Corrosion protection of pipeline structures using cold spray

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Abstract

Pipelines span over 779,000km (1,253,000mi) throughout the United States[1]. Of 272 reported incidents in 2002-2003, 41.9% of failures occurred due to corrosion or weld/material failures. This research intends to investigate the effect of dissimilar cold sprayed metallic coatings on the corrosion properties of pipeline structures. The effects of these coatings in different environments will also be analyzed. Samples will be constructed of welded 1018 mild steel plates cold sprayed with 6061 Aluminum and 304L stainless steel then subjected to ASTM corrosion tests in soil and seawater.

Motivation

Oil being leaked into the environment costs millions of dollars in clean-up and damages, destroys soil, and kills wild animals both on an off shore. By increasing the lifespan of welds, the amount of money spend and environmental damage caused should be mitigated. Not only is the goal to increase overall longevity of pipelines, but to mitigate failures during the service life of the structure and reduce the amount of periodic maintenance required, saving investors time and money, and keeping hazardous materials out of the environment.

Background

- 41.9% of all failures were due to corrosion and/or weld failure, resulting in $48 million in damages and 98,212 barrels of oil lost[2].
- Pipelines average lifespan ranges from 30-35 years old
  - 34% of all current pipelines are 30 years of age or older[3]
- Current fusion-bonded epoxies and cathodic protection used to equally cover protect surface of structure including weld
- Cold-Spray welds and Heat Affected Zone
  - 6061 Aluminum powder onto Steel substrate to create Galvanic Couple, increasing weld/surface protection
  - 304 Stainless increases corrosion resistance of weld

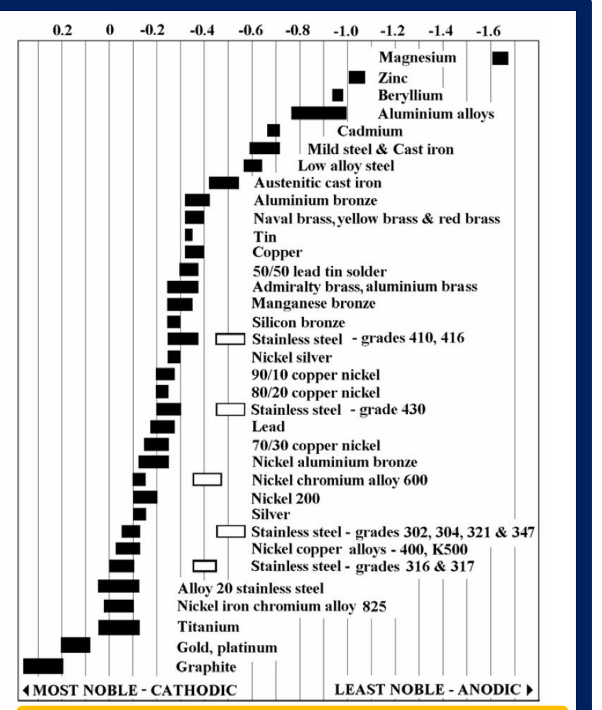

Figure 1: Galvanic Series chart

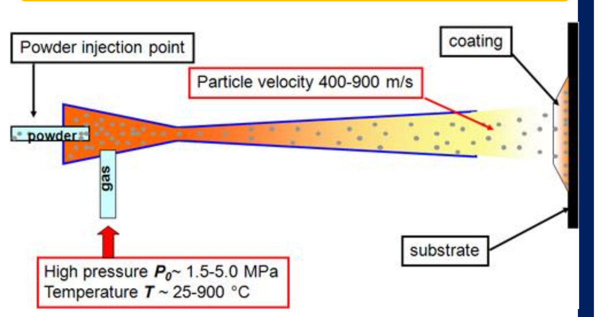

Figure 2: Cold-Spray process

Objectives

- Investigate the effect of dissimilar cold sprayed metallic coatings on the corrosion properties of welded structures
  - 304L Stainless Steel on 1018 mild steel substrate
  - 6061 Aluminum on 1018 mild steel substrate
- Investigate the effects of different coatings in different environments such as soil and seawater to replicate on and offshore corrosion environments

Materials and Procedure

- Samples comprised of two SMAW welded 1018 12"x1½"x¼" steel plates with low hydrogen electrodes
- Welds and heat affected zones cold sprayed with 304L Stainless Steel and 6061 Aluminum
- Water-jet cut sampled to appropriate sizes (1"x1½"x¼")
- Subjected sampled to ASTM Corrosion tests G162 and G44
  - *G162* - Standard Practice for Conducting and Evaluating Laboratory Corrosions Tests in Soils
  - *G44* - Standard Practice for Exposure of Metals and Alloys by Alternate Immersion in Neutral 3.5 % Sodium Chloride Solution
- ASTM G44 required design and assembly of new testing apparatus in order to complete testing on a smaller scale
  - Two glass fish tanks, two plastic water pumps, Arduino controller, and PVC tubes
  - Pumps in sea-water (3.5% pbw NaCl) from overflow tank to parts tank in 10 min (wet) and 50 min (dry) intervals

Figure 3: Steel plate being cold sprayed with 6061 Aluminum

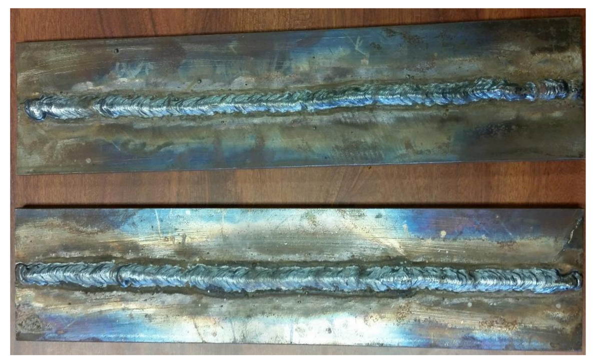

Figure 4: Steel plates after welding (before spray)

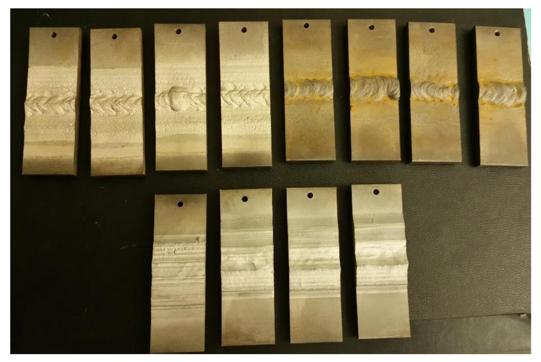

Figure 5: Samples after waterjet-cutting (Stainless, no spray, Aluminum)

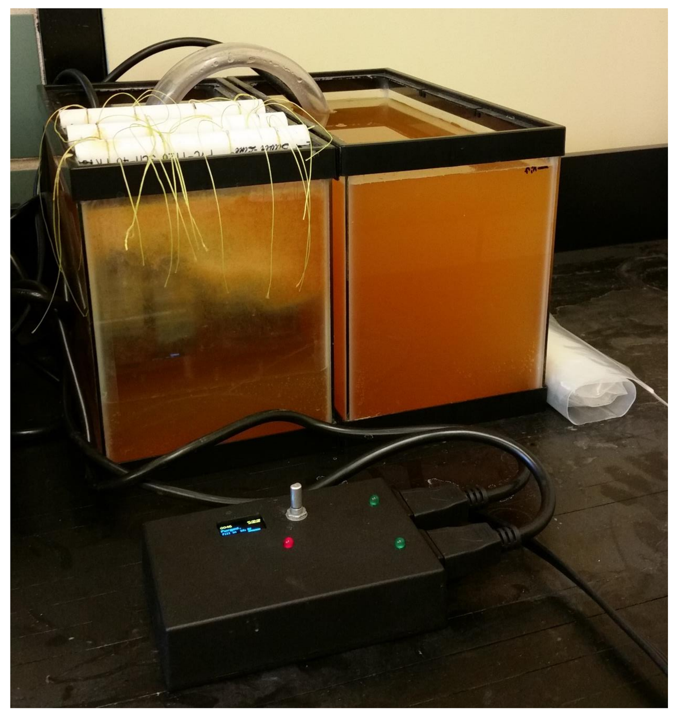

Figure 6: ASTM-G44 testing machine after 7 days exposure

Results

Sea (average mass loss/gain)

- Stainless Steel: **-0.97g**
- Aluminum: **-0.79g**
- No coating: **-1.28g**

Figure 7: Initial removal after 1 week exposure (before cleaning)

Soil (average mass loss/gain)

- Stainless Steel: **-0.38g**
- Aluminum: **-0.31g**
- No Coating: **-0.33g**

*Values calculated by averaging mass loss/gain of all removals

Figure 8: Removal after 7 day exposure (after cleaning)

- 75% of Stainless steel coatings failed after ~10 days of exposure
- Aluminum sprayed samples received less surface corrosion

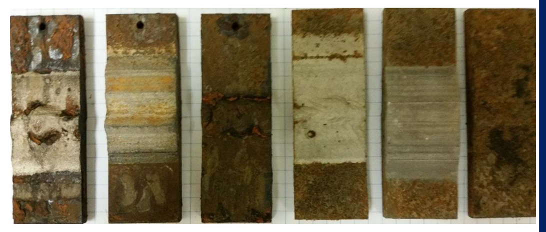

Figure 9: Removal after 10 day exposure (after cleaning)

Conclusion

Cold sprayed aluminum onto a welded mild steel substrate appears to have the greatest corrosion protection based on mass loss alone. Based on appearance, aluminum gives the impression that not only is the weld and HAZ protected, but the exposed substrate is experiencing less corrosion as well. Longer testing is required to gain more accurate results, as testing was ceased due to pump failures within the testing machine. Stainless steel does however seem to provide direct protection of the weld, although most samples had the coating "flake off" during testing, rendering the samples useless.

Future Work

Based on experimental results, parameter development for cold-spraying 304L Stainless Steel powder to a mild steel substrate needs further development. Furthermore, development on techniques and parameters for spraying any metal onto a welded surface needs to be improved.

Acknowledgments

This work was made possible by the National Science Foundation REU Back to the Future Site DMR-1460912. A huge Thank you to Dr. Bharat Jasthi for guidance throughout this process. Also Thank you to Dr. Michael West and Dr. Alfred Boysen for their consistent support

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