Corrosion Webinar Series

Robotic Coating Application

Presented by Allen Skaja
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What is Robotic Coating?

• Automated units are used to replace manual work in coating jobs including:
  • Surface cleaning – water jetting
  • Surface preparation – abrasive blasting
  • Coating application

• Robotic equipment capable of use on pipes up to 32 feet diameter
Why robotic coating application?: Safety!

• Penstocks and other pipelines are considered confined space and require extensive safety preparation for workers including
  • Hazardous Environment: particulates and solvents used in abrasive blasting and coatings application can be considered hazardous materials and require engineering controls to reduce exposure risk
  • Proper air flow and continuous monitoring- may require engineered forced air and/or supplied air respirators

• Case Study: Xcel Energy Cabin Creek Fire 2007
  • Flammable atmosphere in a confined space → Coating was 100% solids epoxy (no solvent) with MEK for cleaning equipment
  • Poor safety planning → No emergency response plan
  • Consequence → 5 painters died during the penstock relining project

• Automation reduces need for workers in hazardous environment
Why robotic coating application?:
Less Outage Time

• Robotic coating application requires less time for site prep, surface prep, and coating application than conventional coating jobs.

• Leads to less outage time and less time lost for power generation or water delivery to customers.
Case Study: Mark Wilmer Discharge Tubes

• Location: Lake Havasu, source for Central Arizona Project (CAP)
• Use: discharge tubes carry 3,000 cfs water from Lake Havasu to series of canals, tunnels, and pumping plants serving Phoenix and Tucson
• Structure: 12-ft diameter, 2500 feet long, ~100,000 sq ft for relining
• Structure: 824-ft change in elevation with slopes 16% to 77%
• Existing Coating System: coal tar enamel with ~35 yrs service
• 90-day outage: June 1- Aug 30, 2016
Mark Wilmer Pumping Plant
Existing Coal Tar Enamel Condition

Photo courtesy of Hartman Walsh
Relining Plan

• Contractor (Hartman Walsh) planned to use robotics
  • Robotic waterjet to remove existing coal tar enamel (modified commercial equipment)
  • Robotic abrasive blast to white metal (modified commercial equipment)
  • Robotic coater (spin coater designed in-house)
  • Proprietary method for working on steep grade

• Extremely large equipment: air compressors, generators, dust collectors, pressure pots, vacuums, air driers, air conditioners etc.

Winch System

The controlled winch system pulled the automation equipment at a constant rate and could be adjusted to the desired rate.

Photos courtesy of Hartman Walsh
Ultrahigh Pressure Water Jet

This project:
• Removal rates up to 100 LF/shift ~ 3,600 sq ft

General benefits:
• Fast removal of coal tar
• Efficient removal of residual oils
• Eliminates hazardous dust exposure
• Coal tar enamel debris is sole hazardous waste generated

Photos courtesy of Hartman Walsh
Abrasive Blast Cleaning

This project:
• Blasting rates up to 50 LF/shift ~ 1,800 sq ft

General benefits:
• Faster production rates compared to conventional operation
• Reduces manual labor
• Eliminated hazardous material exposure during blasting operations
• Reduces hazardous material waste

Photos courtesy of Hartman Walsh
Coating Application

This project:
- 100% Solids Epoxy Duromar HPL 2510 HB
- Plural Component
- Single coat application
- Application rates up to 500 LF/day ~ 18,000 sq ft @ 60 mils

Photos courtesy of Hartman Walsh
Coating Application

General:

• Pump material long distance 800-1000’
• Heated plural lines to mix manifold to single line whip hose to spray guns
  • Replace mix manifold after every stop in production
  • Replace whip hoses after every stop in production
  • Clean spray guns outside confined space
• Better quality compared to conventional application on steep slope
Final Coating Product

Final DFT: 60 mils
1 year inspection: zero defects

Photos courtesy of Hartman Walsh
Other Robotic Blasting Technology

Photo reproduced from Blastrac’s inc.

SSPC 2019 Conference Demo’s
Other Robotic Coating Technology

Photo reproduced from roi360.com

Photo reproduced from roboticpiperepair.com

Photo reproduced from PRDcompany.com
Benefits for Contractors

- Reduced exposure to hazardous conditions and materials in confined spaces
- Reduced number of employees in confined space using ropes access equipment
- Reduced fatigue of employees
- Improved surface cleanliness consistency and coating thickness control
- Fewer coating holidays occur, resulting in less touch-up work
- Reduced fuel consumption due to faster production rates
- Reduced cost of personal protective equipment due to reduced usage
- Reduced blast media and coating material wastage
- Faster return to service, moving onto next job
Benefits to Reclamation

• Robotic application methods results in less exposure of employees and contractors to hazardous conditions
• Higher quality end products resulting in fewer holidays
• Less disturbance to pipe interior due to lack of scaffolding and equipment/personnel mobilization
• Shorter outage times to complete work
• Reduced safety liability
• Reduced labor costs, resulting in overall lower project costs
Corrosion Webinar Series

Field Electrochemical Impedance Spectroscopy (EIS)

Presented by Stephanie Prochaska
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What is EIS Testing?

• Electrochemical Impedance Spectroscopy

• Frequency-dependent application of ohm’s law
  • $\text{Voltage} = \text{current} \times \text{resistance}$
    $V = IR$
  • Non-destructive

• Quantitative data to estimate remaining service life
  • Measures corrosion protection of defect-free lining sample
  • Impedance $> 10^8$ ohms at 0.1 Hz is good protection$^{(1)}$

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$^{(1)}$Bacon, Smith, and Rugg, 1948
Why Use Field EIS Testing?

• Field EIS assessments complement visual inspections
  • Visual inspection qualifies coating damage
  • EIS quantifies undamaged coating performance

• Data-based decision making
  • EIS data thresholds for maintenance
  • Quality control on coating projects
Testing for Remaining Service Life

• Temporary cups glued to coating at regular spacings (i.e. pipe segments); salt water and electrodes added
• Test performed at open circuit potential across many frequencies

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
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<tbody>
<tr>
<td>Cell surface area</td>
<td>2.25-inch diameter (x2)</td>
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<tr>
<td>Reference electrode</td>
<td>Copper-copper sulfate</td>
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<tr>
<td>Counter electrode and working electrode</td>
<td>Platinum mesh</td>
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<td>Measurement frequency</td>
<td>$10^5$ to 0.05 Hz (or 0.1 Hz)</td>
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<tr>
<td>Measurement amplitude</td>
<td>50 mV</td>
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<tr>
<td>Number of data points</td>
<td>5 points per decade</td>
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Case Study – Large Siphon Interior

• Data for 42 pipe locations

• Corrosion protection = impedance, $|Z|$, at low frequencies
  • Desired $>10^9$ ohms
  • Replace $\sim 10^8$ ohms
Testing for Remaining Service Life

- Replace coating on segments 20 to 90, and 200
- Compare $|Z|_{0.05\text{ Hz}}$ to pre-service value for degradation rate
Testing for Remaining Service Life

- Recommend recoating if statistical analysis average (ex. 10% probability method) is < threshold value, $10^8$

- Nonlinearity suggests bias in data, e.g. non-uniform degradation

- Conclusion: majority of pipe coating is in good condition and full-relining may only be needed on select sections
Correlations with Pipe Profile

- Correlating low-impedance sections with the pipe profile may aid in determining failure mechanisms
  - ex. areas of elevation change exhibited more damage → could be due to sediment scour
Summary

• Field EIS testing reveals corrosion protection ability of visibly defect-free lining

• Estimates remaining service life for decision-making using low frequency $|Z|$ vs location and probability plots

• Technical publication now available
Resources

• TSC – Materials and Corrosion Laboratory Staff

• Using Robotics Technology to Reline Large Diameter Piping on Steep Slope:
  • https://www.usbr.gov/research/projects/download_product.cfm?id=2729

• Coating Evaluation by Electrochemical Impedance Spectroscopy (EIS):
  • https://www.usbr.gov/research/publications/download_product.cfm?id=1558
  • https://www.usbr.gov/research/projects/detail.cfm?id=1884
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