Zinc-Rich Coatings Over High Strength Steel

July 2024

NATIONAL SHIPBUILDING RESEARCH PROGRAM™
Taking Shipbuilding and Repair to the Next Level

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Background

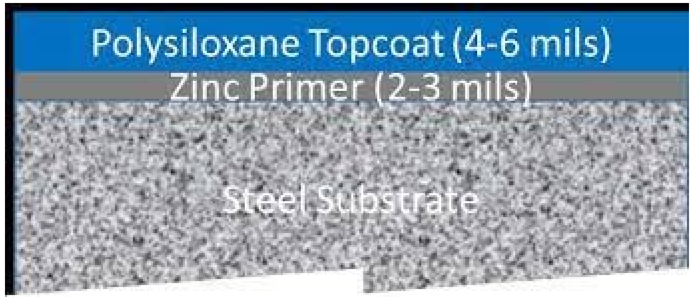
- Zinc-rich coatings are often avoided on high strength steels due to long held concerns of hydrogen embrittlement
- Recent research suggests hydrogen embrittlement may not be an issue with zinc primers, potentially allowing for the use of more effective corrosion barriers throughout ship construction
- The team is working with Navy technical advisors to assess the ability of zinc primers to induce embrittlement in a known susceptible alloy
- Two of the highest strength shipbuilding structural steels are being assessed for their susceptibility to damage resulting from zinc primer exposure

Scope of Work

- This project is evaluating the effect that zinc-rich coatings have on high strength steel
- Goals/Objectives
  - Establish a credible testing protocol to assess base metal susceptibility to reduced properties associated with zinc-rich coatings
  - Generate data to understand the relative impact of zinc-rich coatings on high strength steel
  - Depending on testing results, provide list of alternative coating systems and appropriate areas of application
  - Provide recommendations for shipyard and Navy consideration

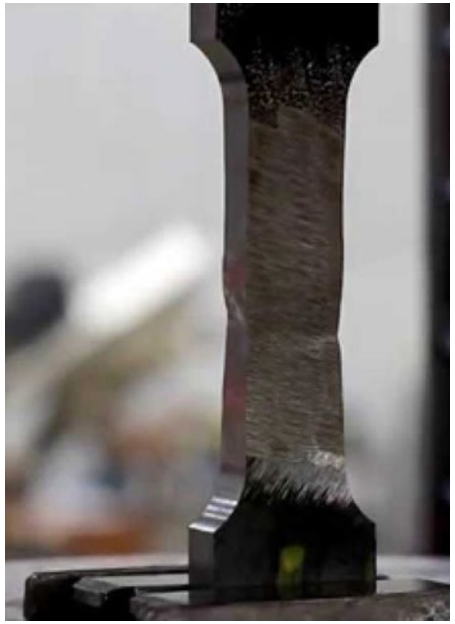
Previous Work

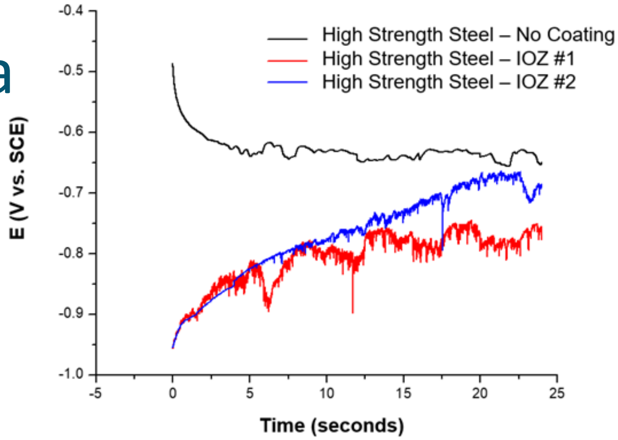
- Zinc-Rich Coatings for Enhanced Performance of Polysiloxane Topside Coatings, 2013
  - Research was done previously demonstrating the benefits of zinc-rich coatings with polysiloxane topcoats on Navy vessels. The study showed that the performance of such a system was beneficial overall but did not examine the possible issue of high strength steel substrate degradation from a zinc coating.
- Sacrificial Coatings for the Corrosion Protection of Armor Steel, 2013
  - Research showed zinc-rich paint on armor steel offers substantial corrosion benefits. Minimal concern for EAC on non-loaded high-hardness armor steel.



Tasks

- Identify Target Applications, Requirements, and Constraints
  - Held kickoff meeting with project team to discuss high value target applications, identify coating types for consideration, discuss performance testing strategies
- Select Candidate Systems, Finalize Test Requirements, and Test Plan
  - Team worked with Navy technical advisors to develop test plan
- Fabrication of Test Articles and Laboratory Testing
  - Test articles have the appropriate zinc-rich coatings applied in a fashion consistent with shipbuilding operations with a focus on potential worst cast situations
- Final Report





Task 1 (Complete) - Identify Target Applications, Requirements, and Constraints

- Kickoff meeting held on 11/9 with Navy technical community
  - 6 technical community leaders in attendance
    - Coatings and Corrosion Engineering Manager, NAVSEA 05P
    - Materials Technical Warrant Holder, NAVSEA 05P
    - Structures Technical Warrant Holder, NAVSEA 05P
    - NSRP Program Manager, NAVSEA 05T
    - Mechanical Engineer, NRL
    - Branch Head of Coating and Corrosion, NRL
- Highlights
  - Discussion of previous DoD efforts
  - Discussion of Navy concerns
  - Proposed testing methods
  - Proposed coating materials and steel substrates

Task 2 (Complete) - Select Candidate Systems, Finalize Test Requirements, and Test Plan

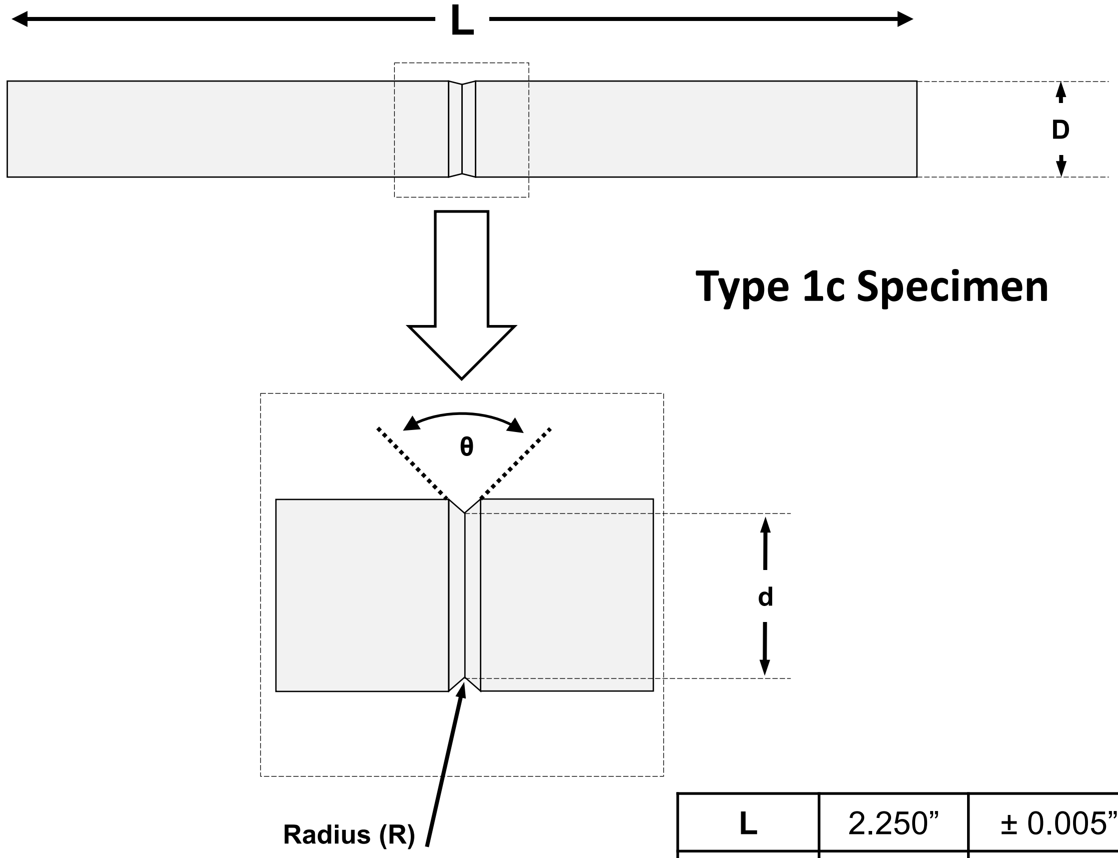
- ASTM F519 - *Mechanical Hydrogen Embrittlement Evaluation of Plating/Coating Processes and Service Environments*
  - Describes mechanical test methods and defines acceptance criteria for coating and plating processes that could potentially cause hydrogen embrittlement in steels
  - Stressed notched bars exposed for 200 hours
  - Time to failure recorded; run-outs incrementally stressed to failure

Task 2 (Complete) - Select Candidate Systems, Finalize Test Requirements, and Test Plan

- Coatings to be evaluated
  - Two inorganic zinc (IOZ) preconstruction primers (PCPs)
  - One IOZ
  - TT-P-664 (Organic PCP)
- Three different substrates to be tested
  - One common high strength steel (4340); two naval high strength steels
- Two different environments for testing
  - Wet vs. Dry
- Test plan reviewed by Navy technical community

Task 3 (Ongoing) - Fabrication of Test Articles / Laboratory Testing

- All coatings received
- High strength steel test specimens (ASTM F519 Sample Type 1c) produced
  - QTY. (48) HY-100
  - QTY. (48) HSLA-100 Composition 3
  - QTY. (48) AISI 4340



Type 1c Specimen

L	2.250”	± 0.005”
R	0.0050”	± 0.0005”
θ	60°	± 1°
d	0.177”	± 0.001”
D	0.248”	± 0.001”

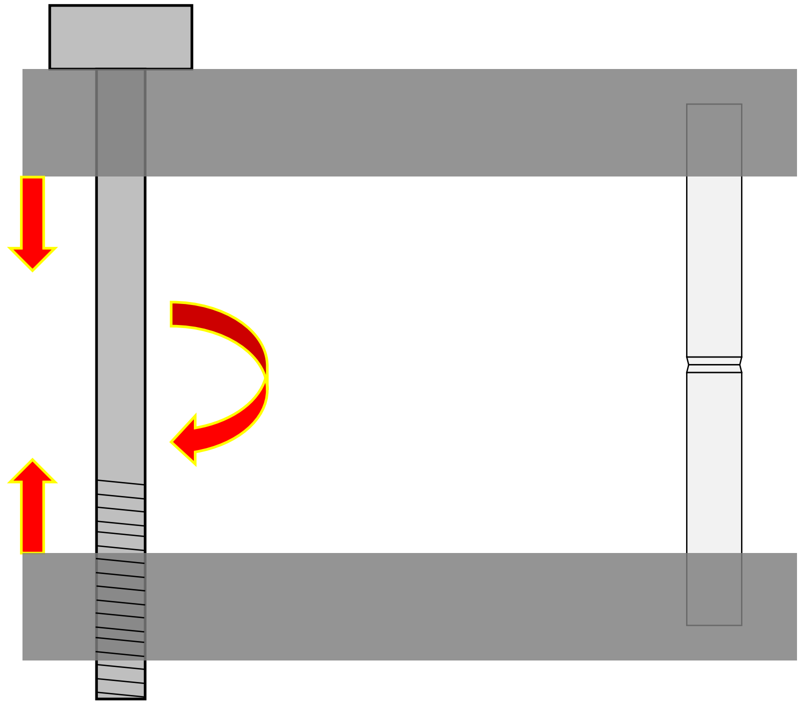
Task 3 (Ongoing) - Fabrication of Test Articles / Laboratory Testing

ID	Coating	Substrate	QTY. Dry	QTY. “Wet”
A-00	None	4340	4	0
A-0	None		4	4
A-1	IOZ PCP #1		4	4
A-2	IOZ PCP #2		4	4
A-3	IOZ		4	4
A-4	TT-P-664		4	4
B-00	None	HY-100	4	0
B-0	None		4	4
B-1	IOZ PCP #1		4	4
B-2	IOZ PCP #2		4	4
B-3	IOZ		4	4
B-4	TT-P-664		4	4
C-00	None	HSLA-100 Composition 3	4	0
C-0	None		4	4
C-1	IOZ PCP #1		4	4
C-2	IOZ PCP #2		4	4
C-3	IOZ		4	4
C-4	TT-P-664		4	4

Task 3 (Ongoing) - Fabrication of Test Articles / Laboratory Testing

- ASTM F519 – *Mechanical Hydrogen Embrittlement Evaluation of Plating / Coating Processes and Service Environments*

1) Clean samples (remove oil/grease)
2) Test n-00 specimens to determine mean number of revolutions to failure (RtF)
3) Roughen samples (except notch)
4) Coat samples that receive coating
5) Load samples to 75% RtF
6) Exposure in "Wet" or Dry environment



Task 3 (Ongoing) - Fabrication of Test Articles / Laboratory Testing

- ASTM F519 – *Mechanical Hydrogen Embrittlement Evaluation of Plating / Coating Processes and Service Environments*

7) Monitor samples to determine time to failure, up to at least 200 hrs.
8) For samples that do not break at 200+ hrs.
    - Increase load by 5% RtF every 2 hours until failure
9) Examine fracture surfaces and unbroken specimens (if any)

Task 3 (Ongoing) - Fabrication of Test Articles / Laboratory Testing

- What if no baseline RtF can be determined at room temperature?

  - HY-100 and HSLA-100 C3 baseline samples did not fully fracture at room temperature
  - Bending occurred without complete fracture until the fixture strain range was at its maximum (30 revolutions)
  - 4340 steel broke and a RtF was established for uncoated, room temperature specimens (RtF = 14)

Task 3 (Ongoing) - Fabrication of Test Articles / Laboratory Testing

- The "Wet" Environment
  - Wetting occurs only after loading
  - Constant drip
    - Drop location is directly over notch
    - Drop rate approximately 15 – 30 drops per minute
  - Laboratory Temperature / RH

- The Dry Environment
  - Laboratory Temperature / RH

Path Forward

- Determine path forward for HY-100 and HSLA-100
- Continue testing and collect data
- Report data to technical community
- Finalize report for distribution

Discussion / Questions

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