

ElectroSpark Deposited Coatings for Replacement of Chrome Electroplating

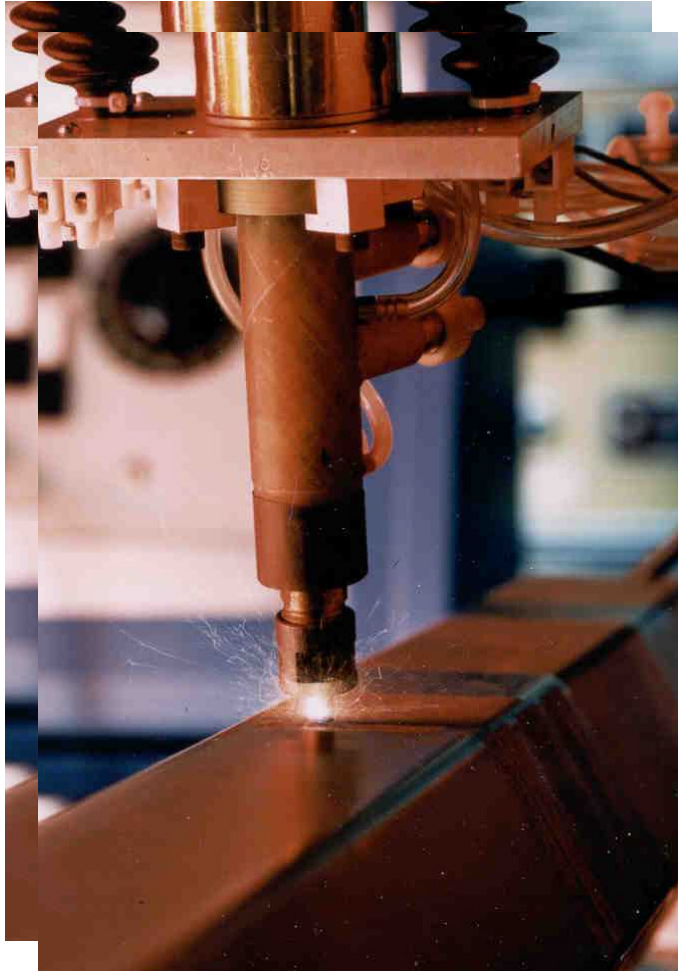
(SERDP Project 1147)

HCAT Meeting - 26 April 2001

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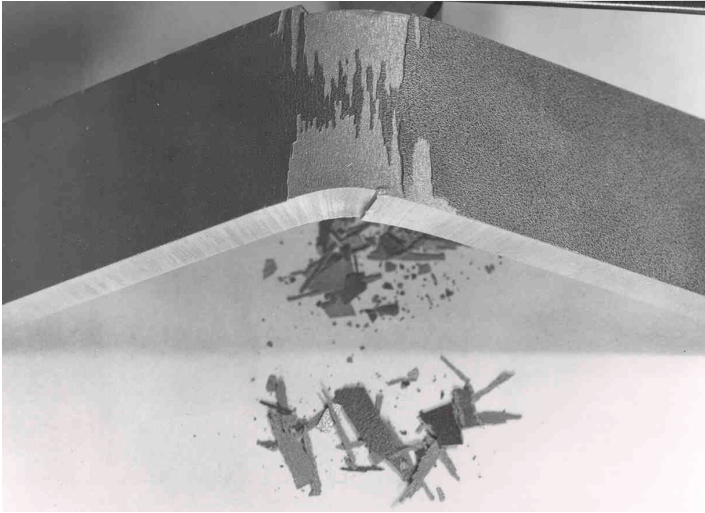
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Electrospark Deposition Technology



- Coatings: Electrically conductive metals, alloys, or cermets
- Micro-welding process
 - Short duration, high current electrical pulses deposit consumable electrode material
 - Low heat input, yet fused bond
 - Manual or automated application
 - Portable, low cost
 - Substrates: Metals

ElectroSpark Deposition Technology



- True metallurgical bonding to substrate
 - Displays superior adhesion to all thermal spray coatings in bend, tension and torsion tests
- Rapid solidification
 - Enables nanostructures
 - Unique tribological and corrosion performance
 - Low heat input

Team Members

ESD Team Members

PNNL - Roger Johnson (PI)

ARDEC – Dr. Joseph Argento, Andrew Goetz, Dr. Sheldon Cytron

TACOM/TARDEC - Karl Tebeau

AFRL/MLQL – Maj. Barnard Ghim

NAVAIR - Dr. Michael Kane

NSWC – Richard Hays

CTC - Melissa Klingenberg

Technical Contributors

PEWG, HCAT, SERDP Program Office (Charles Pellerin)

Problem Statement

■ Hexavalent chromium is a strong human carcinogen.

- EPA and OSHA have imposed stringent regulations
- PEL to be reduced from 0.1 mg/m³ to 0.001 mg/m³
- Control of waste prohibitive, will drive many from business

■ Industry needs alternative coatings/processes

- Must impart similar mechanical, chemical, and physical properties
 - HVOF is being implemented for simple geometry applications
 - HVOF cannot currently accommodate components with angles, crevices, inside diameters, or blind holes
 - ESD is being developed for Non-Line-Of-Sight through a SERDP sponsored project

ESD Complements HVOF Technology

- **ESD applicable to geometries unsuitable for HVOF**
 - Angles
 - Complex geometries
 - Inside Diameters
 - Blind holes
- **ESD best on limited areas or large parts with small area repairs.**
- **ESD frequently can be used on parts “in place”.**
- **No masking required.**
- **HVOF is faster for large areas, simple geometries**

Potential Users

■ Army repair depots

- *Corpus Christi Army Depot*
- *Anniston Army Depot*
- *Red River Army Depot*
- *Tobyhanna Army Depot*

■ Navy repair depots

- *NADEP Cherry Point*
- *NADEP JAX*
- *NADEP North Island*

■ Air Force air logistics centers

- *Oklahoma City ALC*
- *Ogden ALC*
- *Warner Robins ALC*

■ DOD original equipment manufacturers

■ DOD coating service subcontractors

Objectives

- Develop the ESD technology for automated use on complex geometries
- Determine the most appropriate coating compositions that can be deposited by ESD
 - Provide similar or improved hardness, wear resistance, and adhesion
 - Maintain production rate and part quality while minimizing maintenance requirements
 - Maintain or reduce treatment costs
 - Reduce worker safety risks and environmental impact

Approach

- Select coating materials and representative substrates
 - Substrate materials are those used most widely on DOD parts
- Develop ESD parameters to deposit selected coatings
- Conduct screening tests on selected coatings
- Fabricate force and position sensors and develop algorithms to enable deposition on NLOS geometries
- Develop prototype equipment capable of processing NLOS geometries
- Coat NLOS geometries with selected coating(s)

Economic and Environmental Benefits

- No hazardous waste streams generated
- No special Personnel Protection Equipment (fume hoods, sound booths, etc.) required
- Unit is portable for in-field service
- Robust coatings for severe service are produced
- Low heat-input process prevents distortion problems and metallurgical changes in the substrates



Program started March 29, 2000. First year results:

- 1. Selection of candidate coating materials completed.**
- 2. Selection of substrate materials representative of Tri-Service needs completed.**
- 3. Determined effect of wave form on coating quality.**
- 4. High speed videography trials completed, characterization technique eliminated.**
- 5. Development of force sensors and controls in progress.**
- 6. Development of controls and algorithms to maintain optimum deposition parameters in progress.**
- 7. Systematic characterization of parameters started, over 300 specimens coated, evaluation in progress.**
- 8. Screening tests to characterize properties in progress.**

Candidate Coatings

■ Primary candidates

Stellite 6, Stellite 21 -Cobalt-base alloys, for surface build-up, wear, and corrosion

WC-25TaC-13Co - good wear-resistant carbide-base coating (but not for fatigue or corrosion protection applications)

■ Secondary Candidates

- **Chromium Carbide - 15Ni** - High temperature wear and corrosion resistance
- **Nb Carbide -Ni-Mo** - High temperature wear
- **TiAl-TiB₂** - Tough, wear resistant

Candidate Substrates

- **4340 Steel** (Generic Chrome Nickel Molybdenum high Strength Steel used throughout the DOD)
- **Inconel 718** (Representative of Nickel Base High Strength Structural Alloys, Used in Turbine Engines)
- **300 M Steel** (Torsion bars or Springs)
- **PH13-8Mo Stainless Steel** (Precipitation Hardening Stainless Steel Representative)
- **7075-T6 Aluminum** (Generic Aircraft Structural Aluminum)

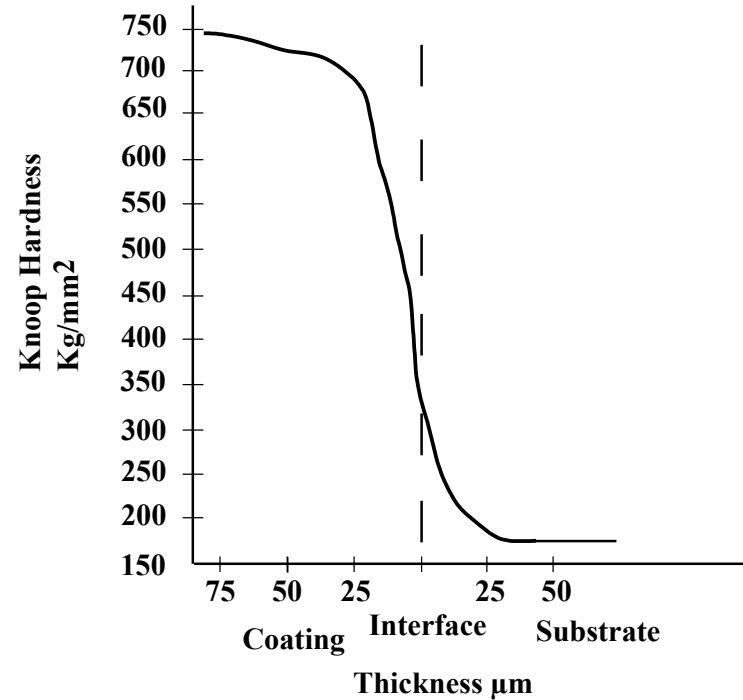
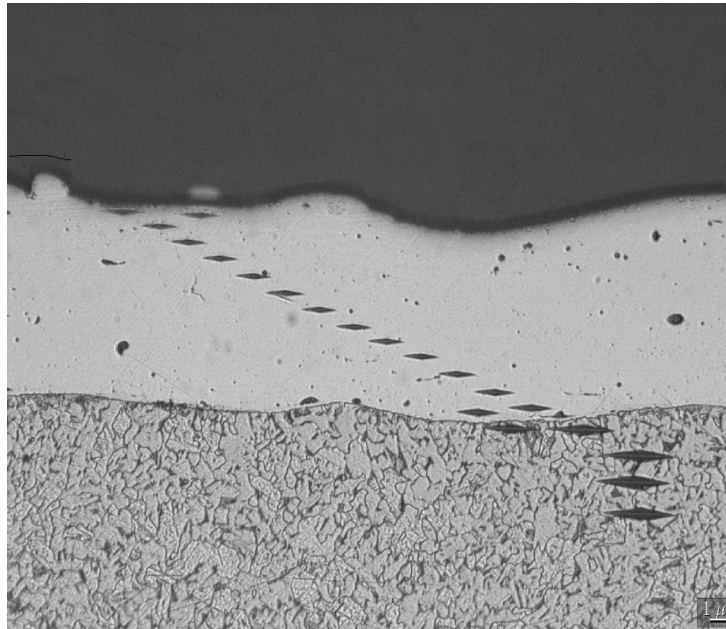
Stellite 6 ESD Deposit

0n steel, 100 gm contact force, 100 μm thick



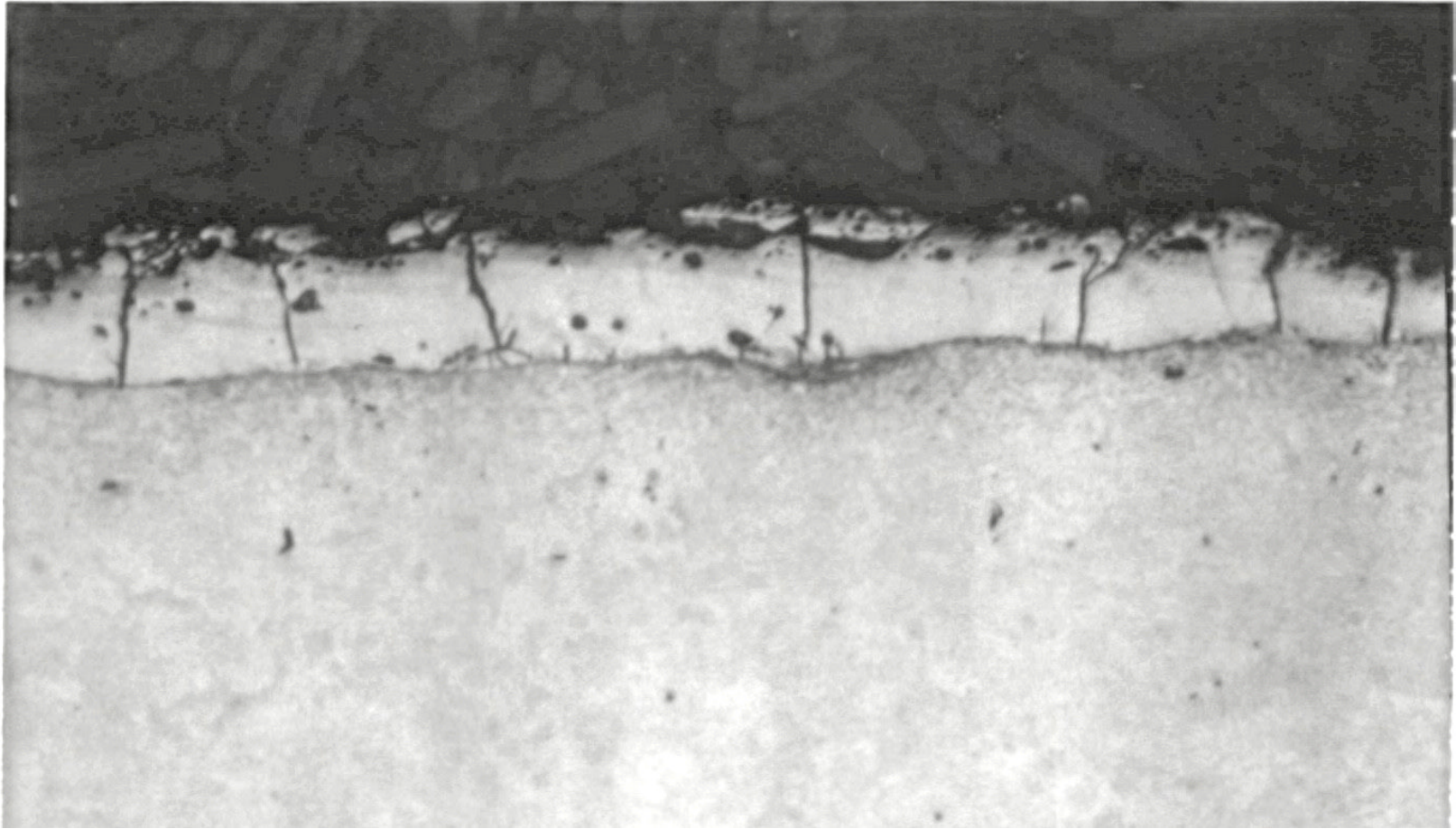
Knoop Hardness vs. Thickness

Stellite 6 coating on steel



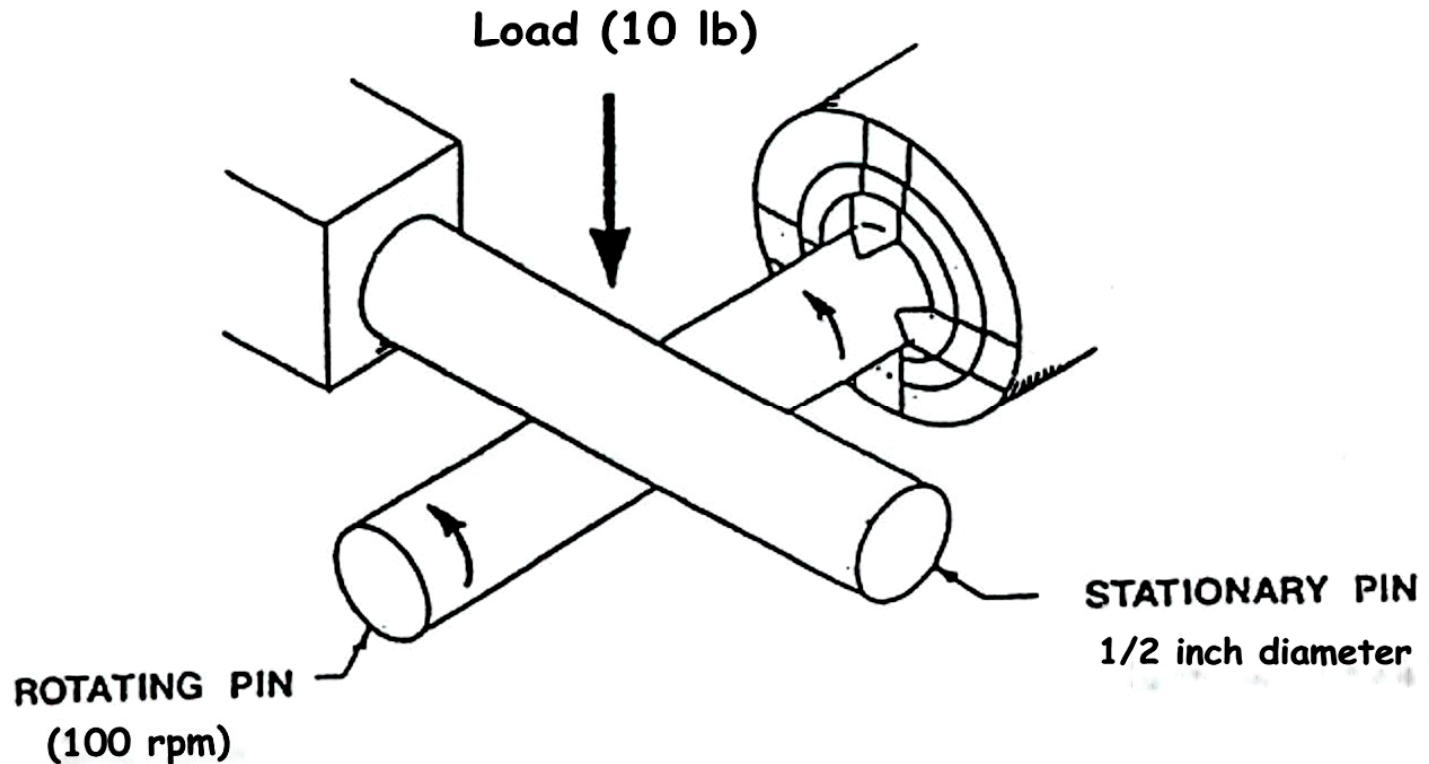
WC-25TaC-13Co ESD Deposit

on 4340 Steel, 35-50 μm thick



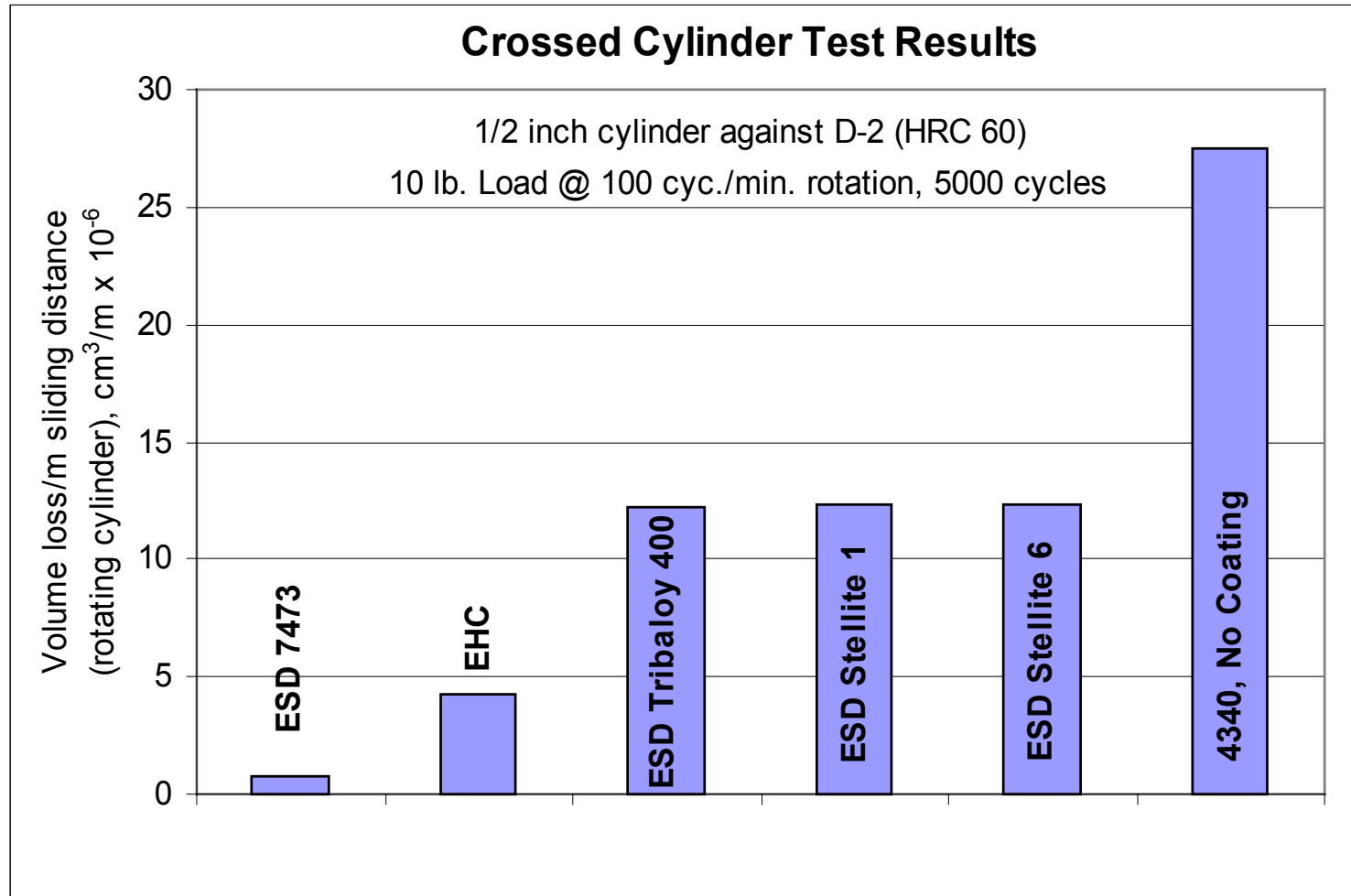
Crossed Cylinder Test

ASTM G-83



Wear Results

single layer coatings on 4340 steel



Salt Fog Tests, ASTM B117

Single Layer Coatings, 48 hrs



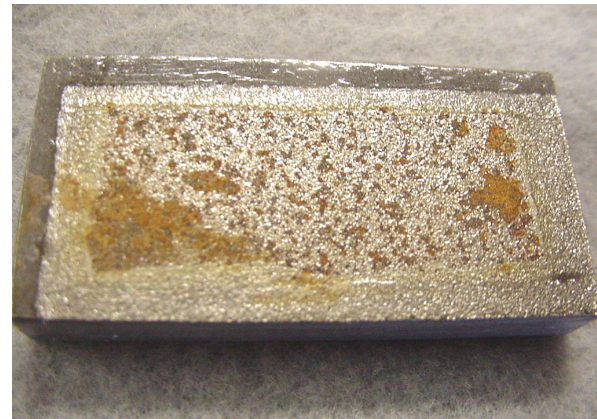
4340, Not Coated



Stellite 6



Hard Chrome Plate



WC-TaC-C0

Contact Force Control

Principal Parameter for NLOS Success

- **Phase 1 – Control force in one axis (automated)**

- Hall-effect magnetic switches

- Laser interferometer controls

- *Completed*

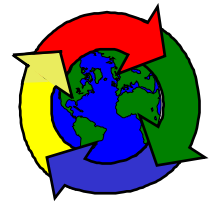
- **Phase 2 – Control force in multiple axes (automated)**

- Requires computer analysis of wave form, correlation with force, and feed back to force control module

- *In progress*

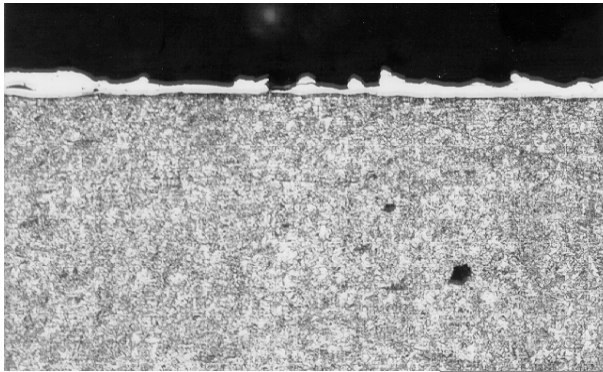
- **Phase 3 – Control force in multiple axes (manual)**

- Computer provides feedback to operator when in optimum range

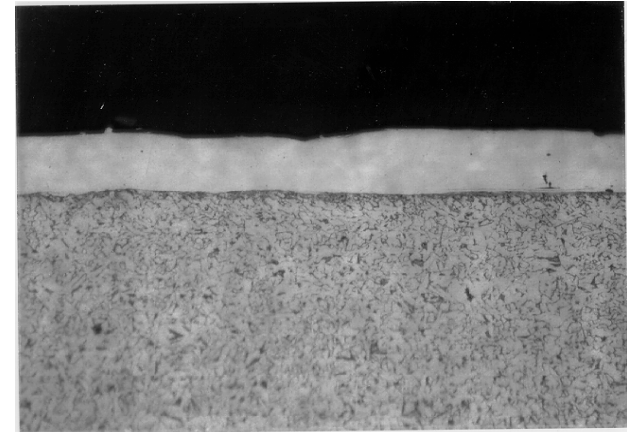


Stellite 6 on 4340 Steel

$30\ \mu\text{F}$

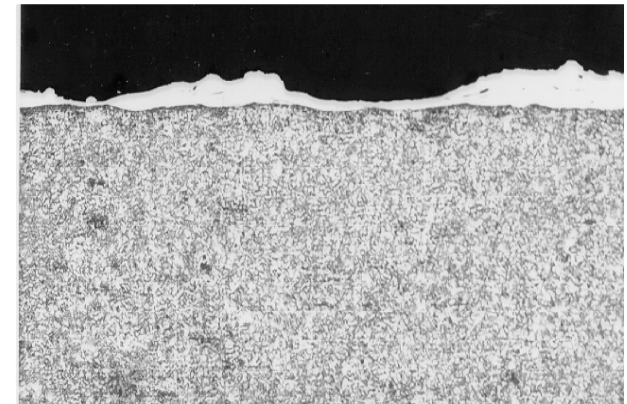
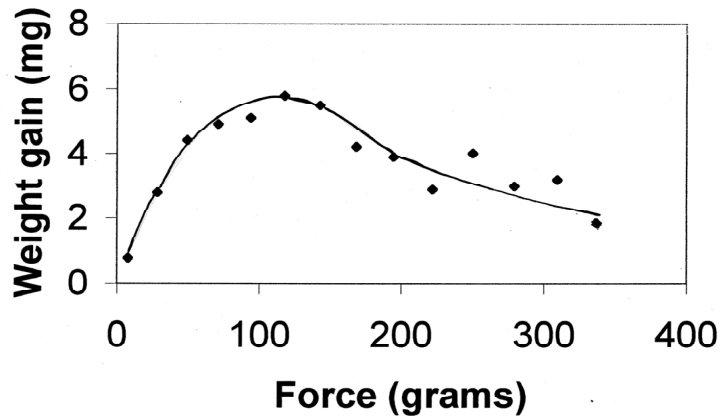


15 g
force



100 g
force

Weight gain vs. contact force



350 g
force

Status

- **Sensors** are being developed to enable real-time analysis of coating deposition parameters in non-line-of-sight applications (where visual observation is currently used to establish parameters).
- **Electronic controls** are being developed to maintain optimum deposition parameters under varying conditions of load, electrode orientation and electrode speed.
- **Candidate coatings and substrates** have been selected.
- **Candidate electrode** materials have been fabricated.

Characterization and Screening Tests

■ Phase 1

- Deposition rates and thickness achievable
- Microstructure

■ Phase 2

- - Density - Adhesion - H₂ Embrittlement
- - Hardness - Porosity

■ Phase 3

- Corrosion
- Wear
- Fatigue

Transition Plan

- Seek ESTCP funding for technology transition
 - Select candidate components
 - Conduct additional coupon testing specific to component or Tri-Service requirements
 - Coat components for demonstration/validation activities
 - Perform component testing: Rig or lead-the-fleet testing
 - Justify ESD use for DOD applications - perform ECAM
 - Prepare process specifications

Transition Plan

- Procure units for DOD facilities through other funding methods
 - Prepare logistics report and implementation plan for each DOD facility
 - Design, fabricate, and install units at DOD facilities
 - Assemble training documentation specific to each unit
 - Train operators and engineers on ESD operation and maintenance
 - Provide follow-up support

Summary

- ESD has the potential to replace hard chromium for NLOS applications, both manual and automated.
- ESD SERDP project has support from the Tri-Services
- Follow-on ESTCP to transition technology to depots