Hard Chrome Alternatives Team

Bruce's Badgers

"Mean To Be Green"

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Report Documentation Page

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Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

Objectives

- Compare performance of coatings applied by different equipment
  - Sulzer-Metco Diamond Jet
  - TAFA JP5000
  - TAFA ST
  - Praxair
- Compare performance of three coating alloys
  - WC-Co
  - WC-Co-Cr
  - T-800
- Compare performance of two powder types
  - agglomerate
  - cast

Objectives (con't.d)

- **Evaluate effect of processing parameters**
  - **grit blasting**
  - **shotpeening**
  - **coating deposition thickness**
  - **coating surface finish**
  - **multiple (3) application/strip cycles**
  - **multiple (2) coating layers**
  - **grooved coating repair**

Approach

- Comparative fatigue testing (185 ksi; R= 0.1)
- Tensile testing
- Adhesion testing
- Corrosion testing
- Metallurgical analysis

23 different configurations

458 specimen

Current Status

- Fatigue testing complete except for specimen to be coated at Ogden ALC using their optimized parameters
- Tensile testing complete
- Adhesion testing complete
- Corrosion testing complete
- Metallurgical Analysis ongoing
- Big tube coating and testing ongoing

Results of Fatigue Testing

- Only specimen coated with WC-Co applied by the TAFA JP 5000 showed fatigue performance inferior to that of EHC
- Specimen coated with WC-Co-Cr applied by the Sulzer-Metco Diamond Jet showed fatigue performance inferior to that of WC-Co, but still better than or equal to EHC
- Specimen coated with T-800 showed fatigue performance similar to that of WC-Co
- Specimen coated with cast WC-Co powder showed fatigue performance inferior to that of agglomerate powder, but still better than or equal to EHC
- WC-Co coated specimen that have been shotpeened, but not grit blasted, showed fatigue performance superior to those that have been shotpeened and grit blasted or to those that have been grit blasted only. Eliminating both shotpeening and grit blasting is the worse case for fatigue performance.

Results of Fatigue Testing (cont'd.)

- Specimen with a thicker preground layer of WC-Co (.008" vs. .005") showed enhanced fatigue performance
- Coating surface finish (16 micro inch vs. 8 micro inch vs. superfinish) had no obvious effect upon fatigue performance
- Multiple WC-Co application/strip cycles had no detrimental effect upon fatigue performance
- Multiple WC-Co coating layers had no detrimental effect upon fatigue performance
- Repair of a grooved WC-Co coating had no detrimental effect upon fatigue performance

Coating Integrity During Fatigue Testing

- Some of the Sulzer-Metco applied WC-Co coatings cracked and delaminated during testing. All of the Praxair applied coatings exhibited this behavior. None of the TAFA applied coatings showed visible cracking or delamination
- WC-Co-Cr coatings showed more cracking and delamination than WC-Co
- NDI of coated specimen after testing revealed that HVOF coatings can appear to be intact but are actually disbonded from the substrate. TAFA applied coatings showed less disbonding than those of the other processes
- EHC showed no tendency to crack or delaminate

Results of Tensile Testing

- For all of the different configurations, no consistent trends were observed concerning any effect of the coating upon specimen tensile strength
- In every case the entire HVOF coating cracked and spalled from the specimen in the post yield region
- EHC remained intact and only spalled near the fracture face

Results of Adhesion Testing

- HVOF applied T-800 coatings showed failure at the substrate interface
- All of the other HVOF applied coatings and EHC showed acceptable bond strength for all configurations

GM 9540 P/B Cyclic Corrosion Test

0.9% NaCl, .1% $CaCl_2$, .25% Na HCO_3 in Distilled H_2O

- **3 Consecutive**

10 min salt mist 90 min @ 75°C, 30-50% RH	5 hrs
10 min salt mist 170 min @ 25ºC, 30-50% RH	3 hrs
8 hrs @ 49ºC, 95-100% RH	8 hrs
8 hrs @ 60ºC, <30% RH	8 hrs
1 cycle =	24 hrs

Results of Corrosion Testing

2000 hours (80 cycles) GM 9540 P/B

- TAFA and Sulzer-Metco applied WC-Co coatings are darkly discolored, have multiple eruption sites and are rough to the touch
- Praxair applied WC-Co coatings are discolored, but have no eruption sites and a smoother surface
- Some WC-Co and WC-Co-Cr specimen show edge corrosion that undercut the coating and attacked the substrate
- WC-Co-Cr coatings are much lighter in color, have no eruption sites and the surface is smooth
- None of the EHC specimen show corrosion

Results of Corrosion Testing (cont'd.)

- Hydraulic fluid wipe of EHC specimen was effective in preventing edge corrosion
- The precracked HVOF coated specimen looked no different than the uncracked ones
- None of the different processing configurations seemed to have any effect upon corrosion testing performance

After 2000 Hours (80 Cycles)

WC-Co

Sulzer-Metco Diamond Jet

WC-Co-Cr

Sulzer-Metco Diamond Jet

EHC

w/o Ni Underlay

After 2000 Hours (80 Cycles)

WC-Co

TAFA JP5000

WC-Co

Praxair

EHC

w/o Ni Underlay

After 2000 Hours (80 Cycles)

WC-Co

TAFA ST

T-800

Sulzer-Metco Diamond Jet

EHC

w/o Ni Underlay

After 2000 Hours (80 Cycles)

EHC

w/o Ni Underlay

EHC

w/Ni Underlay

EHC

w/o Ni underlay w/HydFluid Wipe

Preliminary Post Corrosion Testing Analysis

- HVOF WC-Co coating eruptions are primarily cobalt with no evidence of substrate bleed-through
- Lightly sanding the WC-Co coating removes the corrosive layer revealing a blotchy surface with numerous small pits
- Lightly sanding the WC-Co-Cr coating removes the discoloration layer to reveal a smooth, pit-free surface

Metallurgical Analysis

- 25 specimen evaluated by Cincinnati Thermal Spray determined that most of the HVOF coatings are in compliance with GE Aircraft Engine guidelines
  - Transverse cracks in the coating (1 nonconformance)
  - Coating delamination (1 nonconformance)
  - Contamination of the coating bondline (10 nonconformances)
  - Voids and oxides in the coating (1 nonconformance)
  - Unmelted particles in the coating (0 nonconformance)
  - Abnormalities of the coating (0 nonconformance)
- Our in-house evaluation is ongoing

Non-Destructive Inspection (NDI) Through HVOF Coatings

Objectives

Determine the ability of common NDI techniques to detect substrate cracks under HVOF WC-Co Coatings as compared to those under Electroplated Hard Chrome.

- **Ultrasonics**
- **Eddy-current**
- **Magnetic Particle**
- **Dye Penetrant**
- **Visual**

Work Accomplished (cont'd.)

50 4340 Steel Plates: 2" x 14" x 5/16" thick

2 EDM flaws (.004" deep) per plate

Cracks grown by 3 point bending

EDM flaws machined away

100 Cracks: .040" to .250" Long
.0125" to .089" Deep

Plates Shotpeened

Work Accomplished (cont'd.)

Additional flexing to open the cracks

Materials Directorate Systems Support Division NDI Group characterized cracks prior to coating

- Ultrasonic inspection readily found the cracks
- As expected, dye penetrant wasn't too useful
- Visual inspection was difficult
- Eddy current and magnetic particle techniques didn't reveal the cracks as well as desired
  - Additional flexing didn't help
  - Ancient NDI guru: "the stresses from shotpeening are hindering the alignment of the magnetic domains"
  - Machining .003" from the shotpeened surface solved the problem

Still To Be Done

- Specimen will be HVOF coated or EHC plated
- Specimen will be ground to a .003” or .010” final thickness with an 8 micro inch finish
- NDI of coated specimen and analysis