



Status of Chromium Replacement for Aviation Applications

Solvent Substitution Workshop, December 02

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Summary

- ❑ **HCAT team approach**
- ❑ **Landing gear status**
 - Reports
 - Implementation
- ❑ **Propeller hubs**
 - Reports
 - Implementation
- ❑ **Other HCAT projects**
- ❑ **Workshop on P2 for advanced aircraft**
- ❑ **Lessons learned**



P-3 MLG HVOF WC-Co (NADEP JAX)

HCAT approach

- ❑ **Broad team of industry and DoD organizations, US and Canada**
- ❑ **Initial focus is replacement of hard chrome for aircraft**
- ❑ **Becoming involved with Cd and repair technologies**

HCAT projects do not just produce technical reports, but result in actual implementation of new technologies at multiple DoD repair depots and manufacturers.

Landing gear JTR

- ❑ **Materials part of LG JTR Part 1: Materials Testing complete**
 - **Complete DRAFT version including Wear and Process Optimization**
 - **400+ pages**
 - 200 real report
 - 200 print outs of all data
 - **Excel files of all raw data included**
 - **Does not cover integrity or rig testing as that not in JTP Part 1**
 - This will be covered in later report when work complete

U.S. DEPARTMENT OF DEFENSE
Environmental Security Technology Certification Program (ESTCP)
Joint Group on Pollution Prevention (JG-PP)

JOINT TEST REPORT

Validation of WC/Co HVOF
Thermal Spray Coatings as a
Replacement for Hard Chrome Plating
On Aircraft Landing Gear

PART I: MATERIALS TESTING

Date: February 1, 2001

Prepared By:
U.S. Hard Chrome Alternatives Team (HCAT)



Summary of JTR

□ Fatigue

- Often better than EHC
- HVOF delamination at high load
 - This is the only serious issue for most users
- Passes acceptance criteria

□ Corrosion

- Not as good as EHC
- Fails acceptance criteria
- However, tests were against "superchrome"
 - Would have passed in comparison with "normal" EHC
- Note: HVOF corrodes by Co dissolution

□ Wear

- Less wear of coated rod
- More wear of uncoated bushing
- Passes acceptance criteria

□ Impact

- WC-Co and WC-CoCr both better than EHC
- Passes acceptance criteria

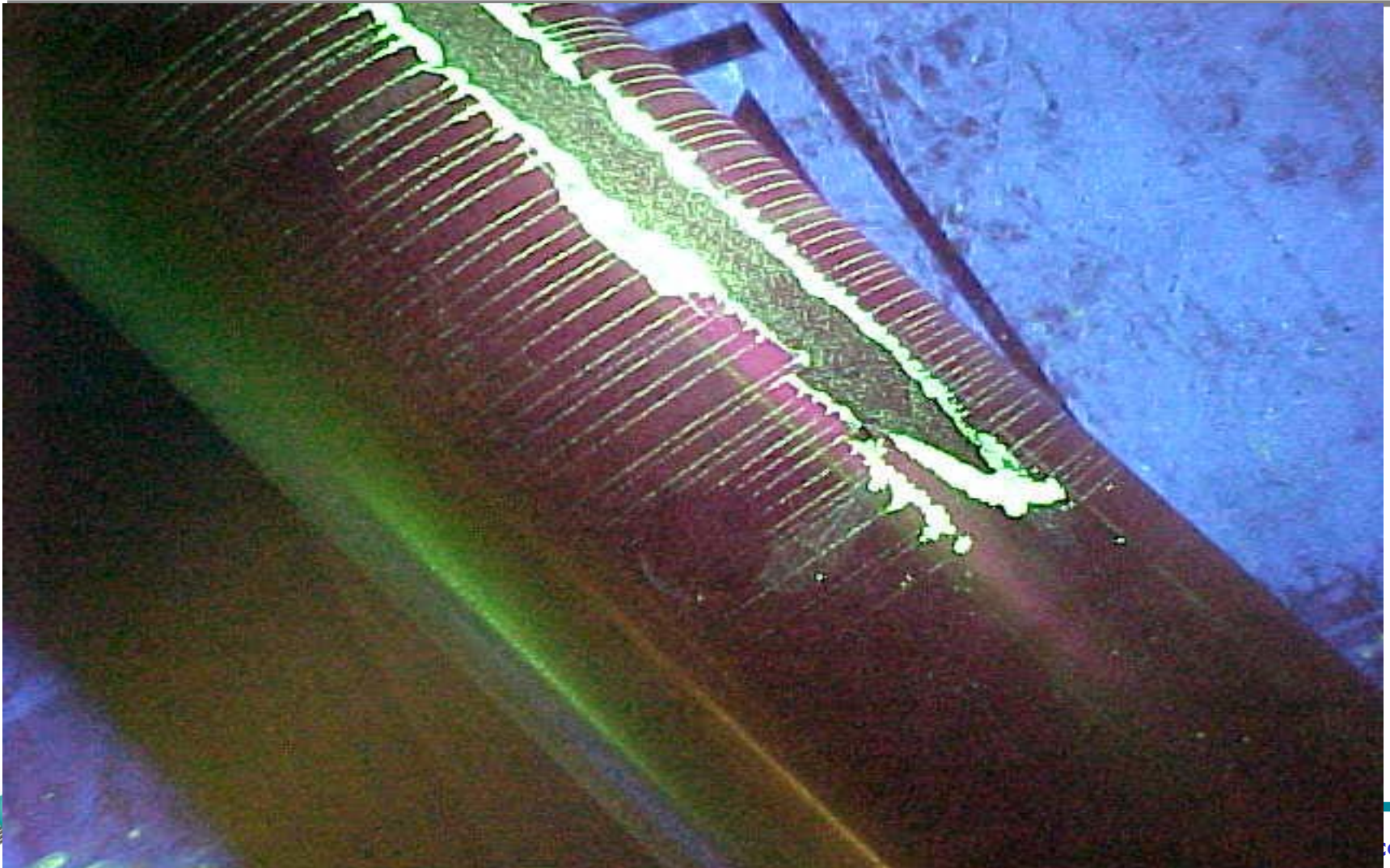
□ Hydrogen embrittlement/SCC (data taken by Boeing Seattle)

➤ Chrome stinks!!

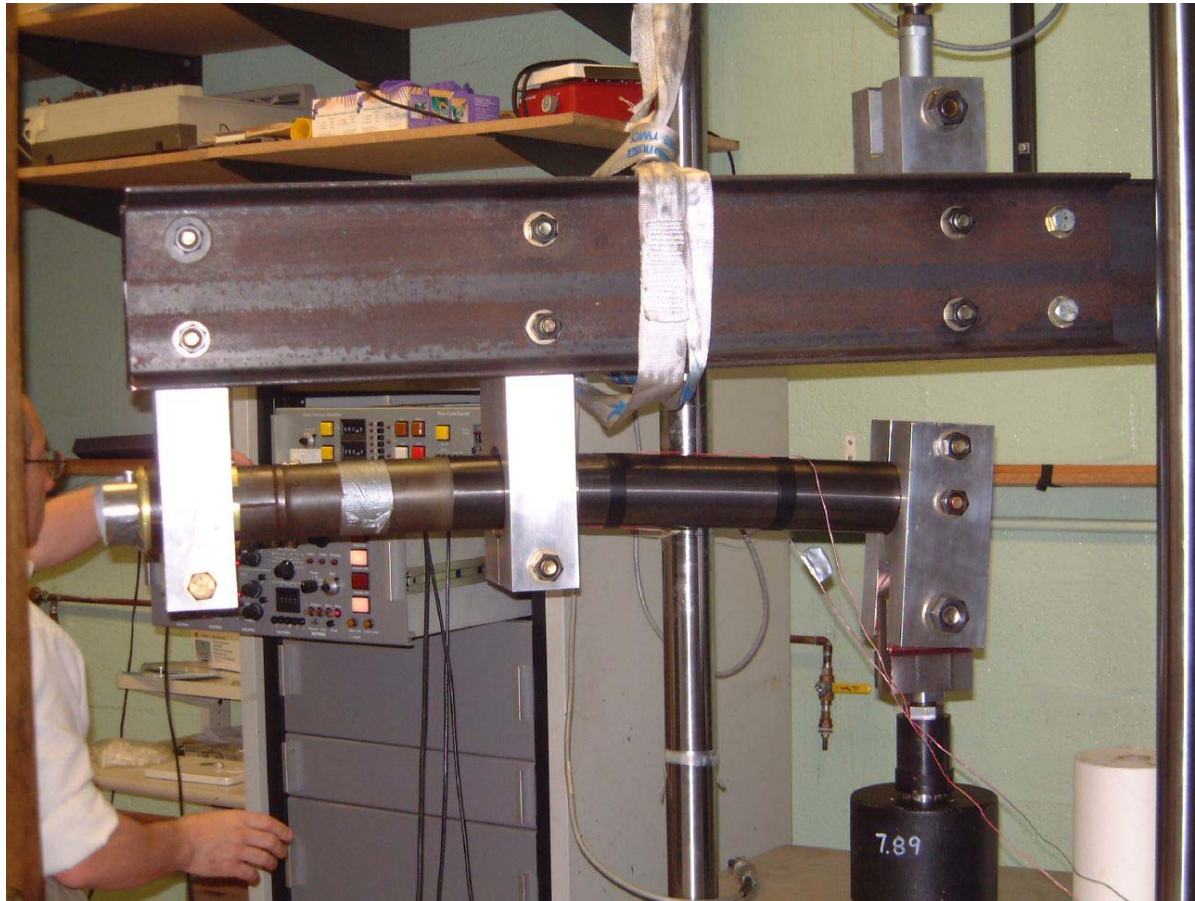
- Environmental embrittlement failure in <10 minutes
- HVOF coatings last 1 - 2 orders of magnitude longer
- HE happens after EHC when improperly baked out
- Difference due to open circuit potential
- HVOF does not cause HE
- Passes acceptance criteria
- Note: this is different from PAX RSL tests

Coating Integrity – Hill/ALGLE

0.015" WC-Co FPI



Coating integrity issue – Hill/ALGLE bend tests



- ❑ **Coatings can spall at high stress (near yield)**
 - **Failure strain lower for thicker and more brittle coatings**
- ❑ **Important issue for carrier-based aircraft**
 - **Not a problem for most land-based aircraft**

Corrosion issues

❑ Corrosion results highly variable

- Canadian HCAT – HVOF much better than EHC
- Beach exposure – HVOF much better than EHC
- JTR tests – HVOF not as good as EHC
 - Turned out used “superchrome” baseline
- **Lesson – use the “real” baseline for most users**

❑ Embrittlement

- F-519 notch test – HVOF much better than EHC
- NAVAIR Rising Step Load (RSL) – HVOF somewhat worse than EHC
- **Lesson – depends on choice of test method and baseline**
 - What is the “right” method?
 - What corresponds best with real-world performance?

Propeller hubs – Hamilton Sundstrand and NADEP Cherry Point

- ❑ **Report by Hamilton Sundstrand and NADEP Cherry Point**
- ❑ **100+ pages**
 - **Wear testing**
 - **Fatigue**
 - **Corrosion**
 - **Rig tests on actual parts**

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JOINT TEST REPORT

Validation of HVOF WC/Co, WC/CoCr and Tribaloy 800
Thermal Spray Coatings as a
Replacement for Hard Chrome Plating on
C-2/E-2/P-3 and C-130 Propeller Hubs & Low Pitch Stop
Lever Sleeve

15 October 2002

Prepared By:
U.S. Hard Chrome Alternatives Team (HCAT)
Joint Group on Pollution Prevention (JG-PP)



Propeller Hubs JTR

- ❑ **HVOF WC-Co in general better performance than HVOF T400**
- ❑ **Wear**
 - **HVOF much better than EHC**
- ❑ **Fatigue**
 - **HVOF better than EHC**
- ❑ **Corrosion**
 - **Ni (best) > HVOF > EHC**
 - **HVOF viable Ni alt.**
- ❑ **Rig tests**
 - **HVOF less wear on coated and counterface**
 - **Toxicity Characteristics Leaching Procedure (TCLP) – powder not haz waste**

Other core HCAT projects

□ GTEs (under way)

- Run by PEWG
- Variety of HVOF and plasma spray coatings
- Variety of steels, inconel substrates
- Includes full scale engine tests with coated seals and shafts
 - Initial TF-33 engine test data look very good – almost no wear

□ Hydraulic actuators (under way)

- Surface finish especially important (superfinish)
- Testing several seal systems
- Rig tests
 - Speed, stroke, temperature profiles

□ Helicopter dynamic components

Not yet begun



Implementation of HVOF

□ Military

- **OO-ALC landing gear**
 - F-16 tension struts, axles
 - C-5 pitch cylinders, ball screws, gudgeon pins
 - KC-135 axles
- **NADEP-CP, H-S**
 - E-2C, C-2, P-3, and C-130: tailshaft, low pitch stop lever sleeve, rocker land.
 - Navy P-3 and Air Force C-130
- **F-35 (JSF)**
 - HVOF baseline for CTOL
 - Convergent nozzle acts.
- **CF-18 steering covers, piston heads, MLG hexagon repair**
- **C-17 NLG shelf test**

□ Commercial

- **Boeing - >100 spot HVOF uses**
- **B767-400 HVOF on landing gear**
- **Airbus 380 spec'd for HVOF WC-CoCr**
- **Boeing permits HVOF for repair to 0.010"**
- **Delta using HVOF landing gear repair in own maintenance shop**
- **Messier-Dowty installing HVOF for landing gear**

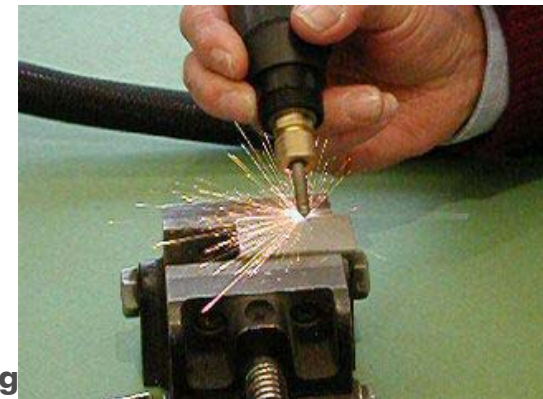
Other HCAT team projects

□ ID plasma spray

- **Replace EHC in IDs and other difficult locations**
- **Plasma spray**
 - T400
 - WC-Co
 - WC-Co self fluxing alloy
- **Works well and efficiently for >2.5" or 3"**
- **Property/performance tests under way**

□ Electrospray Alloying for repair (HCAT/PEWG)

- **Also called Electrospray Deposition (ESA, ESD)**
- **Dry analog of brush plating**
- **Qualified by Rolls Royce Aero for >20 GTE repairs**
- **Dem/val for GTEs, shafts on ships and subs, vehicles**



Keith Legg



Meeting Summary:

Materials Substitution for Pollution Prevention in Advanced Aircraft - Technology Exchange

BWI Airport Marriott, Baltimore, September 4, 5, 2002

Major findings - Chrome plating alternatives

- ❑ **If you use Cr⁶⁺, use a fume suppressant**
 - **Initial pitting problems overcome**
- ❑ **HVOF method of choice for ODs and shallow IDs**
 - **Issues**
 - Spalling at high strain
 - Seal wear and surface finish
 - Co leaching on corrosion
 - NDI through coating
 - Some concerns over reliability/repeatability from vendors
- ❑ **IDs**
 - **Electroless and electroplated Ni - only qualified coating**
 - Issues
 - ◆ inconsistent stress
 - Under evaluation in AFRL NLOS program
 - **SERDP ID programs**
 - Nanograin electroplate
 - ESD
 - Miniature plasma spray
- ❑ **Trivalent chrome (under development)**
 - **Solves Cr⁶⁺ air emissions**
 - **Same grinding waste and wastewater issues from rinsing and stripping**

Major findings - Cd plating alternatives

High strength and low strength components

❑ Avoid high strength steels

- A successful approach for some new programs
 - Ti landing gear
 - ◆ lower strength, larger volume
 - Stainless steel fasteners (engines), Ti fasteners (OML)
 - 15-5 PH stainless
 - ◆ most new actuators
- New high strength stainless for LG (Cartech, QuesTek) under development/test
 - SERDP - OO-ALC, QuesTek
 - DUST - Boeing, OO-ALC

❑ IVD Aluminum

- Qualified, widely used
- Depot use growing
- ID sputtering available, not yet qualified
- Issues:
 - Dissolution in alkaline cleaners
 - Cost
 - Non-uniformity, especially in threads
 - Repair (OEM and depot)

❑ Acid Zn-Ni, Alkaline Zn-Ni

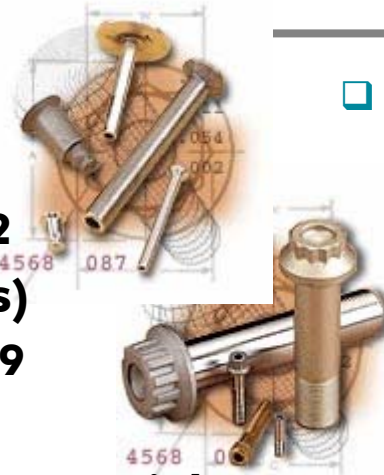
- Qualified for low strength (acid)
- Issues
 - Embrittlement (esp alkaline)
 - Ni strike for some materials

Major findings - Cad plating alternatives

Fasteners and Connectors

Fasteners

- **Ti (OML)**
 - used on F-22
- **Stainless (GTEs)**
 - used in F-119
- **IVD Al on HSS**
 - used on F-15, F-16 inlets
- **Sn-Zn**



Connectors



- **No really good options**
- **Ni-plated polyimide composites**
 - used on F-22
- **Alumiplate**
 - **Issues**
 - ◆ **solderability**
 - ◆ **inadequate electrical conduction**
 - ◆ **insufficient production capacity**
 - ◆ **sole source**

**With all Cd alternatives:
How do you repair them?**

- **Brush Zn-Ni works**
- **embrittlement concerns**

Lessons learned – how can we best field new environmental technologies?

- ❑ **Up front**
 - **Good analysis of what makes most sense**
- ❑ **MUST improve readiness and performance, reduce cost**
 - **Environmentally better just does not cut it**
 - Especially with a long-running war against terrorism to fight
 - **How bad is current tech?**
- ❑ **Strong involvement of stakeholders at all stages**
 - **Close integration of development with user**
- ❑ **Risks and rewards**
 - **Decision makers need both risks and rewards**
 - Better sharing of responsibility and reward between decision makers and depot personnel
 - **Need a champion who sees both risk and gain**
- ❑ **Strong technical team assistance to lower risk, get faster implementation**