super-Finish Belt HVOF Finish 2</th>
<th>800 Grit Wheel HVOF Finish 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Serial #</td>
<td>SAMPLE 2</td>
<td>KPD4536-01 / KPD4536-29</td>
<td>KPD4536-03</td>
<td>KPD4536-10</td>
<td>KPD4536-04</td>
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<tr>
<td>Bushing Material</td>
<td>KAron B</td>
<td>KAron B</td>
<td>KAron B</td>
<td>KAron B</td>
<td>KAron B</td>
</tr>
<tr>
<td>Ra (μin.) Before</td>
<td>5.6</td>
<td>2.5 / 3.4</td>
<td>3.5</td>
<td>2.8</td>
<td>2.9</td>
</tr>
<tr>
<td>Ra (μin.) After</td>
<td>4.5</td>
<td>3.0 / 3.1</td>
<td>2.7</td>
<td>2.7</td>
<td>2.5</td>
</tr>
<tr>
<td>Shaft OD Before</td>
<td>0.9997</td>
<td>1.0001 / 1.0002</td>
<td>0.9995</td>
<td>0.9998</td>
<td>0.9997</td>
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<tr>
<td>Shaft OD After</td>
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<td>1.0001 / 1.0002</td>
<td>0.9995</td>
<td>0.9998</td>
<td>0.9997</td>
</tr>
<tr>
<td>Bushing ID Before</td>
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<td>1.0000 / 1.0000</td>
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<tr>
<td>Bushing ID After</td>
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<td>1.0010 / 1.0008</td>
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<td>Total Wear</td>
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<td>0.0010 / 0.0008</td>
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<td>0.0010</td>
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<td>25,000 / 25,000</td>
<td>25,000</td>
<td>25,000</td>
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</table>
# Test Results

## Journal Bearings KArön B- Dry

### 30 KSI Bearing Pressure Comparison Test Dry

<table>
<thead>
<tr>
<th>Description</th>
<th>220 Grit Wheel Chrome Finish 1</th>
<th>220 Grit Wheel HVOF Finish 1</th>
<th>Super-Finish Stone HVOF Finish 2</th>
<th>Super-Finish Belt HVOF Finish 2</th>
<th>800 Grit Wheel HVOF Finish 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Serial #</td>
<td>Sample 1 / Sample 4</td>
<td>KPD4536-06 / KPD4536-16</td>
<td>KPD4536-35</td>
<td>KPD4536-34</td>
<td>KPD4536-02 / KPD4536-39</td>
</tr>
<tr>
<td>Bushing Material</td>
<td>KArön B</td>
<td>KArön B</td>
<td>KArön B</td>
<td>KArön B</td>
<td>KArön B</td>
</tr>
<tr>
<td>Ra (µin.) Before</td>
<td>6.1 / 5.9</td>
<td>3.5 / 3.4</td>
<td>2.5</td>
<td>2</td>
<td>2.6 / 2.6</td>
</tr>
<tr>
<td>Ra (µin.) After</td>
<td>5.2 / 5.1</td>
<td>2.8 / 3.1</td>
<td>2.1</td>
<td>1.6</td>
<td>2.6 / 2.1</td>
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<tr>
<td>Shaft OD Before</td>
<td>0.9995 / 0.9995</td>
<td>1.0000 / 0.9998</td>
<td>0.9996</td>
<td>1.0000</td>
<td>1.0002 / 0.9997</td>
</tr>
<tr>
<td>Shaft OD After</td>
<td>0.9995 / 0.9995</td>
<td>1.0000 / 0.9998</td>
<td>0.9996</td>
<td>1.0000</td>
<td>1.0002 / 0.9997</td>
</tr>
<tr>
<td>Bushing ID Before</td>
<td>1.0000 / 1.0000</td>
<td>1.0000 / 1.0000</td>
<td>1.0000</td>
<td>1.0002</td>
<td>1.0000 / 1.0005</td>
</tr>
<tr>
<td>Bushing ID After</td>
<td>1.0005 / 1.0010</td>
<td>1.0007 / 1.0009</td>
<td>1.0000</td>
<td>1.0002</td>
<td>1.0010 / 1.0010</td>
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<tr>
<td>Total Wear</td>
<td>0.0005 / 0.0010</td>
<td>0.0007 / 0.0009</td>
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<td>0</td>
<td>0.0010 / 0.0005</td>
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</tbody>
</table>
## Test Results

**Shock Strut Bearings AMS 4640-Lubricated**

<table>
<thead>
<tr>
<th>Description</th>
<th>220 Grit Wheel Chrome Finish 1</th>
<th>220 Grit Wheel HVOF Finish 1</th>
<th>Super-Finish Stone HVOF Finish 2</th>
<th>Super-Finish Belt HVOF Finish 2</th>
<th>800 Grit Wheel HVOF Finish 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Serial #</td>
<td>SAMPLE 1</td>
<td>KPD4547-16</td>
<td>KPD4547-23</td>
<td>KPD4547-07</td>
<td>KPD4547-09</td>
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<td>Bushing Material</td>
<td>AMS4640 - BARE</td>
<td>AMS4640 - BARE</td>
<td>AMS4640 - BARE</td>
<td>AMS4640 - BARE</td>
<td>AMS4640 - BARE</td>
</tr>
<tr>
<td>Ra (µin.) Before</td>
<td>5.7</td>
<td>2.8</td>
<td>3.5</td>
<td>2.3</td>
<td>2.4</td>
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<tr>
<td>Ra (µin.) After</td>
<td>10.7</td>
<td>22.3</td>
<td>4.6</td>
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<td>5.1</td>
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<td>Shaft OD Before</td>
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<td>0.9997</td>
<td>0.9995</td>
<td>0.9996</td>
<td>0.9995</td>
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<tr>
<td>Shaft OD After</td>
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<td>0.9996</td>
<td>0.9995</td>
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<td>Bushing ID Before</td>
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<td>1.0000</td>
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<tr>
<td>Bushing ID After</td>
<td>1.0020</td>
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<td>1.0010</td>
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<td>1.0030</td>
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<td>Total Wear</td>
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</table>
**Test Results**

**Shock Strut Bearings Karon VS - Lubricated**

<table>
<thead>
<tr>
<th>Description</th>
<th>220 Grit Wheel Chrome Finish 1</th>
<th>220 Grit Wheel HVOF Finish 1</th>
<th>Super-Finish Stone HVOF Finish 2</th>
<th>Super-Finish Belt HVOF Finish 2</th>
<th>800 Grit Wheel HVOF Finish 2</th>
</tr>
</thead>
<tbody>
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<td>Karon VS</td>
<td>Karon VS</td>
<td>Karon VS</td>
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<tr>
<td>Ra (μin.) Before</td>
<td>5.5</td>
<td>3.2</td>
<td>2.9</td>
<td>2.9</td>
<td>3.6</td>
</tr>
<tr>
<td>Ra (μin.) After</td>
<td>2.1</td>
<td>3.0</td>
<td>2.5</td>
<td>2.9</td>
<td>2.5</td>
</tr>
<tr>
<td>Shaft OD Before</td>
<td>0.9996</td>
<td>0.9998</td>
<td>0.9996</td>
<td>0.9995</td>
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<tr>
<td>Shaft OD After</td>
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<td>1.0000</td>
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<tr>
<td>Bushing ID Before</td>
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<td>1.0000</td>
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<tr>
<td><strong>Total Wear</strong></td>
<td><strong>0.0060</strong></td>
<td><strong>0.0040</strong></td>
<td><strong>0.0040</strong></td>
<td><strong>0.0030</strong></td>
<td><strong>0.0020</strong></td>
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<tr>
<td><strong>Total Cycles</strong></td>
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<td><strong>25,000</strong></td>
<td><strong>25,000</strong></td>
<td><strong>25,000</strong></td>
</tr>
</tbody>
</table>
Conclusions

- **Lubricated AMS 4640 Journal Bearing Testing @ 30 KSI**
  - HVOF super-finished pins performed poorly
    - Super-finishing does not improve wear rate
    - AMS 4640 bearing compromised during test
    - Significant surface finish degradation
    - Pin size enlarged - material transfer
  - HVOF pins finished with 220 and 800 grit wheels performed well
  - Chrome pin finished with 220 grit wheel had higher wear

- **Lubricated KAron B Journal Bearing Testing @ 30 KSI**
  - Super-finishing HVOF does not appear to improve wear rate
  - Better wear properties than AMS 4640
  - Chrome and HVOF performance equivalent

- **Dry KAron B Journal Bearing Testing @ 30 KSI**
  - Super-finishing HVOF does improve wear rate
  - Best combination for high loaded Joint
Conclusions

- **Lubricated AMS 4640 Shock Strut Bearing Testing @ 10 KSI**
  - All process exhibited equivalent wear rates except 220 grit HVOF (nearly double)
  - Baseline chrome AMS 4640 bearing performed as well as any
  - 220 grit wheel Belt super-finish had significant surface degradation

- **Lubricated KAron VS Journal Bearing Testing @ 10 KSI**
  - Super-finishing does appear to improve wear rate
  - KAron VS similar wear properties to AMS 4640
  - Surface finish degradation less on KAron VS

- **All processes tested exhibited similar performance to the baseline**

- **Tests results once approved by USAF will be placed on HCAT web site**
Questions??