Electrodeposited Nano Co-P: Coating Development and Technology Insertion at NADEP-JAX

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Surface Finishing and Repair Issues for Sustaining New Military Aircraft
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History of Cr-Replacement Project

Objectives

- Develop an environmentally benign advanced nanocrystalline based coating technology that:
  - Is compatible with conventional electroplating infrastructure
  - Meets or exceed the performance of hard chrome
  - Costs similar to or less than existing hard chrome processes
  - Will be applied to non-line-of-sight surfaces

Progress

- SERDP Project #PP-1152
  - Nano Co-P developed and demonstrated at the lab scale
- ESTCP Project #PP-0411
  - Scaled up to industrial production & moved to depot (NADEP-JAX)
  - Performance testing (JTP) in progress

nCoP Process & Properties

Simply an electrodeposition process

- Plating Efficiency >90%
- High Deposition rates (0.002”- 0.008” per hour)
- 10x the plating rate of EHC
- 1/10th the power consumption at the same plating rate

		nCoP	Hard Chrome
Hardness		530-580 VHN	800-1200 VHN
Ductility	*Elongation*	2-7%	< 1%
Abrasive Wear (Taber)	*CS-17 wheels*	17-20 mg/1000 cycles	3 mg/1000 cycles
Adhesive Wear (Pin-on-disc)	*Volume wear loss*	$5\text{-}6\times10^{-6}$ mm^3/Nm (Al_2O_3 ball on nCoP disk)	$9\text{-}11\times10^{-6}$ mm^3/Nm (Al_2O_3 ball on Cr disk)
	Coefficient of Friction	0.5 (Al_2O_3 ball)	0.7 (Al_2O_3 ball)
Corrosion	*Salt Spray (1000 h)*	Protection rating 7	Protection rating 2

Industrial Scale-up & Technology Transfer

Industrial Scale-up

Scaled-up process produces acceptable nanostructured coatings

Integran Technologies

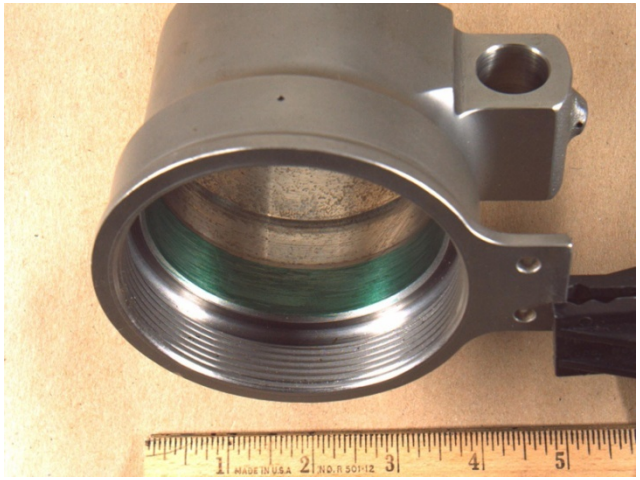
- 1300 L system
- In operation for 39 months
- No major issues to date

NADEP-JAX

- 1100 L system
- In operation for 21 months
- Some growing pains – have been resolved

Technology Transfer to NADEP-JAX

Proposed Demo Parts to be Plated at NADEP-JAX



P-3 MLG Actuating Cylinder

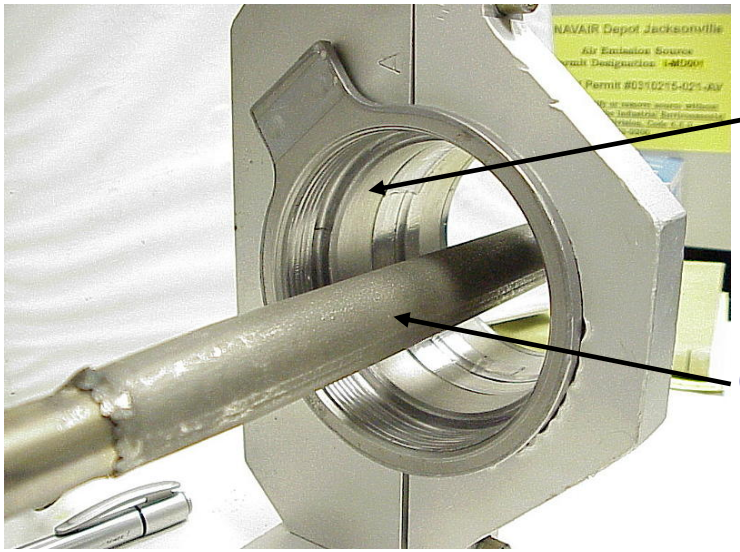
J52 Bevel Gear

P3 MLG Cylinder Section, Axle Journal

Technology Transfer to NADEP-JAX

P-3 MLG Actuating Cylinder – Plating Trials

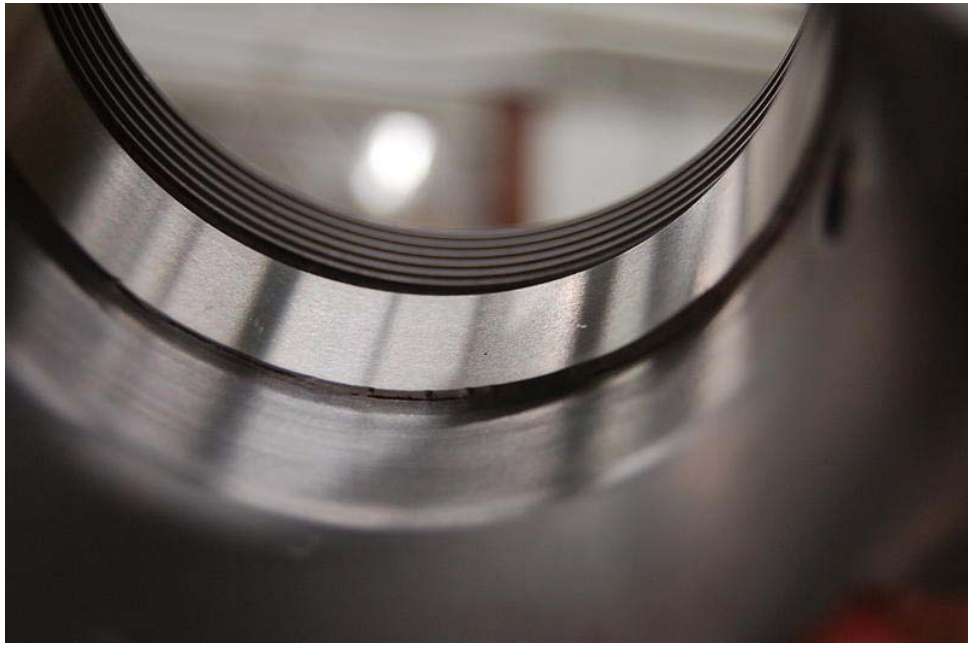
- 4340 steel
- Area to be plated: 5/8” band, 3” ID
- Cobalt anode rod



Technology Transfer to NADEP-JAX

P-3 MLG Actuating Cylinder – Plating Trials

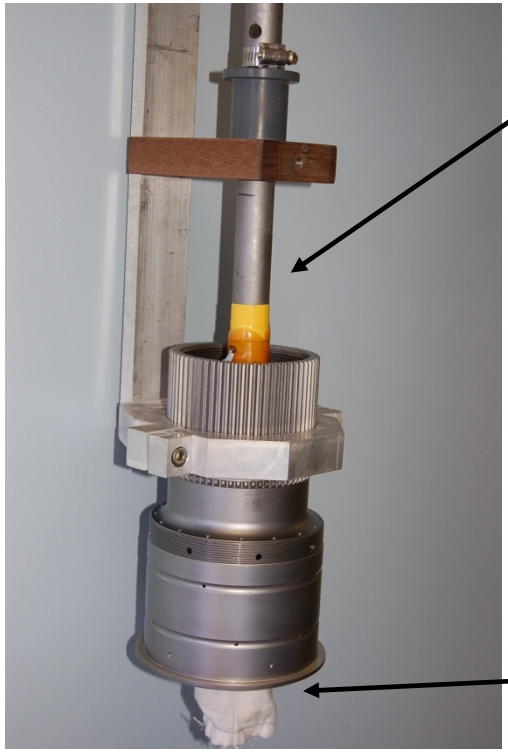
- Plating rate ~ 0.005”/hr
- Thickness
  - 0.010” (as-deposited)
  - 0.005” (following grind)
- Good adhesion
- Visible pit after grinding



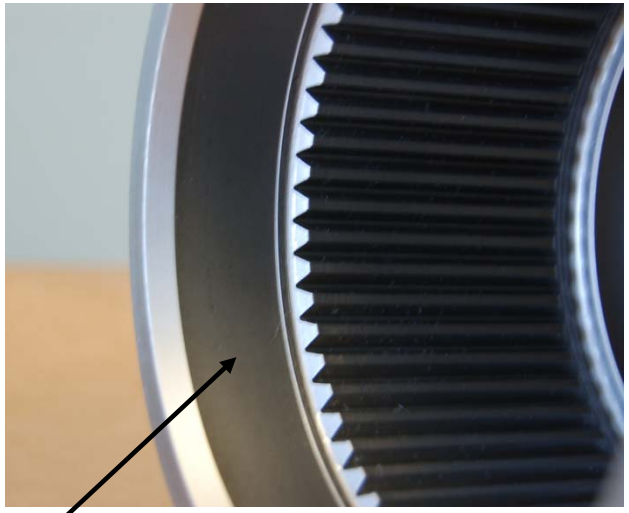
Technology Transfer to NADEP-JAX

J52 Coupling, Turbine Shaft Actuating Cylinder – Plating Trials

- 4340 steel
- 4.3” ID
- Anode basket



Demo part shown in rack assembly with anode basket in place

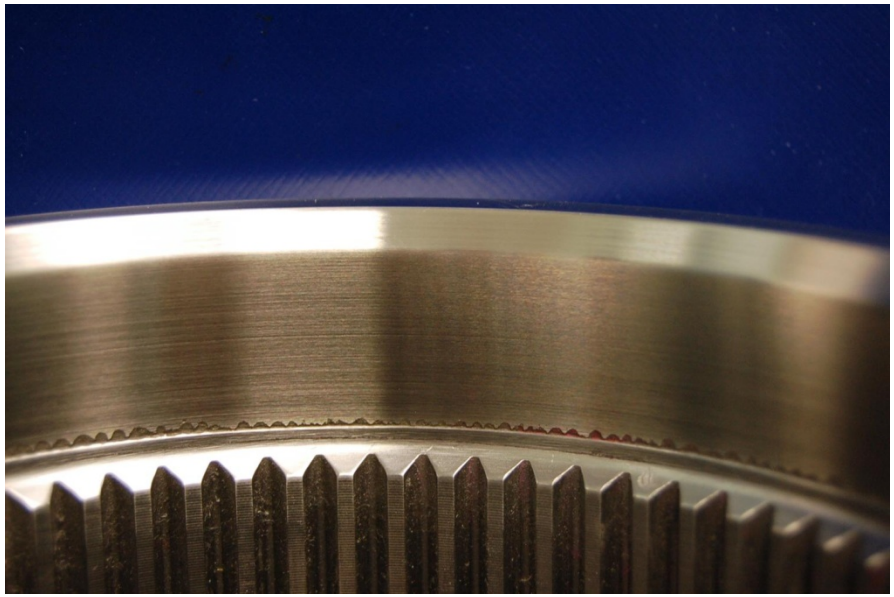


ID area to receive plating

Technology Transfer to NADEP-JAX

J52 Coupling, Turbine Shaft Actuating Cylinder – Plating Trials

- Plating rate ~ 0.0075”/hr
- Thickness
  - 0.015” (as-deposited)
  - 0.0075” (following grind)
- Good adhesion
- 4 Ra surface finish



Joint Test Protocol (JTP)

Performance Testing

Adhesion

- demonstrated for 4340, 15-5PH, Aermet 100, 7075 Al

Pre-test Grinding Study

- Mil-Std-866 acceptable for nCoP
- Finished to a 2-3µin roughness

Fluid Immersion

- nCoP compatible with most service and overhaul fluids

Corrosion (ASTM B117 & G85) & Rod-Seal Wear

- Samples prepared – testing pending

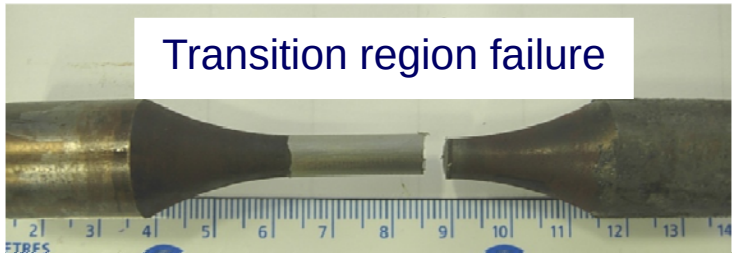
Hydrogen Embrittlement

- Deposition parameters seem to affect test outcome
- To be resolved in follow-on study

Performance Testing

Axial Fatigue

- 0.003”, 0.010” and 0.015” thick
- 4340, 15-5PH, 7075Al, Aermet 100 substrates
- Data showed debit compared to Cr
    - Found to be artefact of testing
- Post-test evaluation
    - Over 70% of bars failed at transition region (not on gage)
    - Due to high stress concentration (no runout)



Prior fatigue data invalid – testing to be repeated

Follow-on Study

Repeat fatigue testing

- Small scale study
- Obtain preliminary view of CoP fatigue performance

Re-evaluate process window

- Previously optimized for hardness, composition, appearance, wear
- Current work will optimize for embrittlement

Data Acquisition

- As required, re-evaluate properties using new deposition parameters

Producibility

- Plate tube IDs & flat test specimens and evaluate

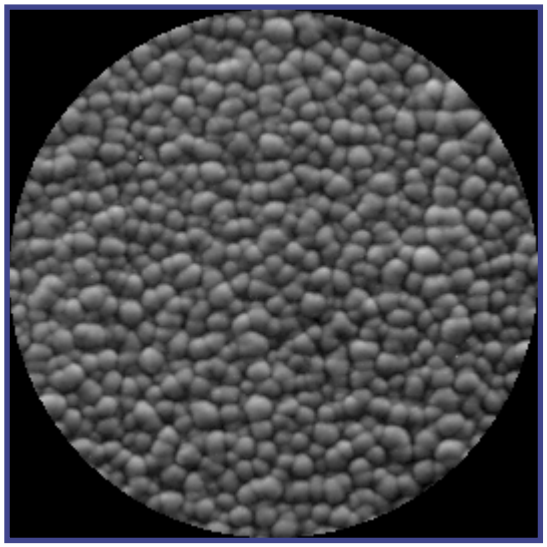
Cost benefit analysis

Reporting

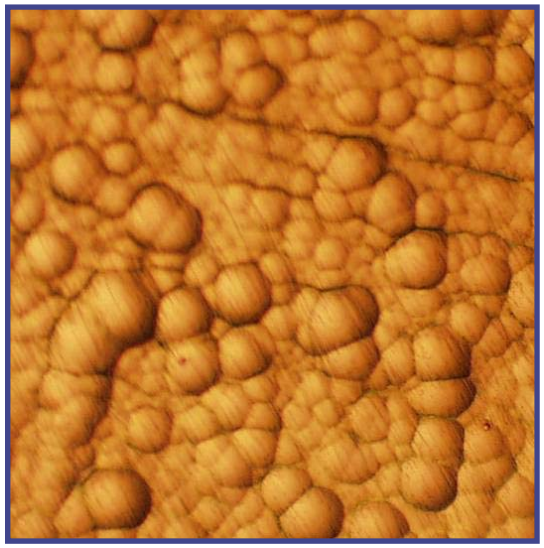
Thin Dense Chrome (TDC) Alternative

TDC Alternative Development

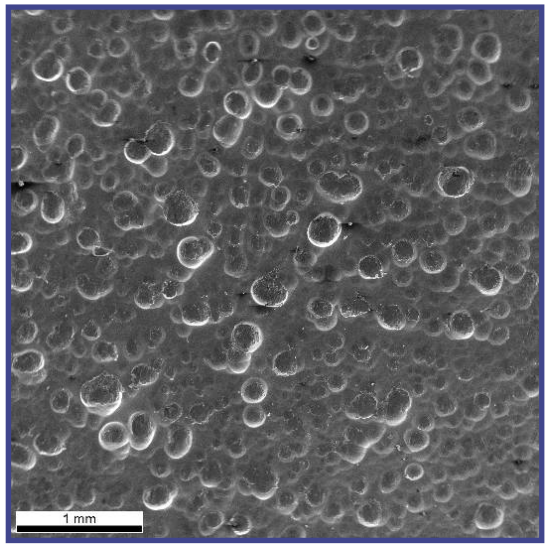
- Investigated Range of CoP Alloys (0-12wt%P)
- Benchmark comparison made against TDC (AMS 2438A)



Thin Dense Chrome



CoP (low P)



CoP (high P)

TDC Alternative Properties

	Class 1 nCoP (low P)	Class 2 nCoP (high P)
Application Types	When corrosion resistance is required and the substrates cannot be HT	When corrosion resistance is not required and the substrates can be HT
Surface Morhpology	Nodular (similar to TDC)	
Thickness Uniformity	Need proper masking/shielding to achieve	
Surface Finish	Unaltered after coating to 0.0005”	
Adhesion	Pass	Pass
Ductility	2-7%	~1%
Salt Spray Corrosion	Pass	Fail
Hardness	530-580 VHN	1000-1150 VHN
Wear (Sliding)	Good	Good
Wear (Abrasive)	17-20 mg/1000cycles	8-10 mg/1000cycles
Hydrogen Embrittlement	Pass (Type 1a2)	Not tested
Fatigue	Testing planned (Q2)	-

Technology Commercialization

Commercialization Status

nCoP Development and Testing

	EHC replacement	TDC replacement
Process Development	✓	✓
Process Stability	✓	✓
Basic Property Testing	✓	✓
Advanced Property Testing	Q4	Q2

New Product Introduction

	NADEP-JAX	Aerospace	Industrial Enduro	Other Industrial
Coupon Testing	✓	✓	✓	✓
Advanced Samples & Testing	In progress	✓	✓	✓
Deploy Dem/Val Tank	✓	`08	✓	`08
Production	TBD		✓	

Looking for customers to participate in Dem/Val (2H08)

Commercial Deployments

Example: Enduro Industries

- Hydraulic / Fluid Power Industry
- Carbon steel bars
- Cr replacement

1. **Coupon Testing**
   - "Thin" coating – up to 1 mil
   - No post plate grind or polish required
   - Even distribution – to specifications
2. **Advanced Samples & Testing**
   - Completed full performance testing for fluid power industry
   - Tests include: salt spray, adhesion, sliding wear, elastomer seal wear, deflection testing, endurance testing with side loads
3. **Commercial Scale Deployment**
   - As pictured at their facility
4. **Production**
   - Material deployed with customers

Summary

- **nCoP developed as alternative to EHC and TDC**
- **NADEP-JAX Dem/Val**
  - Demo parts plated successfully
- **JTP Testing**
  - Prior fatigue testing invalid
  - Follow-on study initiated
- **TDC Alternative Development**
  - Development and preliminary testing complete
  - Fatigue testing planned
- **Technology Commercialization**
  - Industrial deployments successful to date
  - New product testing and validation ongoing
  - Additional deployments planned

The End

THANK YOU FOR LISTENING!