1. Marine infrastructure in different continents

2. Characteristic corrosion results:
   • Galvanized & uncoated high strength steel
   • The role of surface treatments on AA7075
   • B-Al coating on P91 steel

3. Realistic testing

4. Summary

Outline of the talk
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### Facility: Pier side Atmospheric Test Facility
The test facility was established in 2017 with an objective of providing in-situ corrosion experiments. The corrosion test bed is located on a raised pier 50 feet above the Ocean elements.

### Facility: Seawater Submersion Testing System Capability:
The facility along the pier has been dredged ~100 feet deep to allow the capability to test specimens that require complete immersion in natural seawater. This is critical especially when studying coatings and concrete coupons in an ever changing seawater kinematics and chemical conditions.

### Payoff:
Seawater Submersion Testing can be used to study the impacts of tidal velocity and environmental changes over a given season on erosion corrosion, cavitation & impingement corrosion etc.

### Payoff:
Corrosion Bed facility can be used to test coated test coupons, stress corrosion cracking of various functional component parts.

### Data Collection Approach:
1) Gravimetric Weight loss
2) Microscopic and Spectroscopic techniques
On-shore and Offshore Corrosion Capabilities  TAMU-Galveston

**Facility:** Access to Offshore Oil Rig Platforms in the Gulf of Mexico Ocean
For extreme long term Ocean exposure of deep sea and hydrostatic pressure effects on corrosion

**Payoff:** Access to deep sea platforms allows for experimental surface and subsurface in-situ deep-sea environmental and microbial induced corrosion studies on ferrous and non-ferrous materials systems.

Electron Microscopy for Surface Analysis Approaches: The PI uses state of the art electron microscopic and spectroscopic analysis to study surface corrosion mechanism’s, the impacts of elemental species on the rate of corrosion.
On-shore and Offshore Corrosion Capabilities  TAMU-Galveston

Research Vessels

R/V Trident:
- 70ft long, has a draft of 4ft and a cruising speed of 17 knots & equipped with scientific sampling gear.
- It has a capacity of 12-44 persons and can operate 24hrs per day for up to 5 days between port calls
- Saltwater pump to supply a flow through system
- For shallow water and offshore research

R/V Earl L Milan:
- A versatile 47 ft vessel for offshore deployment
On-shore and Offshore Corrosion Capabilities  TAMU-Galveston

Flat Bottom Skiffs are also available for Shallow protected Ocean Water

- **32’ Pro Line Express Sea Dragon Vessel**: For offshore deployment
- **M/V Lithos**: 30’ Berge Vessel for Shallow protected Ocean Water
- **M/V Rockport**: 22 ft Vessel for Shallow protected Ocean Water

- Also available are flat bottom skiff named Rockport and Bateau that are meant for deployment in shallow protected waters within the Gulf.
- Some of the images are shown.
Current Research
Sensor technique for in-situ monitoring

Manufactured ship with Sensor
Docking platform

The coating and corrosion evaluation test

1) E. David (2017) – Nace Corrosion Conference #8834
Corrosion testing facilities

TEES-AUTH joint center

ISO 17025

Stress Corrosion Cracking

Electrochemical corrosion

Environmental simulation

Corrosion-fatigue

Salt spray corrosion

Offshore corrosion testing
Marine environment and ship for testing at AUTH
Thess INTEC Thessaloniki International Technology Center - GREECE

Offshore corrosion testing facility
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Corrosion fatigue test ring
Hot-dip galvanizing (industrially the prevalent coating method)
- automotive, marine, drilling, pipeline infrastructures etc where synergistic action of cyclic loads and a corrosive medium are required
- It is important to know the implication of this corrosion-resistant surface treatment on the mechanical properties of the component.
Structure of the produced galvanized coating on 51CrV4
- Fe-Zn intermetallic phases: \( \Gamma \) (gamma) \([\Gamma+\Gamma_1]\), \( \delta \) (delta) and \( \zeta \) (zeta).

- \( \eta \) (eta) phase: Solid solution of Zn containing \( \sim 0.03 \) wt.% Fe.
<table>
<thead>
<tr>
<th>Phase</th>
<th>Young Modulus [GPa]</th>
<th>Poisson ratio</th>
<th>Thickness [µm]</th>
<th>Number of elements</th>
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<tr>
<td>delta</td>
<td>111</td>
<td>0.3</td>
<td>10</td>
<td>29.943</td>
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<tr>
<td>Zeta</td>
<td>82.5</td>
<td>0.3</td>
<td>40</td>
<td>43.251</td>
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<tr>
<td>Eta</td>
<td>77</td>
<td>0.3</td>
<td>20</td>
<td>56.559</td>
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<tr>
<td>Steel substrate</td>
<td>210</td>
<td>0.33</td>
<td>1500</td>
<td>9.981</td>
</tr>
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</table>
FEM-determined von Mises stresses developed under a load of 500 N for each coating layer and steel substrate for the galvanized C-ring model.
von Mises stress field developed in the C-ring under a maximum alternating load of 500 N
Corrosion fatigue life is increased about 4 times with galvanization.
At 400 N, galvanized samples achieved more than $3 \times 10^6$ cycles without fracture.
Fractographs for coated and uncoated high-strength steel tested at a maximum alternating load of 500 N
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Confocal microscopy images of the variously surface-treated samples, prior to corrosion fatigue testing.

Wire-EDMed:
- Max. peak height: 7 μm
- Max. valley depth: 12 μm

Blasted:
- Max. peak height: 11 μm
- Max. valley depth: 23 μm

Anodized:
- Max. peak height: 12 μm
- Max. valley depth: 62 μm
Typical SEM images of fractured surfaces for the examined samples, tested at 3.5 wt% NaCl aqueous solution.
Average number of cycles to failure in corrosion fatigue testing of AA7075-T651 under different surface treatments and corrosive environments.
Microstructure of AA7075-T651 and experimental setup for testing the in-situ electrochemical corrosion fatigue
Evolution of open circuit potential (OCP) during cyclic loading
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SEM and EDS analyses of the boride coating showing a Fe (Cr) boride layer and the P91 substrate in a (a) corner and (b) planar sample region.
Optical microscopy cross-section view of borided P91 steel, presenting the Vickers micro-indentation marks in the film, the transition region and the matrix

<table>
<thead>
<tr>
<th>Point Nr.</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
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<tbody>
<tr>
<td>$D$ [μm]</td>
<td>5.6</td>
<td>7.4</td>
<td>10.1</td>
<td>10.2</td>
</tr>
<tr>
<td>$HV_{25}$</td>
<td>1478</td>
<td>846.6</td>
<td>454.5</td>
<td>445.6</td>
</tr>
</tbody>
</table>
Inclined cross-sections of the uncoated P91 after exposure in the salt spray chamber for (a) 24h and (b) 48h

Salt spray: 5%wt NaCl, 35°C
SEM micrographs of the B-coated samples after exposure in the salt spray chamber for (a) 24h and (b) 48h.
Marine infrastructure for testing in applied science and corrosion technology in different continents

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The corrosion fatigue device with in-situ thermal cycling

Specifications:
- Mechanical load range: 0 – 5 kN
- Mechanical load frequency: 0 – 600 Hz
- Temperature range: 25 – 600°C
- Temperature frequency: 0.001 – 0.1 Hz
- Actuation fatigue
Force – Temperature vs. time diagrams
Force – Temperature vs. time diagrams
Force – Temperature vs. time diagrams
Marine infrastructure for testing in applied science and corrosion technology in different continents

Nikolaos Michailidis

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✓ Advanced marine infrastructure for testing corrosion in different continents is offered for comparing results.

✓ Coatings and surface treatments can significantly improve corrosion and corrosion-fatigue performance of materials.

✓ Realistic in-situ thermomechanical corrosion-fatigue testing offers reliable estimations of parts’ life span.