Zinc-Rich Coatings Over High Strength Steel

September 2024

Background

- Zinc-rich coatings are often avoided on high strength steels due to long held concerns of hydrogen embrittlement, particularly in heat affected zones
- 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 will work with Navy technical advisors to develop requirements and conduct testing to demonstrate the effects of zinc-rich coatings under environmental and hot work conditions in order to pursue future approval for use on Navy ships

Scope of Work

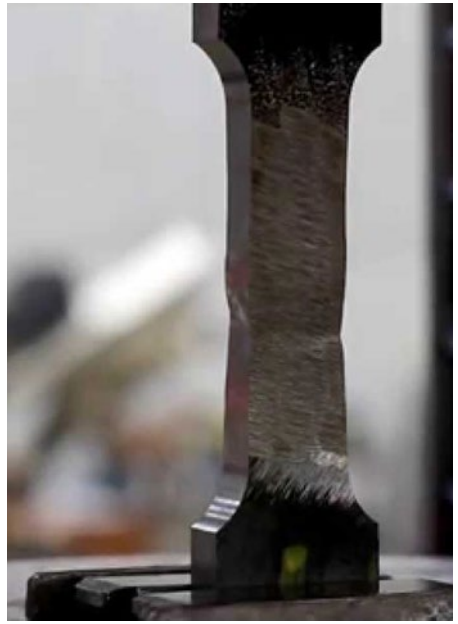
- This project will evaluate the effect that zinc-rich coatings have on high strength steel.
- Goals/Objectives
  - Establish a credible testing protocol to assess base metal and deposit filler metal susceptibility to reduced properties associated with zinc-rich coatings
  - Generate data to understand the relative impact of zinc-rich 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

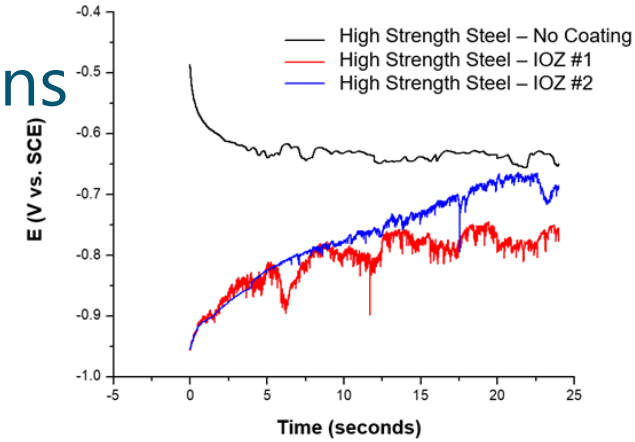
Previous Work

- 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 hard armor steel

Tasks

- Identify Target Applications, Requirements, and constraints
  - Hold 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 will work with Navy Technical advisors to develop test plan
- Fabrication of Test Articles and Laboratory Testing
  - Test articles will 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 (Completed) - 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 on previous DoD efforts
  - Discussion on Navy concerns
  - Proposed testing
  - Proposed types of zinc coatings

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

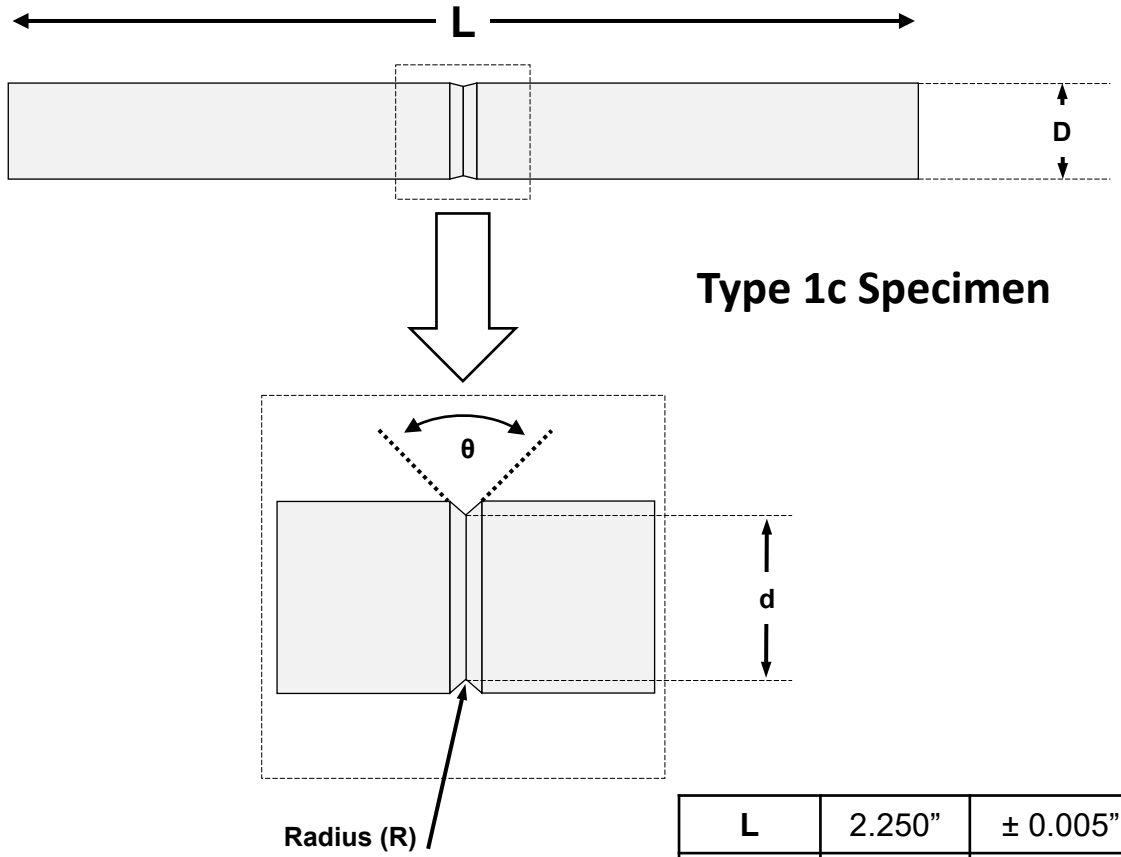
- ASTM F519 Type 1C, Mechanical Hydrogen Embrittlement Evaluation of Plating/Coating Processes and Service Environments
  - Describes mechanical test methods and defines acceptance criteria for coating and plating processes that can cause hydrogen embrittlement in steels
  - Stressed notched bars exposed for 200 hours
  - Time to failure recorded; run-outs stressed to failure

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

- Coatings to be evaluated
  - Two IOZ PCPs
  - One IOZ
  - TT-P-664
- Three different substrates to be tested
  - One common steel (4340); two 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”

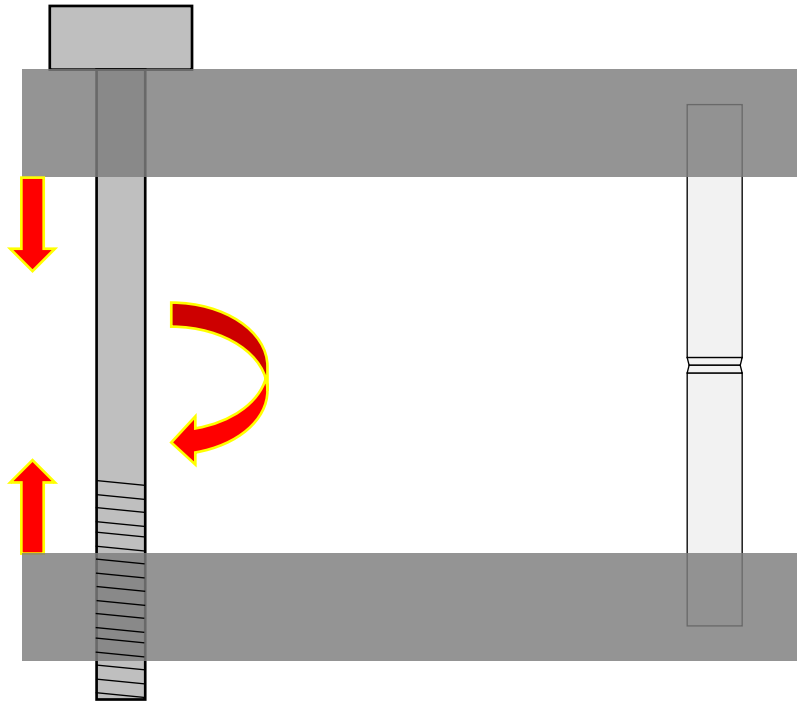
Task 3 (Ongoing) - Fabrication of Test Articles / Laboratory Testing

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 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

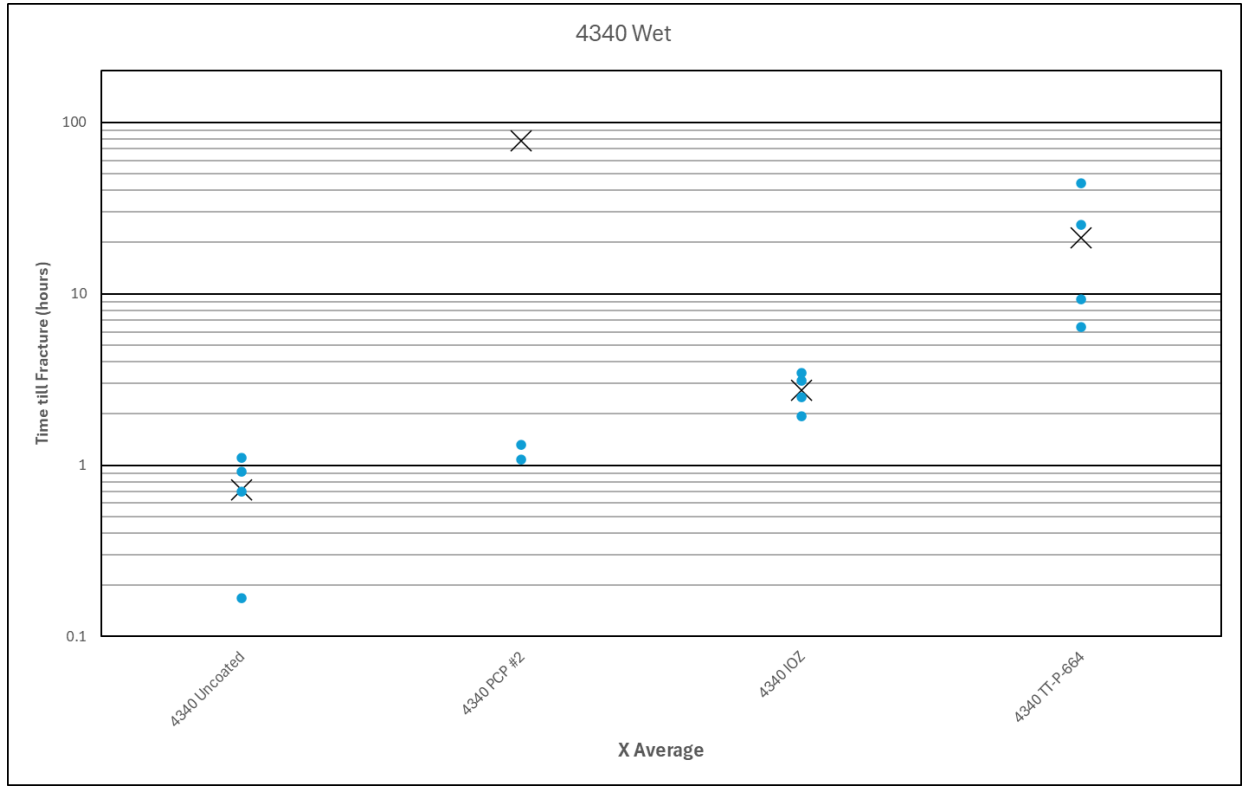
- The “Wet” Environment
  - Wetting occurs only after loading
  - Under constant drip
    - Drip location is on the notch.
    - Approximately 15~30 drops per minute
  - Laboratory conditions

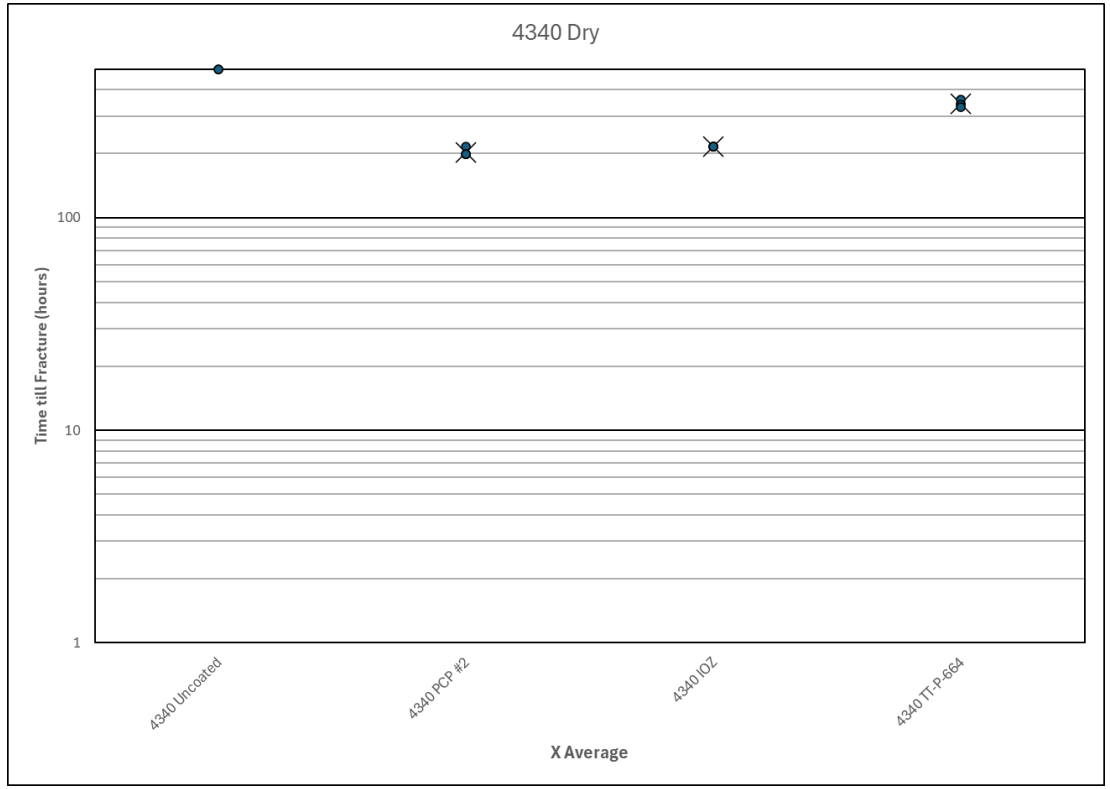
- The “Dry” Environment
  - Laboratory conditions

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 fracture at room temperature
  - Bending occurred without fracture until the fixture strain range was at its maximum (30 revolutions) – Determined 20 was failure and loaded samples to 15 turns
  - 4340 steel broke and a RtF was established for uncoated, room temperature specimens (RtF = 14)

Task 3 (Ongoing) – 4340 test results

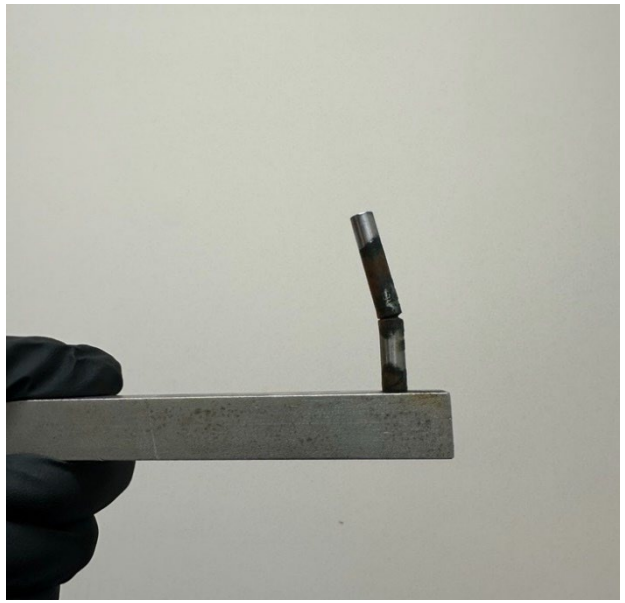




- The "Wet" Environment shows that the zinc coatings protect uncoated steel from early fatigue
- *Dry samples so no differences in terms of failure differences.*

Task 3 (Ongoing) – HY and HSLA test results

- No differences seen in either Wet or Dry environments during testing.
- No breaking of either material has to the witnessed.
- Two systems in current testing.
- PCP Coating Chipped off all Systems



Path Forward

- Share data with Navy Technical Community
- Continue testing and collect data
- Finalize report for distribution
- Make recommendations on additional testing or tests to better determine if Hydrogen embrittlement is an issue with any of these coatings.
  - Early 4340 data from this program suggests it might not be an issue

Questions?