ACCELERATED MISSION TEST EVALUATION OF TF33 ENGINE COMPONENTS COATED WITH HIGH VELOCITY OXY-FUEL (HVOF) THERMAL SPRAY COATINGS IN LIEU OF HARD CHROME

Gary C. Shubert / Melvin Freling
Program Managers
Pratt & Whitney

Report Documentation Page

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Program Objectives

- To reduce the use of chrome plating in the rework of gas turbine engines and improve the performance of coatings used for wear and corrosion prevention
- Qualify HVOF as an advanced coating replacement for chrome plating at Tinker Air Force Base, Oklahoma City Air Logistics Overhaul Center

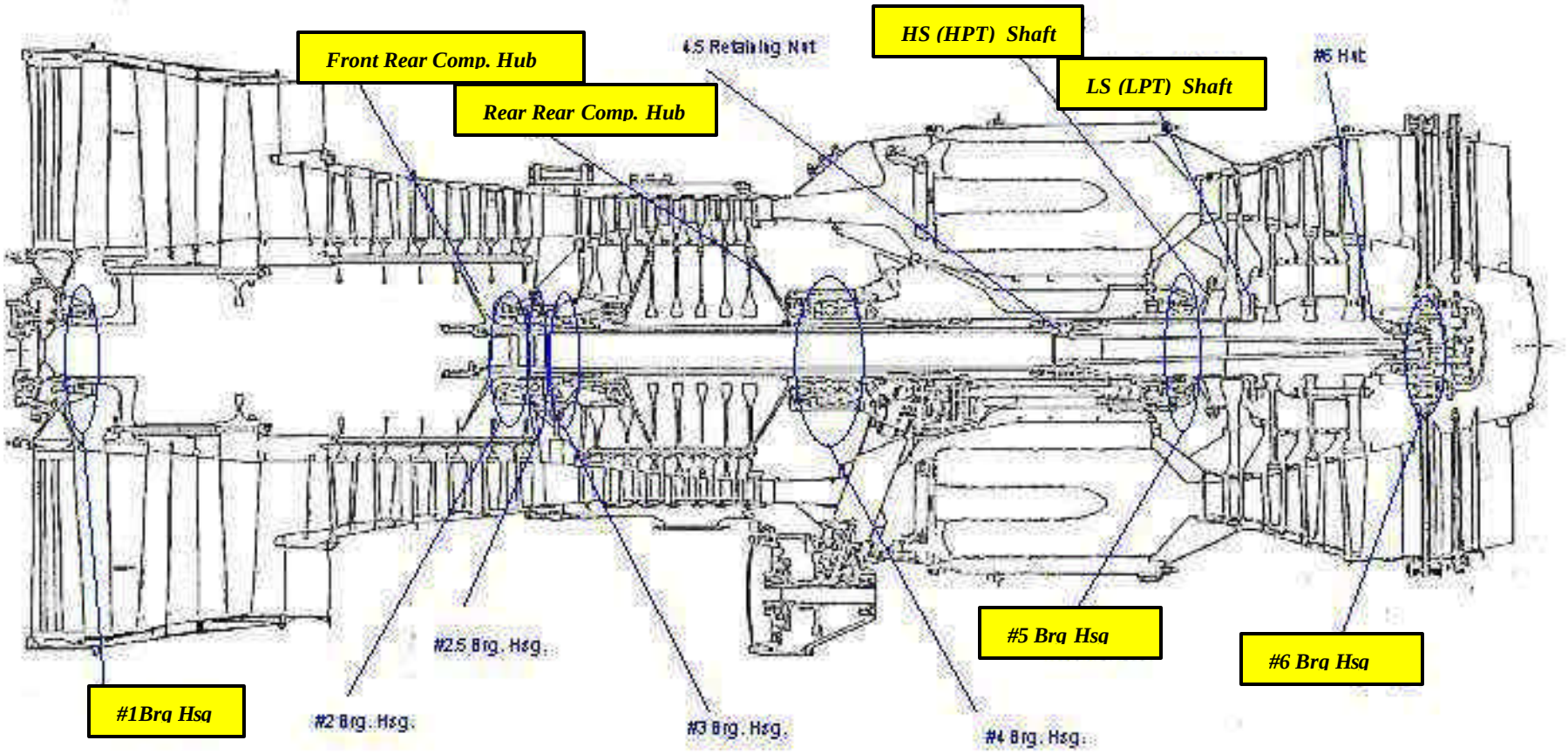
Prior Program Effort

- Identify engine part classes that are high volume HVOF repair candidates
- Select components to be HVOF coated and evaluated in a TF33 Accelerated Mission Test (AMT) engine

Part Selection Criteria

- Discussions among personnel from Tinker ALC and P&W resulted in the selection of seven (7) TF33 part families for the AMT engine test
  - Low Pressure Turbine Shaft
  - High Pressure Turbine Shaft
  - Bearing Housings #1, #5, #6
  - Rear Compressor Rear Hub
  - Front Compressor Rear Hub

Selected Component Locations



Coating Material Selection Criteria

- Based on the operating temperatures of the components and previous P&W commercial experience, tungsten carbide-cobalt (WC-Co) was selected to be applied onto the AMT hardware

General Test Concept

- Functional Testing
  - Simulate assembly / disassembly
  - Metallurgical analysis
- Endurance Testing
  - Accelerated Mission Test (AMT)
- Metallurgical Examination of Selected Engine Test Components

Functional Test / Results

- Test consisted of repeatedly pressing bearings onto and into the HVOF coated components
  - Coatings visually examined for evidence of chipping, flaking, and cracking between test cycles
    - NO VISUAL DEFECTS OBSERVED
  - FPI examination after testing identified an area of chipping on the #6 bearing housing
    - Testing of this component included an additional test simulating an "aggressive assembly"
- Metallographic evaluation
  - NO COATING DETERIOATION OBSERVED

Functional Test Summary

- All parts were acceptable
- As the #6 bearing test was very aggressive, compared to normal installation, the HVOF coating was accepted on the #6 bearing
- Based on these results, all AMT components were HVOF coated with WC-Co

Accelerated Mission Test (AMT)

- Test Duration
  - 4500 EFH (Equivalent Flight Hours)
- Oil and Filter Analyses
  - Spectrometric Oil Analysis Program (SOAP)
  - Energy Dispersive X-Ray Fluorescence (ED-XRF)
  - Inductively Coupled Plasma-Mass Spectrometry (ICP-MS)
  - COBRA Analysis (Complete Oil Breakdown Rate Analyzer)

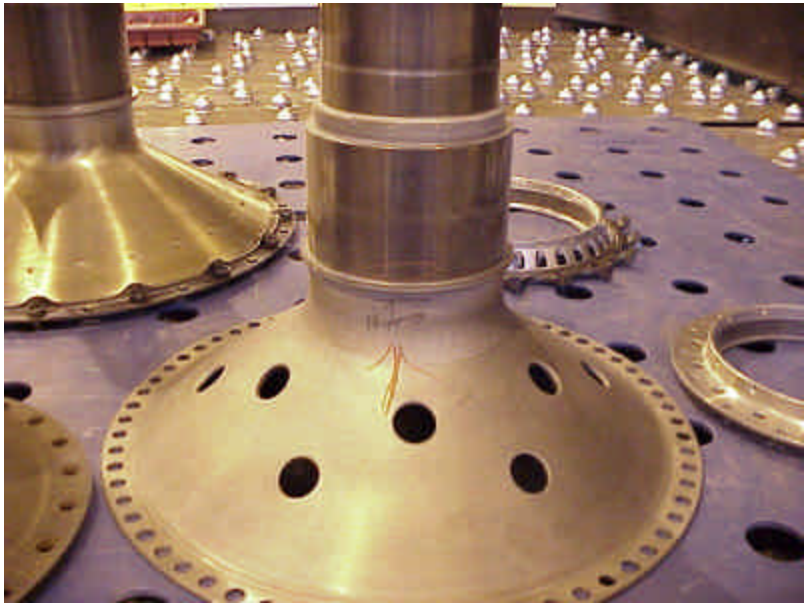
Post AMT Hardware Evaluations

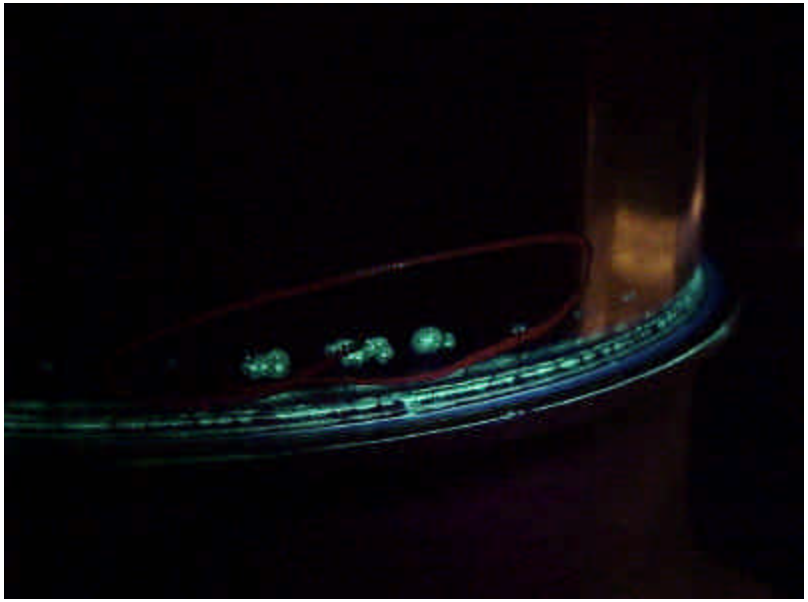
- Visual inspection at teardown
  - No defects identified
- Dirty inspection
  - Oil coke but no chipped or worn coating
- Second visual inspection (acetone cleaning)
  - No defects identified
- Third visual inspection (caustic cleaning)
  - No defects identified

Post AMT Hardware Evaluations (Cont.)

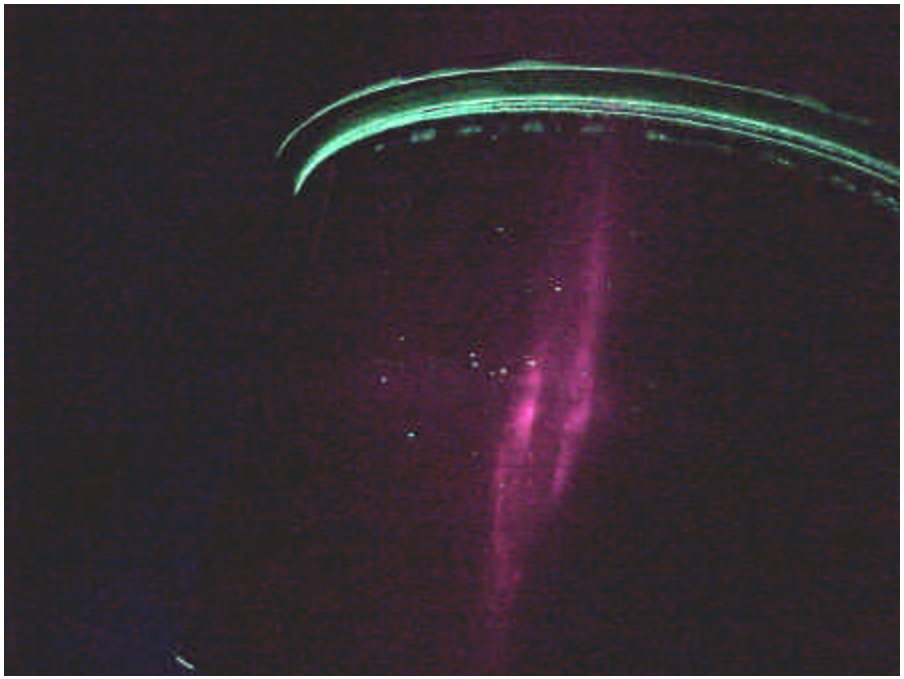
- FPI Inspection (Normal & High Sensitivity)
  - Various indications identified
- Dimensional Inspection
  - Coated areas changed in dimension by a maximum of +/-0.0002”
    - All coated components met the dimensional requirements for continued engine service
- Metallographic Evaluation
  - Verified acceptable coating structures
  - Confirmed FPI indications
    - Indications due to coating finish grind

No. 2 Bearing Journal FPI Indications Attributed to Coating Grind

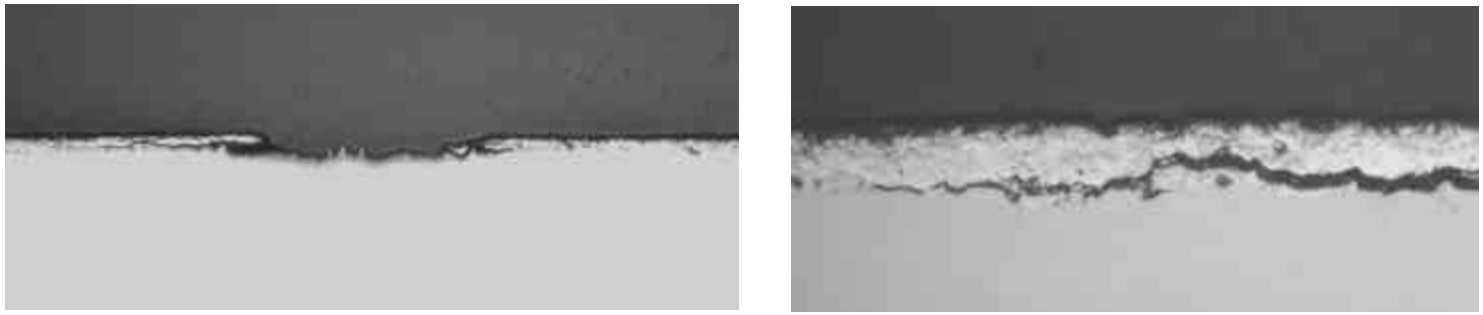




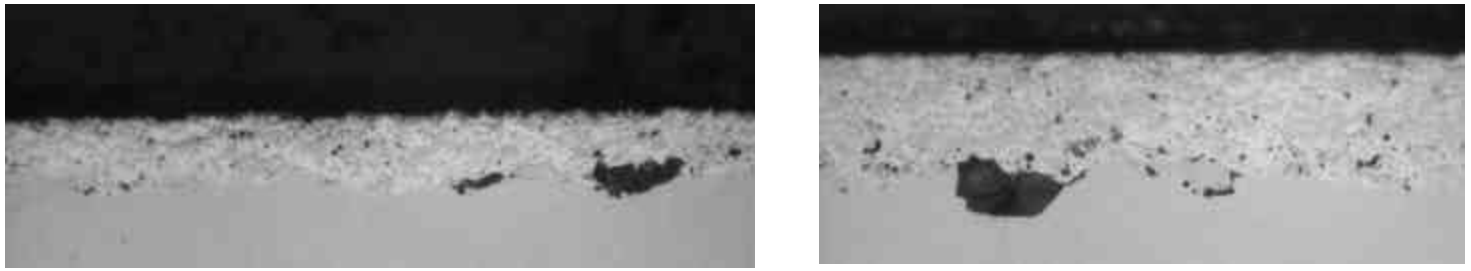
No. 2 Bearing Journal High Sensitivity FPI Coating Indications Indicative of Carbide Pullout



Indications Attributed to Variations In As Ground Coating Thickness

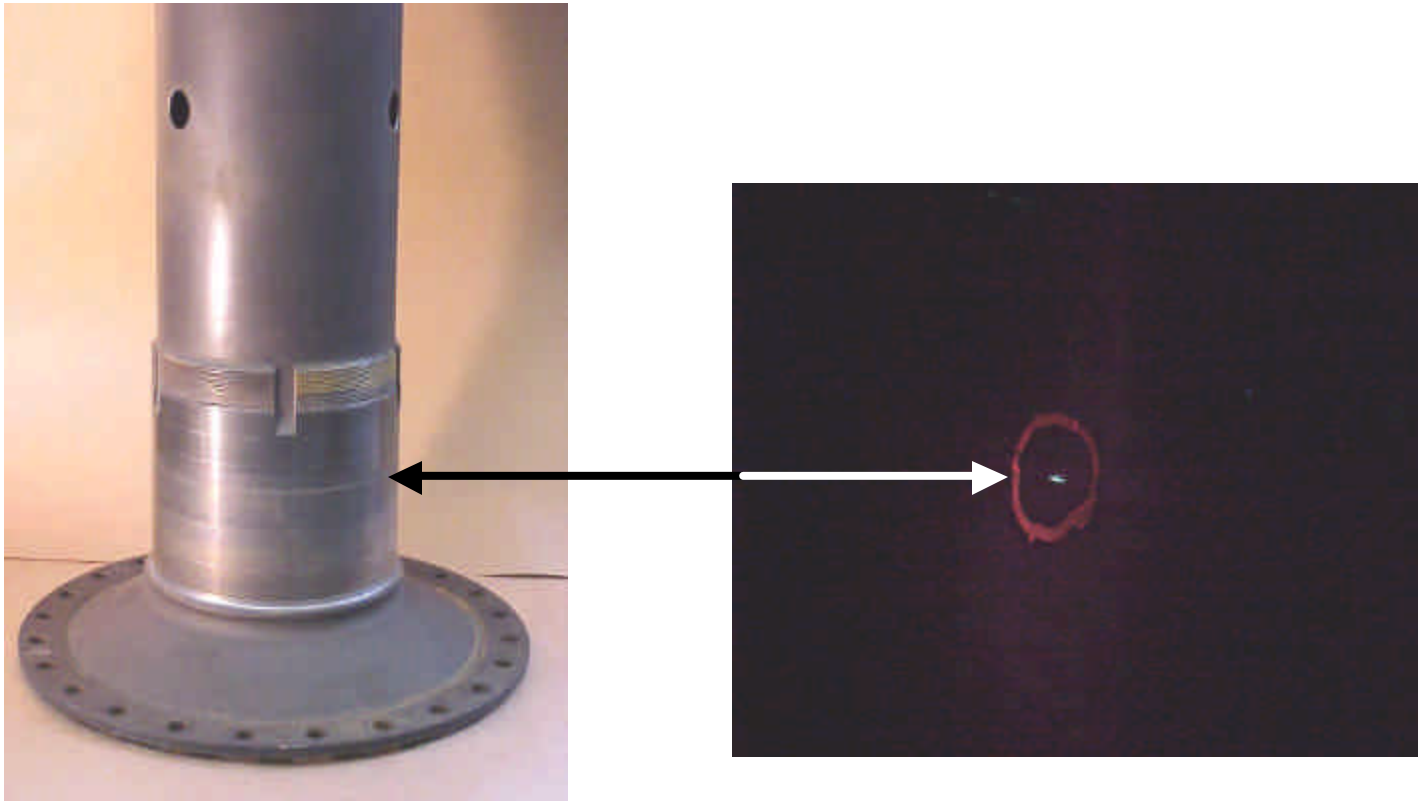


Front Compressor Rear Hub Showing Loss of Coating at FPI Indication (left) and Disbonded Coating Adjacent to Indication (right)

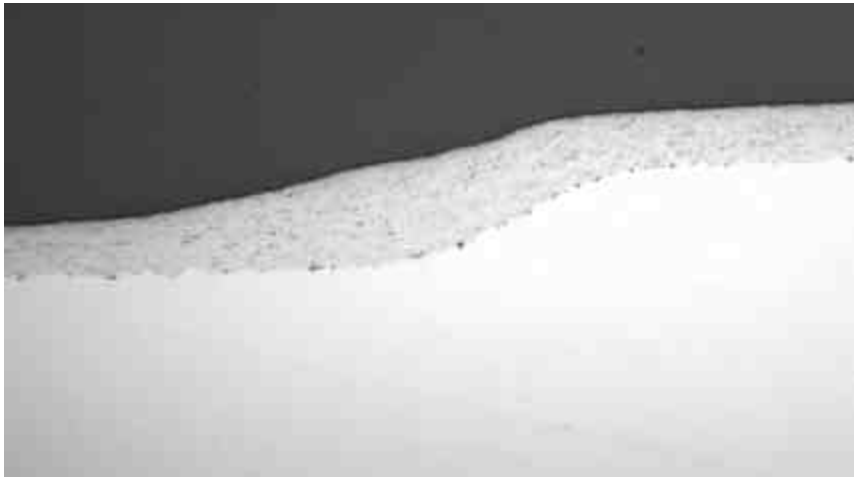


Front Compressor Rear Hub Showing Coating ~0.8 mils in Chatter Region (left) and ~1.8 Mils in Non Chatter Region (right)

FPI Coating Indication on the No.5 Bearing Journal



Metallographic Cross-Section of No.5 Bearing Journal FPI Indication



No Defect Found

Concerns

- HVOF coating configuration will be different from chrome plating
  - HVOF coating of OD corners would lead to cracking
  - HVOF coating adjacent to a 90 degree vertical face will lead to poor coating structure
  - HVOF masking is more difficult than plate masking and necessitates review of transition coating areas

Concerns

- As-sprayed coating thickness target needed to be established to allow for a minimum of 2.0 mils of ground coating
- Grinding techniques will be needed to ensure acceptable transitions between adjacent HVOF coated surfaces
- "No-Coat" areas need to be identified and evaluated to eliminate grinding into radii

Additional Benefit

- Low wear rate in AMT indicate potential for prolonged component life

Summary

- All HVOF Coated Surfaces Evaluated Passed Test Requirements
  - "As Good or Better Than Chrome"
- No Oil Contamination as a Result of HVOF Coatings
  - Test Data Currently (Design Substation Memo's) Currently in Signature Process
- T.O. modifications to allow HVOF option to Hard Chrome Plate to be Generated in Next Phase of Program