ElectroSpark Deposition

studies for

gas turbine engine component repair

Norma Price
Advanced Surfaces and Processes, Inc.

*HCAT Program Review Meeting*
Grandover Resort & Conference Center
Greensboro, NC 27407

March 17, 2005
**Report Documentation Page**

Public reporting burden for the collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to a penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.

<table>
<thead>
<tr>
<th>1. REPORT DATE</th>
<th>17 MAR 2005</th>
</tr>
</thead>
<tbody>
<tr>
<td>2. REPORT TYPE</td>
<td></td>
</tr>
<tr>
<td>3. DATES COVERED</td>
<td>00-00-2005 to 00-00-2005</td>
</tr>
<tr>
<td>4. TITLE AND SUBTITLE</td>
<td>ElectroSpark Deposition studies for gas turbine engine component repair</td>
</tr>
<tr>
<td>5a. CONTRACT NUMBER</td>
<td></td>
</tr>
<tr>
<td>5b. GRANT NUMBER</td>
<td></td>
</tr>
<tr>
<td>5c. PROGRAM ELEMENT NUMBER</td>
<td></td>
</tr>
<tr>
<td>5d. PROJECT NUMBER</td>
<td></td>
</tr>
<tr>
<td>5e. TASK NUMBER</td>
<td></td>
</tr>
<tr>
<td>5f. WORK UNIT NUMBER</td>
<td></td>
</tr>
<tr>
<td>6. AUTHOR(S)</td>
<td></td>
</tr>
<tr>
<td>7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)</td>
<td>Advanced Surfaces and Processes, Inc, 85 N. 26th Ave, Cornelius, OR, 97113</td>
</tr>
<tr>
<td>8. PERFORMING ORGANIZATION REPORT NUMBER</td>
<td></td>
</tr>
<tr>
<td>9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)</td>
<td></td>
</tr>
<tr>
<td>10. SPONSOR/MONITOR’S ACRONYM(S)</td>
<td></td>
</tr>
<tr>
<td>11. SPONSOR/MONITOR’S REPORT NUMBER(S)</td>
<td></td>
</tr>
<tr>
<td>12. DISTRIBUTION/AVAILABILITY STATEMENT</td>
<td>Approved for public release; distribution unlimited</td>
</tr>
<tr>
<td>14. ABSTRACT</td>
<td></td>
</tr>
<tr>
<td>15. SUBJECT TERMS</td>
<td></td>
</tr>
<tr>
<td>16. SECURITY CLASSIFICATION OF:</td>
<td></td>
</tr>
<tr>
<td>a. REPORT unclassified</td>
<td></td>
</tr>
<tr>
<td>b. ABSTRACT unclassified</td>
<td></td>
</tr>
<tr>
<td>c. THIS PAGE unclassified</td>
<td></td>
</tr>
<tr>
<td>17. LIMITATION OF ABSTRACT Same as Report (SAR)</td>
<td></td>
</tr>
<tr>
<td>18. NUMBER OF PAGES 26</td>
<td></td>
</tr>
<tr>
<td>19a. NAME OF RESPONSIBLE PERSON</td>
<td></td>
</tr>
</tbody>
</table>

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

The goals of this project are to *demonstrate and validate* ElectroSpark Deposition (ESD) as technically feasible and commercially viable for a production-scale process, and to perform the tests necessary to transition ESD for use on gas turbine engine components.
Participants

- ESTCP/HCAT
- PEWG
- Portland State University
- Edison Welding Institute
- Rowan Technology Group
- Pacific Northwest National Lab
- Air Force Research Lab
- General Electric Aircraft Engines
- Pratt & Whitney
- Tinker AFB
What is ESD?

The ESD process is comprised of an electric arc through a consumable electrode energized by a series of capacitors. During the generation of the arc, small particles of the electrode material are melted and build-up occurs incrementally.

- Metallurgical bond
- Low heat input
- Rapid solidification
- No pre-ESD preparation
- No post-ESD processing
- Environmentally benign
- Portable
- Applicable for NLOS
Demonstration Plan

- Execution of a Joint Test Protocol
- Joint Test Report due 2006
- Component Specific
- Cost/Benefit Analysis performed by CTC
- Materials of Interest
  - IN718 on IN 718
  - 410 SS on 410 SS
  - Ti-6Al-4V on Ti-6Al-4V
  - IN 718 on chrome plated IN 718

EPP0202 Demo Plan Revision A.doc
www.hcat.org
HCAT Member WorkSpace → ESD → Test Plans → Demonstration Plan
http://207.152.96.131/w2g/cgi/kmcgi.exe?O=DIR0000000GPM&V=0

March 17, 2005
Optimization

- IN 718 on IN 718
- DOE Optimization
- Added UIT
- Metallurgical Evaluation
  - Deposition Rate
  - Microhardness
  - Porosity
- Two Parameter Sets Selected

Optimization Document Project # EPP 0202 (January 2005)

www.hcat.org
http://207.152.96.131/w2g/cgi/kmcgi.exe?O=DIR0000000GPM&V=0
Joint Test Protocol

- Pin on Disk Wear
- Fatigue
- Residual Stress
- Corrosion
- Adhesion Bond
- Tensile
- Hamilton Sundstrand Wear

JTP Project # EPP 0202 (January 2005)

www.hcat.org
http://207.152.96.131/w2g/cgi/kmcgi.exe?O=DIR0000000GPM&V=0

March 17, 2005
Pin on Disk Wear

<table>
<thead>
<tr>
<th>Specimen</th>
<th>Maximum Groove Depth</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Base Metal</td>
</tr>
<tr>
<td>2-1</td>
<td>114</td>
</tr>
<tr>
<td>2-2</td>
<td>92</td>
</tr>
<tr>
<td>2-4</td>
<td>128</td>
</tr>
<tr>
<td>2-3 (long test)</td>
<td>218</td>
</tr>
</tbody>
</table>
Fatigue
Fatigue

Baseline – No Defect
Baseline – With Defect
Fatigue

Baseline – No Defect
Baseline – With Defect
ESD V4
Fatigue

Baseline – No Defect
Baseline – With Defect
ESD #32
Fatigue

Baseline – No Defect
Baseline – With Defect
ESD – As Deposited

Cycles to Failure

Fatigue Stress Level (psi)
Residual Stress

- Tensile stresses with ESD
- Higher tensile stresses with increased energy
- Investigating stresses in ESD with UIT

Almen Readings

#32
V4
Corrosion

- Preliminary corrosion testing conducted following ASTM G-48, heated ferric chloride.
- Salt Fog ASTM B117 to be performed

Adhesion Bond

- ASTM C 633 to be performed
**Tensile**

- *Tensile specimens being prepared by ASAP*
- *Some specimens will receive UIT*
- *Specimens sent for final surface finishing*
- *Tensile testing to be performed by PSU*
Hamilton Sundstrand Wear

- Specimens to be procured and prepared by ASAP
- Some specimens will receive UIT
- Specimens sent for final surface finishing
- Wear testing to be performed by Hamilton Sundstrand
10-12 Stator Segment

- ESD parameters under evaluation via JTP
- ESD process technique developed

>0.005” deep wear in hook non-line-of-sight

Current repair:
Cut off hook,
weld on new,
heat treat part

no repair if the part has met permissible heat treat cycles

P/N 4077880
F100 – 229
Inconel 718
JTP for other materials

- 410 SS on 410 SS
- Ti-6Al-4V on Ti-6Al-4V
- IN 718 on chrome plated IN 718
Other ESTCP/HCAT/PEWG Activities

- Chrome Plate repair
- Particle Emission testing
- ESD/Robotics/UIT
- #5 Bearing Housing
ESD, Robotics and UIT

Improvement in ESD

Automated with UIT vs. Manual

<table>
<thead>
<tr>
<th>Metric</th>
<th>Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Production Rates</td>
<td>11 X</td>
</tr>
<tr>
<td>Discontinuities</td>
<td>0.8 X</td>
</tr>
<tr>
<td>Hardness</td>
<td>1.3 X</td>
</tr>
</tbody>
</table>
#5 Bearing Housing

P/N 712141
TF 33
AMS 5613
(410 stainless steel)
#5 Bearing Housing

Excavate the defective area

Fill with ESD

Blend to original surface
#5 Bearing Housing

ElectroSpark Deposition

studies for
gas turbine engine component repair

Advanced Surfaces and Processes, Inc.
85 N. 26th Ave, Cornelius, OR 97113
PO Box 729, Forest Grove, OR 97116
503.640.4072
Fax: 503.640.8070

wwwadvanced-surfaces.com