Navy ManTech
Development and Application of Cold Spray Repair For Shipboard Components

NSRP Program Review
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Distribution Statement A: Approved for Public Release
Issue Description

- Puget Sound Naval Shipyard and the Intermediate Maintenance Facility (PSNS & IMF) has identified a number of repair issues for shipboard components
- Several components do not have approved repair processes
- Many of the approved repair processes are inadequate
- Long lead times for replacement reduce readiness and create issues with scheduling.
- Rigid schedule for vessel refurbishment
  - Schedule
  - Quality of repair
  - Cost
- Corrosion and/or wear damage is extensive
- Repairs are needed for Al-6061 T651, Monel (70Ni/30Cu), 70/30 (70Cu/30Ni), Inconel, brass, bronze and steel
Objective:

• Develop and transition cold spray repair and restoration processes for shipboard repair/restoration of components

Program Outline/Approach:

• Identify candidate components for Cold Spray Repair
• Down select and rank four components/material systems for repair
  • Hydraulic Actuators/Controllers
  • Electric Motor End Bell Bore Repair
  • Replacement for Copper Plating
  • Seawater Pump Components
• Develop, qualify and transition repairs
• Repairs performed with a VRC High Pressure Cold Spray System
• Develop Navy Repair Procedures for repairs
  • General Cold Spray Procedure
  • Specific Repair
    • UIPI – Universal Industrial Process Instruction
• Cost analysis
TD-63 Actuator Repair

The Problem

6061 Aluminum Hydraulic Actuator

CUNI 70/30 Seawater Valve
TD-63 Actuator Repair
TD-63 Hydraulic Actuator:
- Material Al-6061
- Damage - bore has pitting and wear damage
- Damage is internal to the bore
- Repairs were performed by VRC Metal Systems in partnership with Mid-America Aviation, A Moog Company
- Technical support from the Army Research Laboratory

Spray Parameters
- System: VRC Gen III
- Head: 45° head
- Powder: Valimet 6061 Aluminum
- Carrier gas: Helium
- Gas temp (nominal): 500° C
- Gas pressure (nominal): 500 psi
TD-63 Hydraulic Actuator Repair Development:
Pre-approval
- PSNS&IMF
- NAVSEA 05
- Coating Development
  - Nozzle angle to reach desired surfaces
  - Nozzle path and traverse speed
  - Rotate component
- Spray test coupons with the nozzle angle and traverse speed used in the repair
  - Porosity
  - Hardness
  - Adhesion Strength
    - ASTM C633
- Dye pen
- Fabricate a block of Al6061
  - Tensile tests
TD-63 Hydraulic Actuator Repair Development:
• Fabricated full-scale Al-6061 cylinder with same bore dimensions for repair development
• Over machined bore to represent damage removal
• Grit blasted surface prior to coating
• Applied Al-6061 coating
• Machined to final dimensions
• Sectioned test article to evaluate interfaces
TD-63 Hydraulic Actuator Repair:
• Repair using parameters selected in development phase
  • He (Pressure and Temperature)
  • Nozzle angle and traverse speed
  • Part rotation
• Witness Coupons
  • Sprayed at the same time the actuator was repaired
    • Bond strength
    • Tensile Strength
    • Hardness
    • Porosity
• Actuator shipped to Puget Sound Naval Shipyards
• Inspected
• Granted two year use approval
• Tom Stamey received an individual NAVSEA Excellence Award winner for Cold Spray application
• **Tensile testing:**
  • Test coupons (dog bones) manufactured per ASTM E8.
  • Test coupons were entirely cold spray.
  • Tensile strength of the cold spray was 35,800 psi.
  • Min tensile strength of the actuator body is 37,000 psi.

• **Bond testing:**
  • Testing performed per ASTM C633.
  • For critical surfaces, bond strength is in excess of 10,000 psi.
  • Testing was limited by the strength of the glue, not the cold spray.

• **Metallurgical examination:**
  • Examination of test coupons showed less than 1% porosity.
  • Examination of a sectioned mock-up in the reentrant corner showed porosity around 5%.
The following tests were performed by PSNS & IMF on the assembled actuator:

- Internally hydrostatically tested to 1.5x operating pressure.
- Joint tightness testing to operating pressure.
- Operational testing.
- All testing was per the applicable maintenance standard.
- The actuator passed all testing.

TD-16 is in process of being repaired.
Motor Bell Housing Repair

Repair:

• Copper plating is not a long term solution
• Bell housing material – cast iron or steel
• Rotation of the motor shaft and vibration
• Wear and deformation of housing/bearing interface
  • Machine worn area to remove damage
• Surface Preparation
  • Restore surface to original dimension
• Develop repair process
  • Material selection
    • Similar to housing material
    • Add material that will reduce wear and deformation
Repair Of the Inner Diameters

Develop coating that is more wear resistant than the steel substrate

- Need balance between adhesion strength and hardness
  - Ni 300 VHN
  - C$_3$rC$_2$-25Ni 526 VHN
  - C$_3$rC$_2$-25NiCr 843 VHN
- Adhesion Strength > 8ksi glue failures
Alloy 70Cu/30Ni on the ID of a 4140 Steel Pipe
- AEE 70Cu/30Ni powder 35µm average particles diameter
- Coating thickness 0.025 and 0.04 inches
- <0.34% porosity

6 in ID 4140 steel pipe
Copper-Nickel microstructure 500x
• Navy has many bronze components that are damaged by corrosion and wear
• Components include pump components, tubes, and valve components
• Develop Repair Procedure for Bronze components
• Substrate C90300 Bronze

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<th>Cu</th>
<th>Sn</th>
<th>Zn</th>
<th>Ni</th>
<th>Density</th>
<th>Hardness</th>
<th>UTS</th>
<th>YS</th>
<th>Elongation</th>
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<tr>
<td>86-89%</td>
<td>7.5-9%</td>
<td>3-5%</td>
<td>1%</td>
<td>8 g/cc</td>
<td>70 HB (500 kg)</td>
<td>44 ksi</td>
<td>22 ksi</td>
<td>30% in 2”</td>
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</table>

• Powder – AcuPowder DT-31

<table>
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<tr>
<th>Cu</th>
<th>Sn</th>
<th>Zn</th>
<th>Density</th>
<th>Size</th>
<th>Shape</th>
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</thead>
<tbody>
<tr>
<td>88%</td>
<td>10%</td>
<td>2%</td>
<td>3.4 g/cc</td>
<td>-400 mesh</td>
<td>irregular</td>
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</table>
Bond Bar Adhesion ASTM C633
AcuPowder DT-31 powder on Substrate C90300
Adhesion Strength 11345, 11784, 10620, 10583 psi
Failure Mechanism: All glue failures

Deposit Micrographs
ASTM G71 Corrosion Testing
• Excellent galvanic corrosion performance coupled with C90300 substrate. 0.0002 inches/year corrosion rate highest value.

Future Work
• B117 Salt Fog Corrosion Testing
• Tensile Properties
• Deposition on Representative Hardware
• Component Repair

70Cu/30Ni – Repair
• 70Cu/30Ni or similar material on 70Cu/30Ni
• Galvanic Compatibility
• Resistant to Crevice Corrosion
Quantitative Benefits:

- Qualified Repair Process
  - Repair parts that currently have to be removed from service or have no approved repair process
- Ability to meet rigid repair schedule
- Economical Repair Process

Qualitative Benefits:

- Reduced Environmental Impact
  - Reduced hazardous material usage
- Improved Life-Cycle Affordability
  - Repair parts that had to be scrapped
  - Multiple repairs possible
  - Improves readiness/reduced down time
- Applicable to other Navy assets for repair and restoration

Current Process: Hydraulic Actuator

No approved repair:
- Cost of new hydraulic actuator = $70k
- Replacement Cost = 5 damaged/year
- $350k/year

Proposed Process

Assumption: Can repair all damaged housings
- Cold Spray Repair = $10K/repair
- = 5 repairs/yr. X $10k
- = $50k/ yr..

Cost Avoidance
- Hydraulic Actuator Repair = ($4350-$50k)/yr. = $300k/ yr.
- = $1.5M – over 5 years

ManTech Present Value (5 YR) ROI = 2.5:1

Readiness
- Lead time for a new actuator can be as long as 1 year
- Requirements for inventory
• The Cold Spray process has been approved for repairing the TD-63 Al-6061 hydraulic actuator
  • TD-63 – two year approval
  • Each repair must be approved
  • UIPI – for each repair
• TD-16 Al-6061 hydraulic actuator repair underway
• Repair processes are being developed for
  • Motor Bell Housing Repair
  • Bronze components
• Cold Spray viable repair process
• Meet rigid ship refurbishment schedule
• Repair of long lead time items
• Repair of legacy assets
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