
Presented by: Brad Martin
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Overview

- HVOF Implementation process
- HVOF Implementation progress
- Other engineering services
HVOF Implementation Process

- All line-of-site Chrome plated high strength steel components are targeted
- **3-Step Component Approval:**
  - 3D Modeling
  - Stress Analysis
  - System Safety Evaluation (SSE)
- **6-Step Part Conversion:**
  - HVOF Fixture Design
  - HVOF Fixture Fabrication
  - HVOF Spray prototype
  - Grind Prototype
  - Process Order Digital Display System (PODDS)
- **Technical Documentation:**
  - Technical Order Update
  - Engineering Change Orders (ECO)
HVOF Implementation Process

- **Step 1 of 3 - 3D Modeling:**
  - Used for component stress analysis (later used for fixture design)
  - Generated from original prints
  - Pro-E or Solidworks

- **Step 2 of 3 - Stress Analysis:**
  - Each component must go through a stress analysis at coating location
  - Performed using limit loads to ensure function under normal stress conditions
  - Not all components identified are suitable for HVOF conversion
    - High stress thin walled (spallation)
HVOF Implementation Process

• **Step 3 of 3 - System Safety Evaluation (SSE):**
  • An SSE must be performed on each component
    • Formal review of safety related changes to original part configuration
  • Separated into two separate cases:
    • General case SSE:
      • Limit stress are below material yield or 226 KSI and at least one of the following:
      • HVOF and EHC finished thickness are equal
      • HVOF is replacing an existing flame spray repair
      • HVOF is specified by the OEM
    • Special case SSE:
      • All others not defined by the General case
HVOF Implementation Process

- Step 1 of 6 - HVOF Fixture Design:
  - Uses previously generated 3D model
  - Fixtures are designed with consideration of booth(s) to be used including:
    - Movement restrictions and limitations.
    - Cost effective manufacturing methods
    - Ease of overspray stripping
    - Ease of operator use

- Step 2 of 6 - HVOF Fixture Fabrication:
  - Fixture validation:
    - Dimensional inspection
    - Fit check on actual component
  - Fixture delivery:
    - Custom container including all hardware, fixture blueprints, tolerance stack and run out sheets
    - Recommended spare parts lists
    - Instruction manual
HVOF Implementation Process

- **Step 3 of 6 - HVOF Spray Prototype:**
  - Prototyping ensures:
    - Application program incorporates all optimized coating methods
    - Ensures part cooling cycles are correct
    - Verifies actual part processing times
    - Verifies tolerances

- **Step 4 of 6 - HVOF Grind Prototype:**
  - Prototyped component is diamond ground
  - Ensures final dimensional and surface finish attributes are achievable within optimized grinding parameters
  - Grinding accomplished per Air Force drawing 200310642
HVOF Implementation Process

- **Step 5 of 6 - Process Order Digital Display System (PODDS):**
  - Process Orders are the detailed, step-by-step instructions for operators to use to ensure process repeatability
  - The digital instruction database is available on line for all operators

- **Step 6 of 6 – Technical Documentation:**
  - Technical Orders updated
  - Engineering Change Orders:
    - Ensures new procurement using HVOF WC/Co in lieu of EHC
    - Converting components ensures future use of EHC will be reduced, thus lowering hexavalent chrome volume and related exposure issues
HVOF Implementation Progress

[Bar chart showing the number of parts converted, in process, and identified for different aircraft models: A-10, T-38, F-15, F-16, C-5, KC-135, E-3, C-130, B-1, B-52.]
Other Engineering Services

- Duplex Coating

- **Finishing Methods:**
  - Diamond Grinding
  - Superfinishing
  - Diamond Belt Finishing

- **Stripping Methods:**
  - Rochelle Salt
  - Pulsed Water Jet

- **WC/Co Alternatives**

- **WC/Co & WC/Co/Cr Qualification**
Duplex Coating:

- The optimized HVOF WC/Co coatings are currently limited to 0.003”-0.015”

- Coatings thicker than 0.015” are periodically needed

- Duplex coating enables application up to 0.030” while maintaining all mechanical properties

- Phase I complete and working on Phase II

Table 5: Experiment Design Candidates Summary

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<thead>
<tr>
<th>Experiment Design Candidates</th>
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* No replicates at corner and axial points. Multiple replicates, however, placed on center point.
Duplex Coating  
(Phase I)

- **Phase I:**
  - Identified initial group of coating chemistries
  - Tested per Air Force drawing 200310641
  - Down-selected to 4 chemistries
  - Generated a coating model tool using a Design of Experiment (DOE) method
    - DOE input parameters:
      - Oxygen Flow Rate
      - Fuel Flow Rate
      - Powder Flow Rate
      - Stand-off Distance
  - Coating model tool predicts coating bond strength, ductility, porosity and hardness given changes in the input variables
    - Significantly reduces Phase II testing
Duplex Coating
(Phase II)

- **Phase II:**
  - 4-point bend integrity testing:
    - 0.020” and 0.030” total coating thickness with 0.003” inch WC-Co cap
    - 0.017” and 0.027” total coating thickness without WC-Co cap
    - 5 cycles at 190ksi, 210ksi and 230ksi stress levels or until failure (spallation)
  - Corrosion testing of duplex system to chrome and WC-Co
    - Per ASTM B117
  - Coating integrity (large bar) testing of 2 best chemistries
Phase II Coating Integrity Testing Results:

- The optimized build coat performed worse than expected
- Adding WC-Co cap to build coat failed coupons at lower than predicted stress levels
- Important observations:
  - The bond strength of WC-Co to build coat was very high
  - The bond strength of build coat to substrate was low
  - Possibly WC-Co bond coat followed by build coat could improve overall bond
- Integrity testing with WC-Co bond coat:
  - Much better results (at 230 ksi):
    - No spallation at 0.027 without WC-Co top coat
    - No spallation at 0.030 from 3 of 4 chemistries with WC-Co top coat
Duplex Coating (Phase II)

WC/Co Bond-0.027 Build-0.003 WC/Co Top @ 230 ksi
Finishing Methods

• **Diamond Grinding of 300M:**
  • Air Force drawing 200310642:
    • Cylindrical, Face (contoured) and Surface grinding techniques were optimized to reduce/eliminate grinding burns

• **Superfinishing:**
  • Seal surfaces containing HVOF applied WC/Co coatings must be Superfinished after diamond grinding has been completed
  • Superfinishing methods were optimized and written into AF Drawing 200310642

• **Diamond Belt Finishing:**
  • The initial results of testing indicate an increase of processing efficiency by 3-5 times over standard diamond wheel grinding
  • HAFB long bed grinder has been retrofitted with belt attachment
  • Optimization testing will begin this year, specification to follow.
Stripping Methods

• **Rochelle Salt Stripping:**
  - Industry standard for removing HVOF applied WC/Co materials
  - Electrolytic method under controlled temperature and pH to break down the binder (Co) in the HVOF applied coating
  - Parameters identified within Air Force HVOF application specification-200310641

• **Forced Pulse Water Jet:**
  - Optimized for HVOF WC/Co and WC/Co/Cr stripping
  - Environmentally friendly
  - Fast, very efficient
WC-Co Alternatives

- **WC/Co Alternatives:**
  - Currently, HVOF WC/Co & WC/Co/Cr is the only approved Landing Gear coating
  - These coatings are expensive and have fatigue and spallation concerns
  - It is desirable to qualify alternative coatings which provide:
    - As good as or better than chrome performance characteristics
    - More cost effective
    - Conventionally finished
  - Landing Gear Thermal Spray Specification
    - Requirements which will enable the Air Force to qualify other thermal spray chemistries
    - Modeled after the Landing Gear HCAT JTP
WC/Co & WC/Co/Cr Qualification

- WC/Co & WC/Co/Cr Qualification:
  - Enables the USAF to qualify vendors for HVOF WC application on OEM components
  - Qualification based on coatings passing standard metallurgical and performance baselines
  - Specification completed and signed off on 28 July 2009 (200925098)
  - Located at www.fbo.gov
Conclusion

• **Benefits:**
  - Improved wear performance
  - Removing a known embrittling process
  - Component longevity
  - Reduction in hexavalent chrome waste stream
  - Greatly reduced rework
  - Faster processing of parts

• **Issues:**
  - Solid infrastructure for EHC
  - Momentum change