ElectroSpark Deposited Coatings for Replacement of Chrome Electroplating

(SERDP Project 1147)

HCAT Meeting - 26 April 2001

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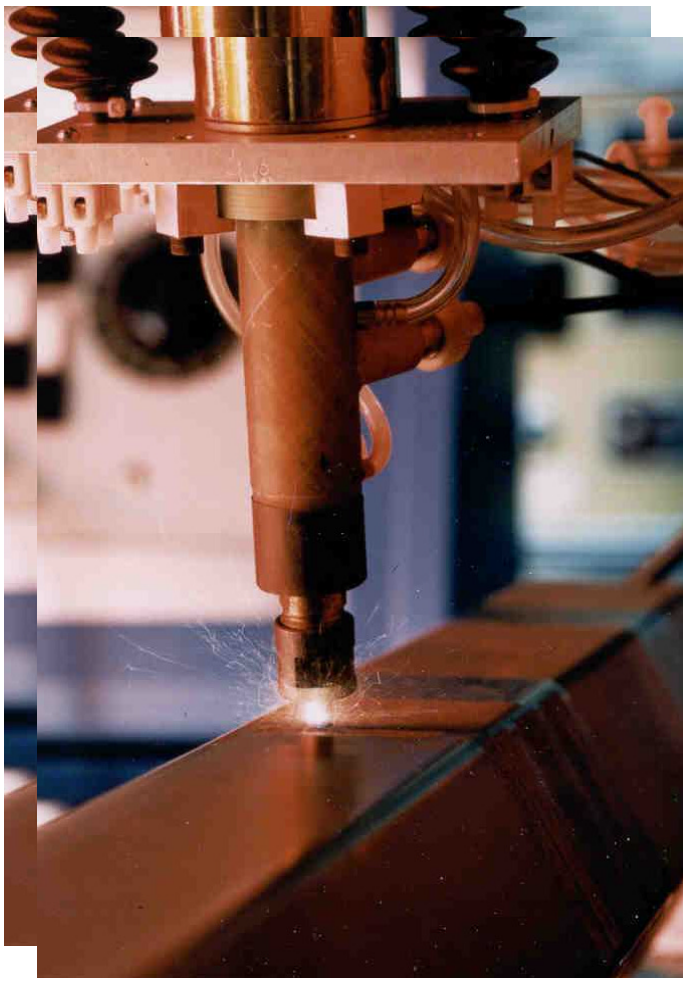
Electrospark Deposition Technology



- 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/m^3 to 0.001 mg/m^3
  - 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
  - Inside Diameters
  - Complex geometries
  - 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

ACCOMPLISHMENTS

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)

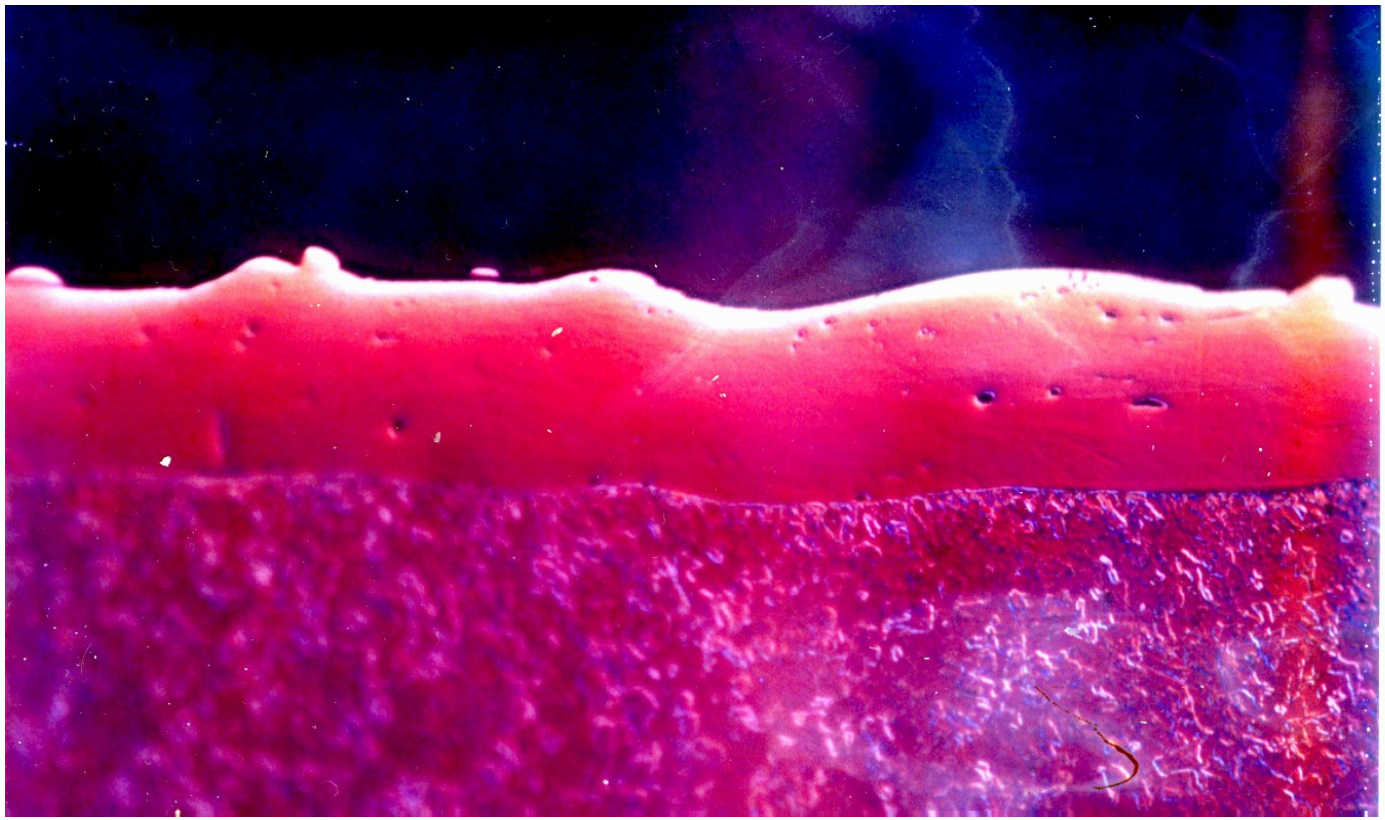
- **Secondary Candidates**
  - **Chromium Carbide - 15Ni -** High temperature wear and corrosion resistance
  - **Nb Carbide -Ni-Mo -** High temperature wear
  - **TiAl-TiB_2 -** Tough, wear resistant

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)

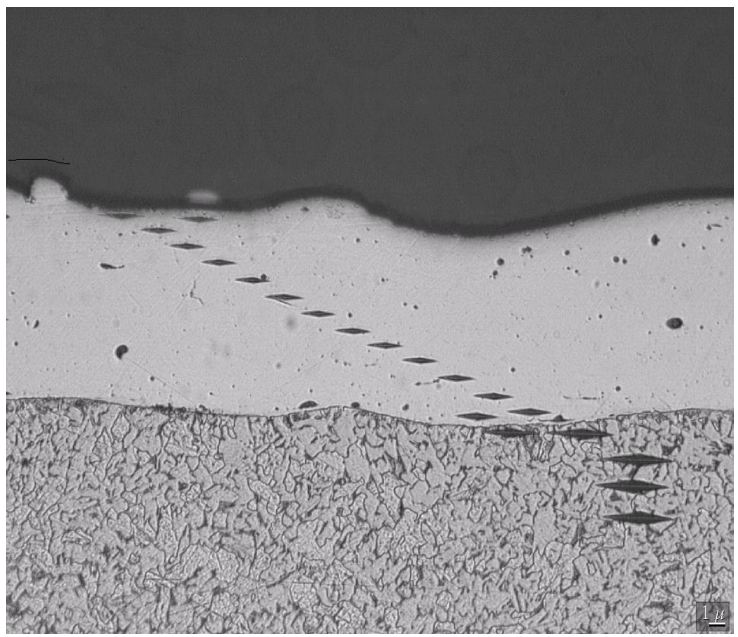
Stellite 6 ESD Deposit

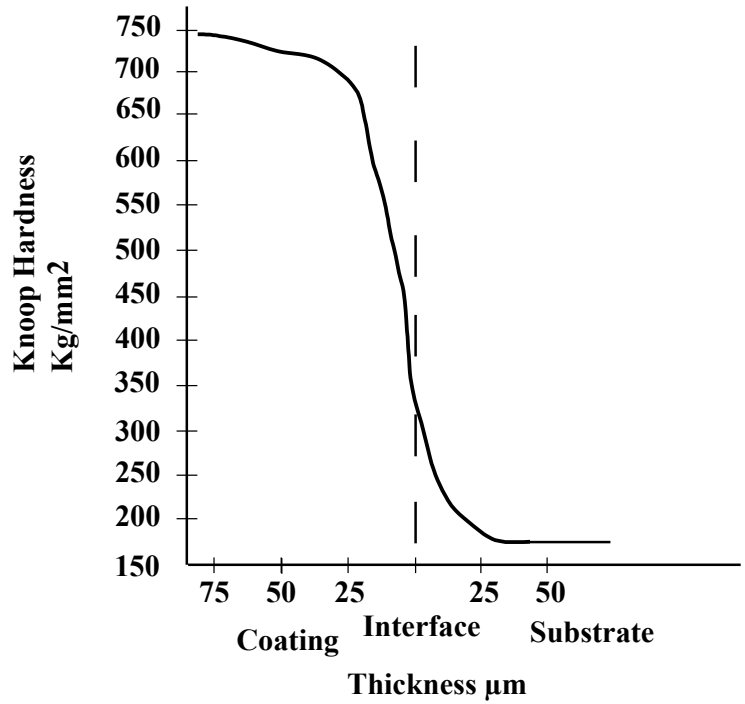
0n steel, 100 gm contact force, 100 μm thick



Knoop Hardness vs. Thickness

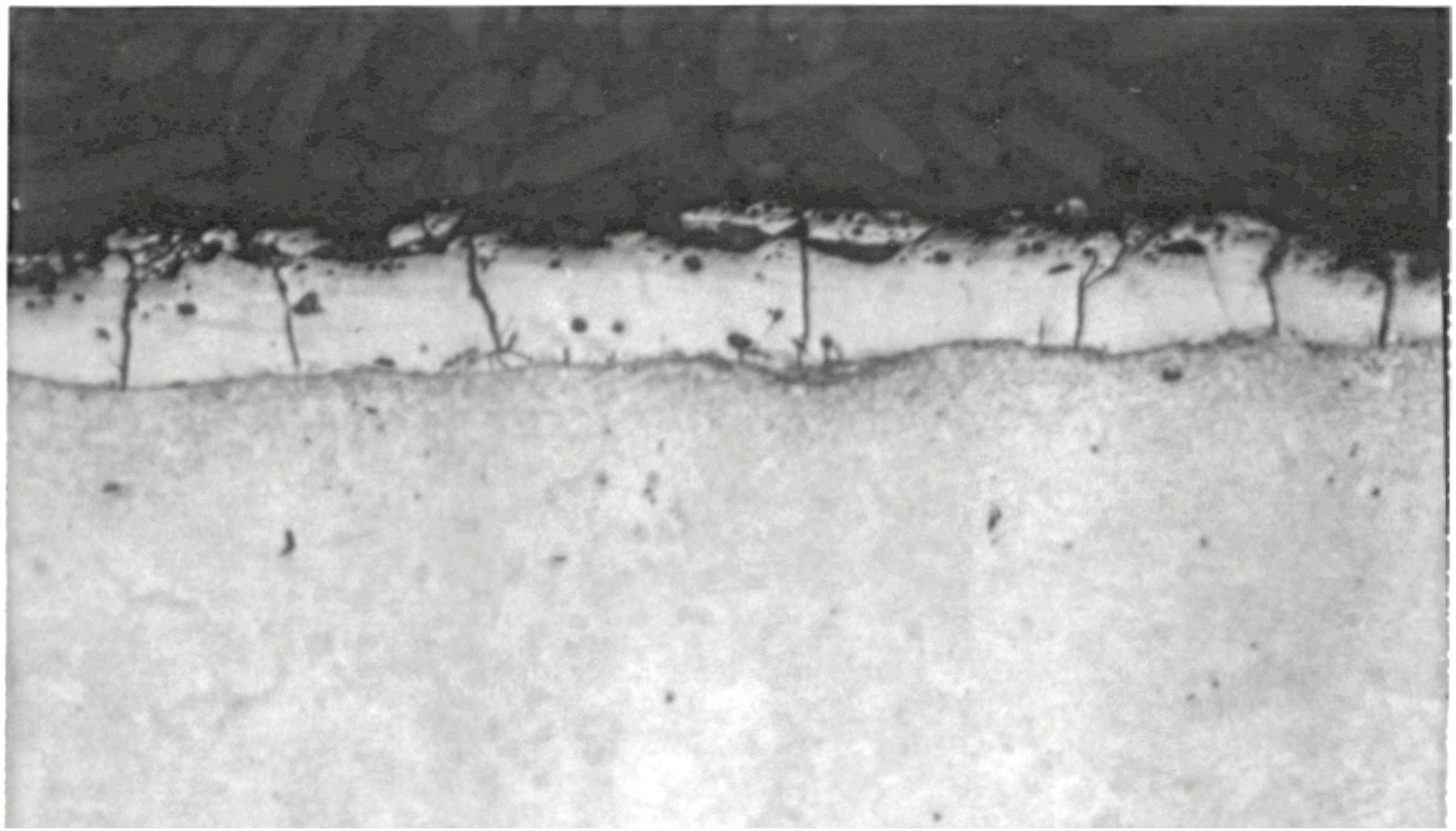
Stellite 6 coating on steel





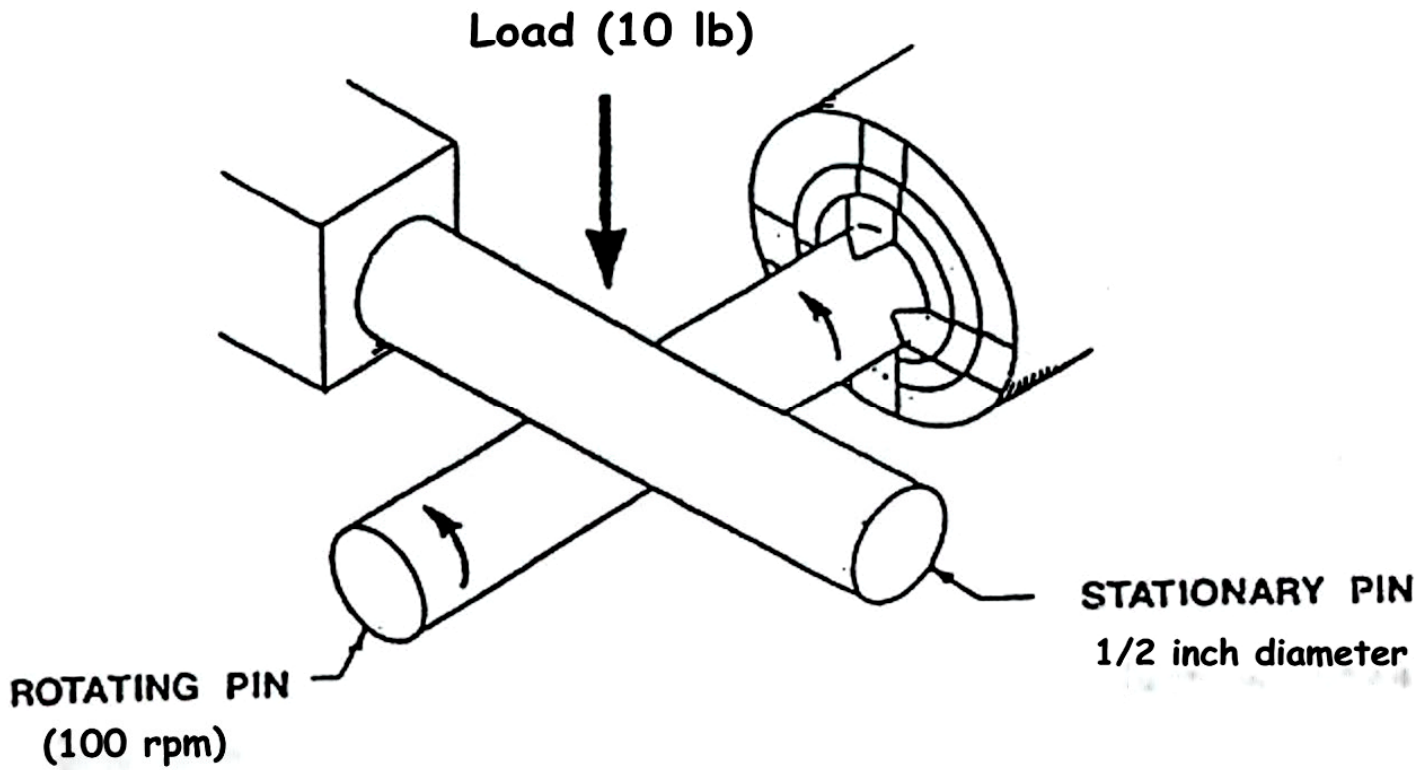
WC-25TaC-13Co ESD Deposit

on 4340 Steel, 35-50 µm thick



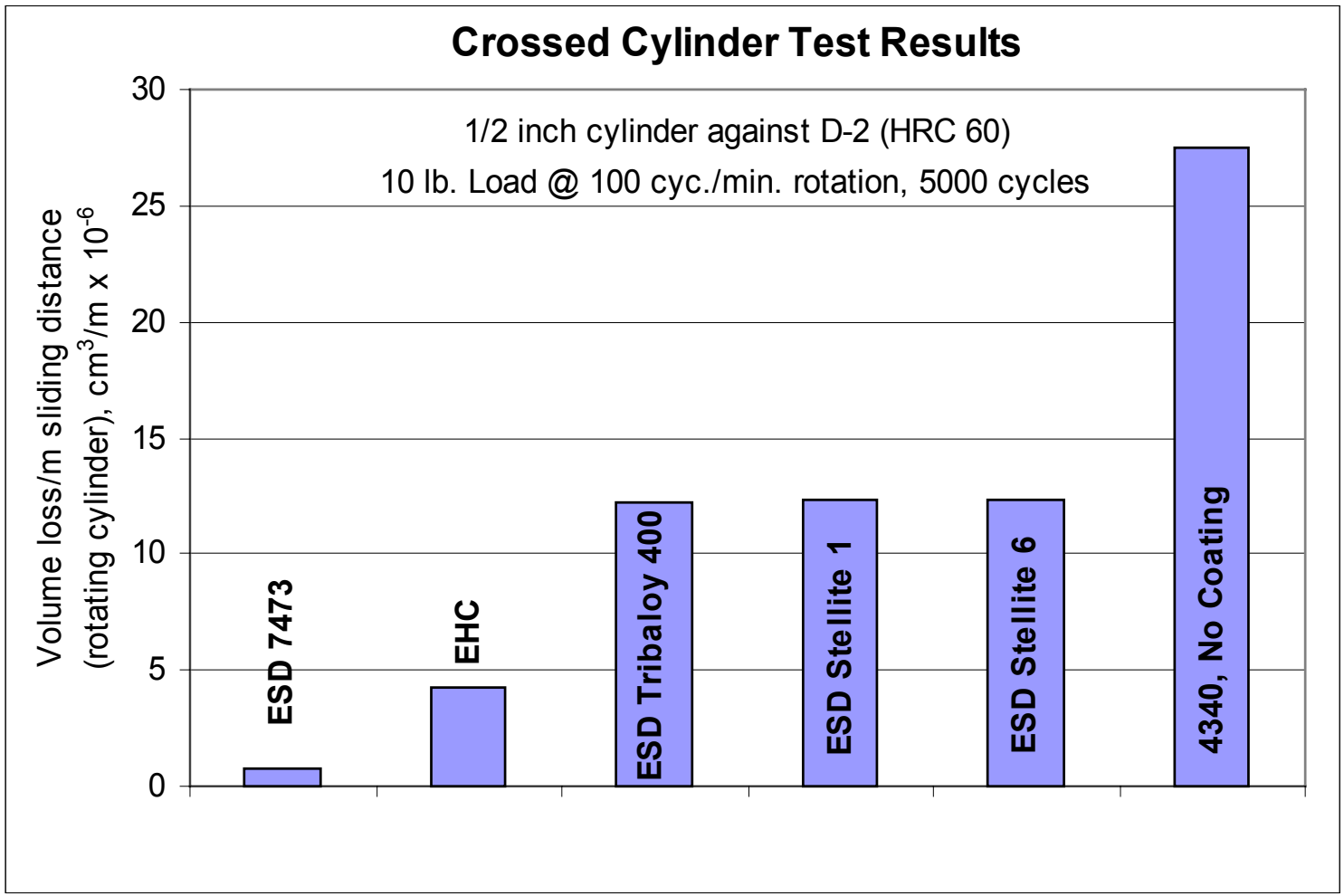
Crossed Cylinder Test

ASTM G-83



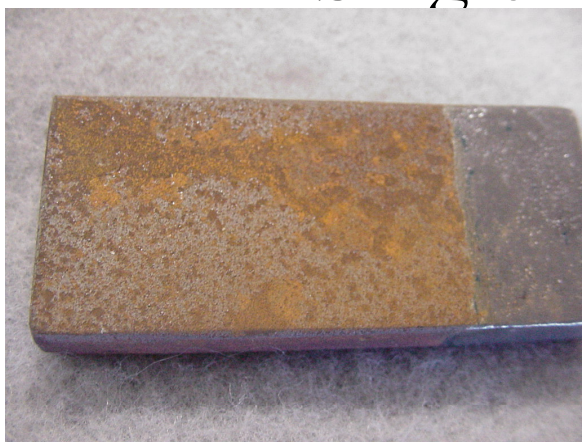
Wear Results

single layer coatings on 4340 steel

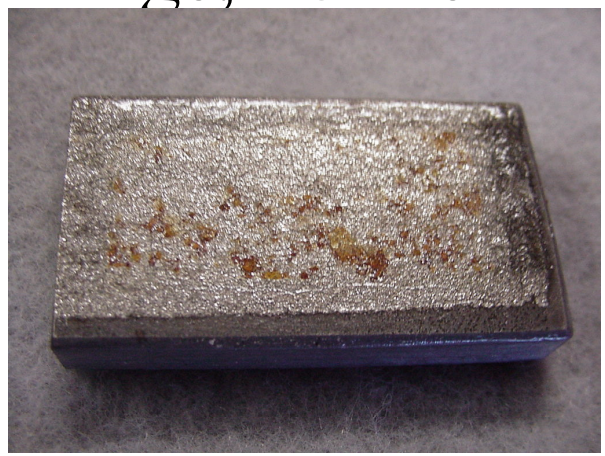


Salt Fog Tests, ASTM B117

Single Layer Coatings, 48 hrs

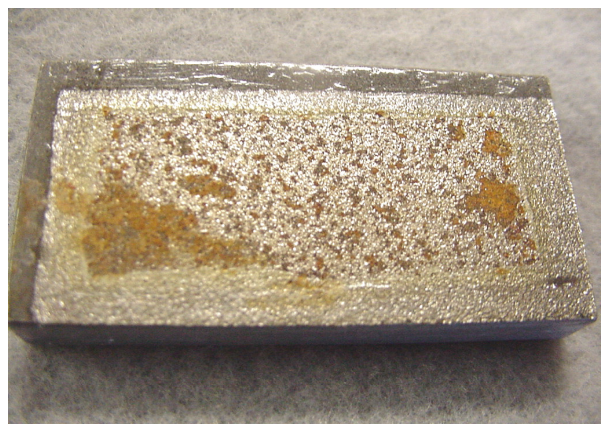


4340, Not Coated



Stellite 6

Hard Chrome Plate



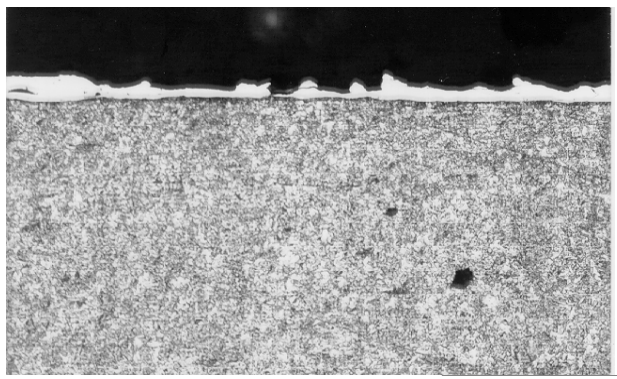
WC-TaC-C0

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

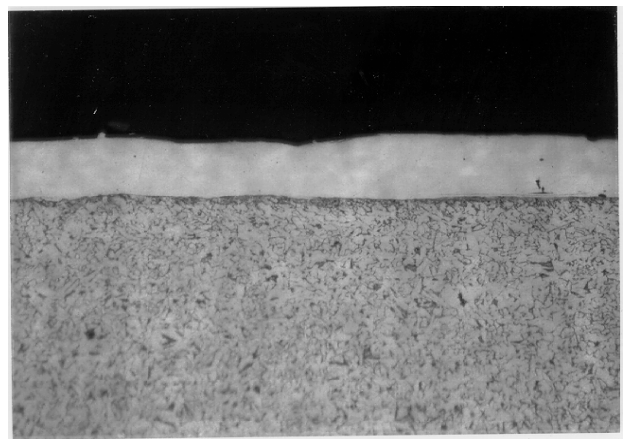
Stellite 6 on 4340 Steel

30 μF

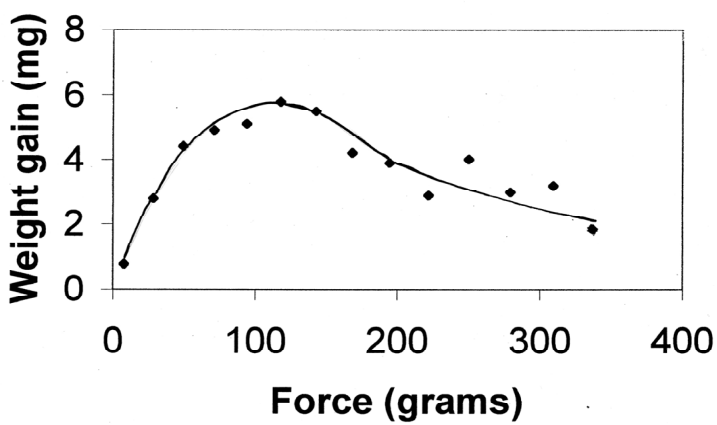


15 g force

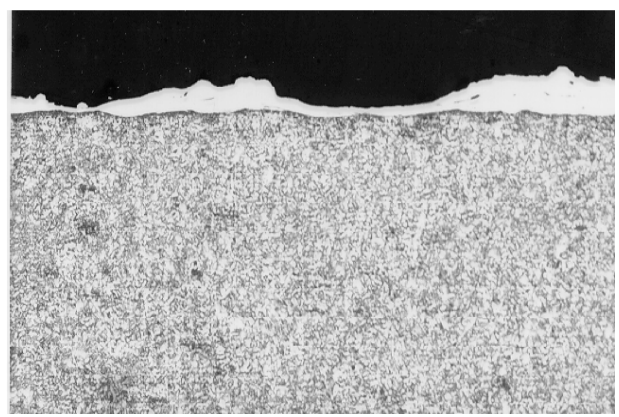
100 g force



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 - H_2 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