



Influence of Fastener Coating on Corrosion Behavior of Thixomolded Magnesium

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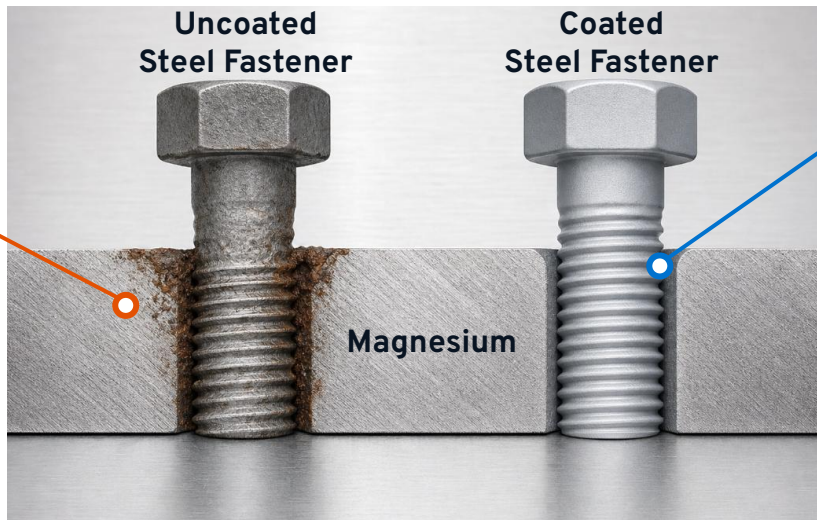
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Why Fastener Coating Study Matter?

Dissimilar-metal contact between magnesium and steel fastener creates a high risk for galvanic corrosion.

Galvanic Corrosion

Fastener interface
can become a
local corrosion
initiation site



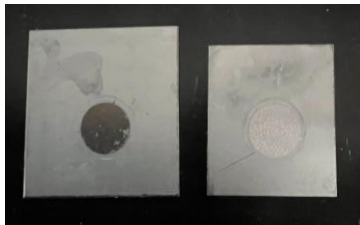
Protected Interface

Fastener coatings
can help reduce
electrical coupling
and slow
corrosion damage
at the joint

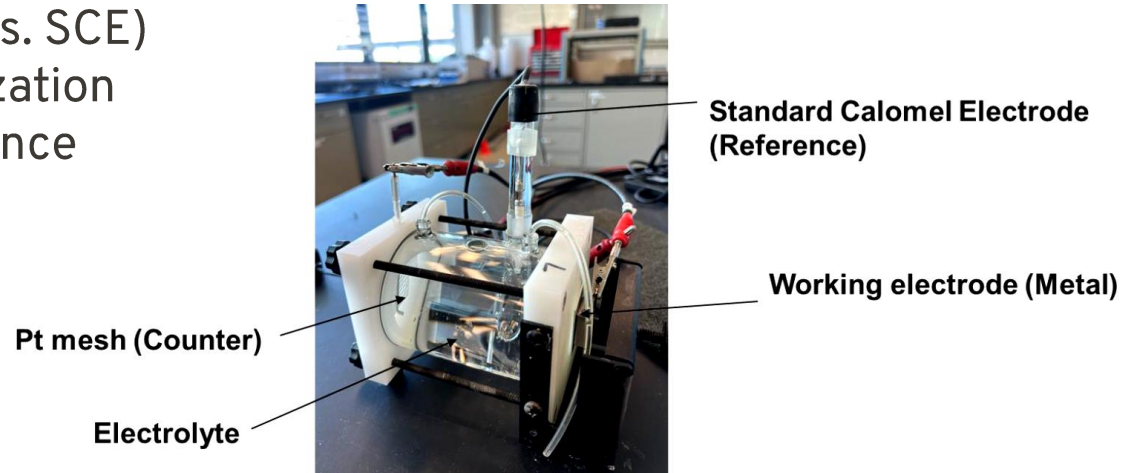
A robust fastener coating strategy is therefore essential for durable magnesium application.

Test Descriptions (1) Electrochemical Assessment

- **Sample** : Flat steel coupons with fastener plating
- **Electrolyte** : 3.5 wt.% NaCl solution
- **Tests**
 - Open circuit potential (vs. SCE)
 - Potentiodynamic polarization
 - Electrochemical impedance spectroscopy (EIS)



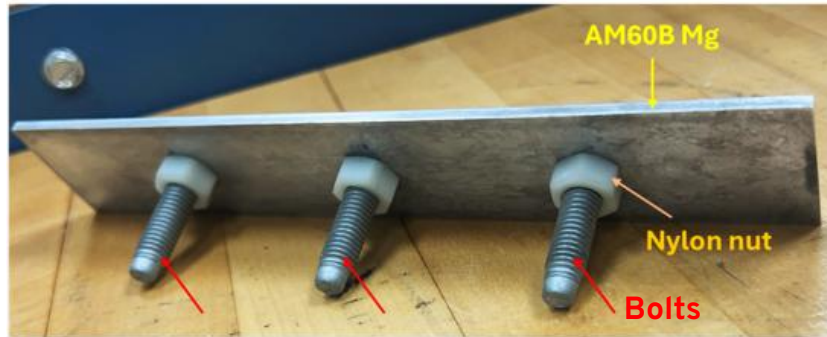
Zn-Magni after polarization test



Standard Flat Corrosion Cell

Test Descriptions (2) Neutral Salt Spray (NSS) Assessment

- **Test method:** ASTM B117 (GMW 14872)
with 5% NaCl solution at a temperature of 35 °C for 240 hours
- **Substrate Material:** Thixomolded AM60B



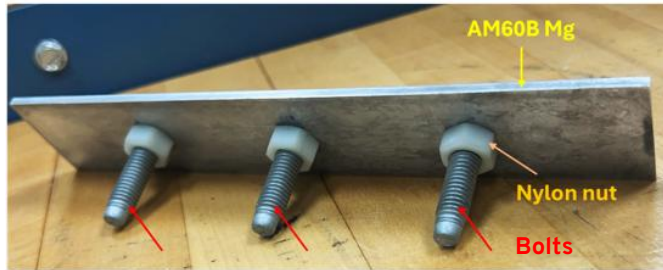
Tested Coupon



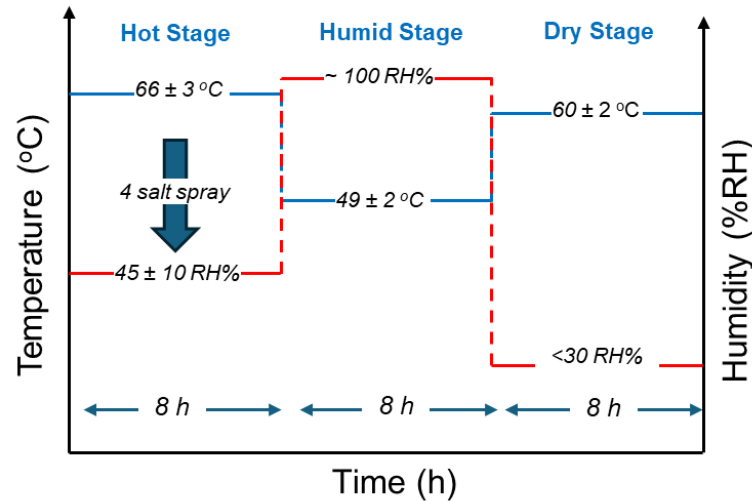
Salt Spray for 240 hrs.

Test Descriptions (3) Cyclic Corrosion Testing

- **Test method:** GMW 14872 Option 6 (Underbody Exposures D and E) with 3% salt and fireclay solution
- **Substrate Material:** Thixomolded AM60B



Tested Coupon



Exposures D

10 years equivalent
38 cycles (43 ± 5)

Exposures E

15 years equivalent
58 cycles (65 ± 7)

Coating Variants and Installation Procedure

Fastener

M8 hex head bolts with nominal diameter of 8 mm and pitch diameter of 1.25 mm



Al-plated (w/Ni)

List of Coatings

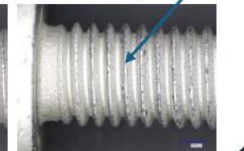
Zn-Ni coated carbon steel
Sn-Zn coated carbon steel
Magni 565 coated carbon steel
Zn-Ni with Nyshield®
Al alloy (6061-T6)
Al-plated carbon steel (without Ni pre-strike), passivated
Al-plated carbon steel (with Ni pre-strike), passivated
Al-plated steel (with Ni pre-strike) & anodized
Al-plated steel (Ni pre-plate), unpassivated
Zn-Ni with 6061-T6 Al washer
Magni 565 with 6061-T6 Al washer



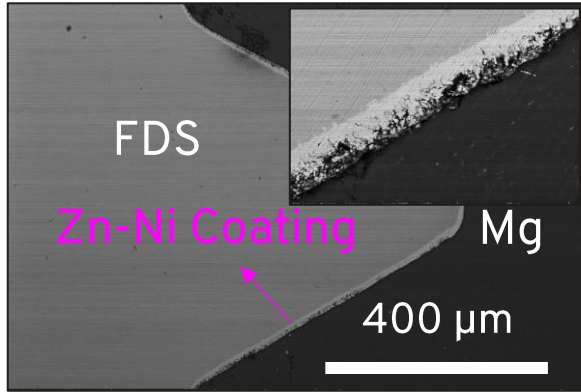
Pre-driven bolts (Torqued to 25 Nm into a steel nut and then backed out)

Bolts before pre-driving

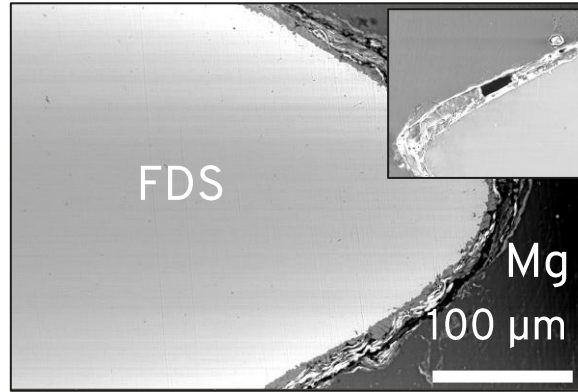
Bolts after pre-driving



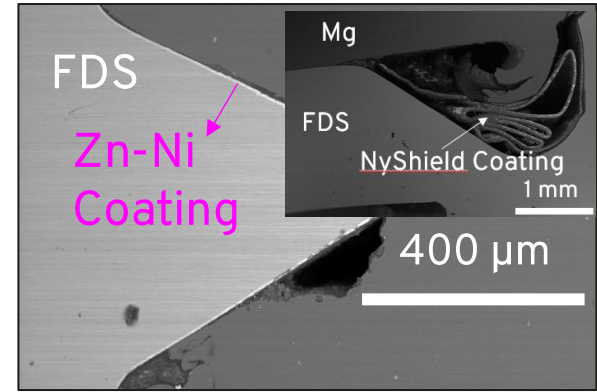
Effect of Installation Force on Coatings Integrity in Mg



Zn-Ni



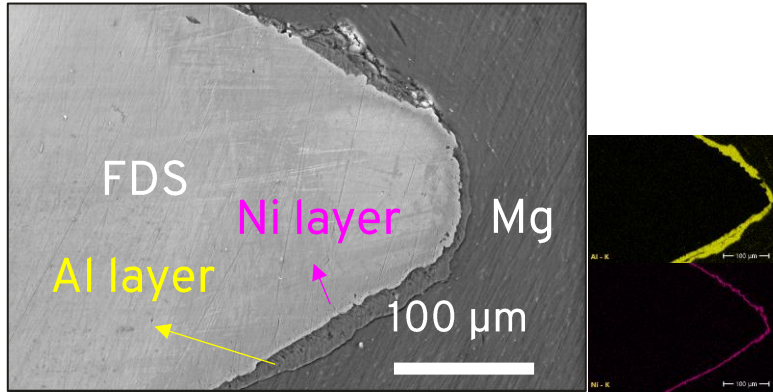
Magni



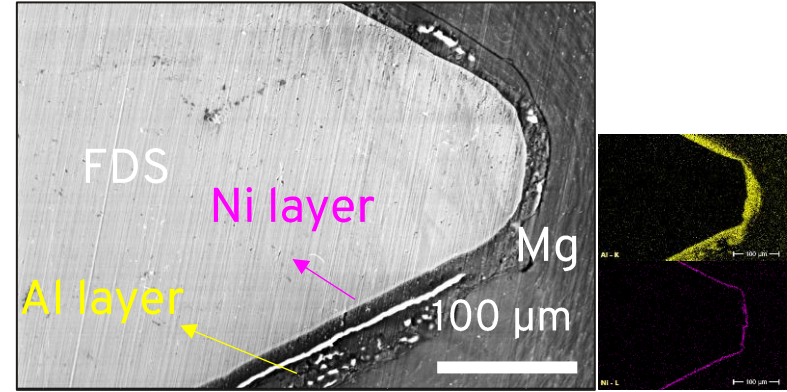
NyShield

- **Zn-Ni** and **Magni** coatings exhibited surface-originated damage penetrating to ~50% of the coating thickness.
- The **NyShield** was removed during fastener driving, with only the Zn-Ni layer remaining.

Microstructure of Coatings



Al passivation (Ni pre-strike)



Al anodization (Ni pre-strike)

Microscopic examination confirmed that both the Al layer and the pre-strike Ni layer remained intact on the **Al-plated fastener** after driving.

Results (1) Electrochemical Assessment

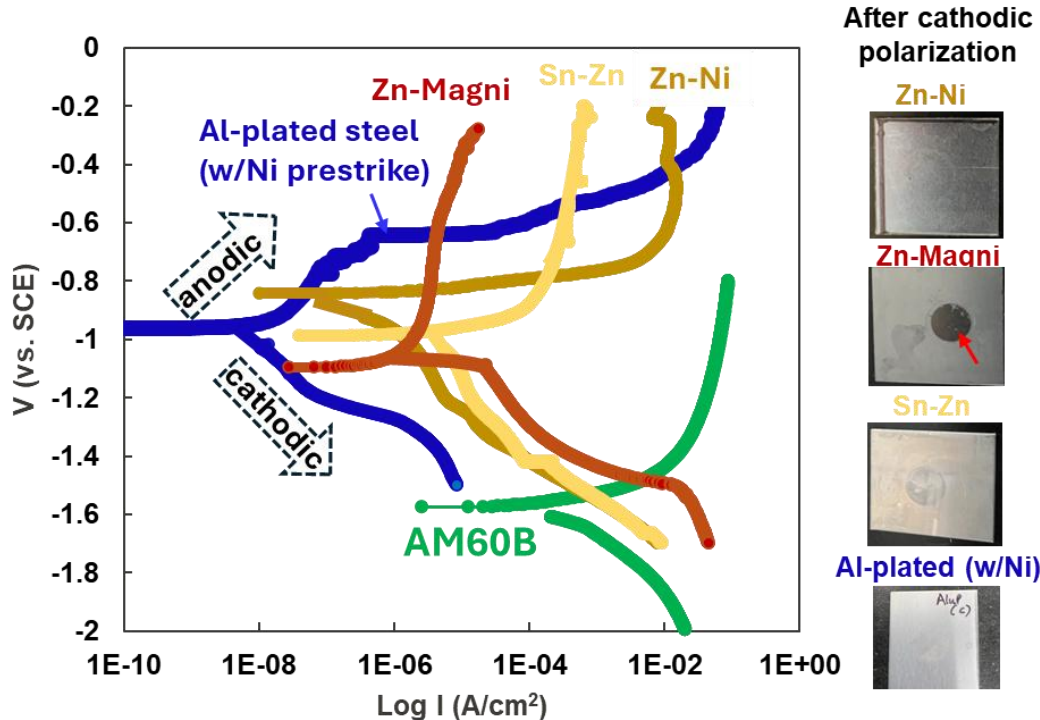
I. Open Circuit Potential

Material	OCP vs. SCE (Hg Hg+)
Substrate	
AM60B Magnesium	-1.58 V
Fastener Substrate/Coatings	
Bare Carbon steel	-0.63 V
Zn-Ni plated carbon steel	-0.84 V
Sn-Zn plated carbon steel	-0.98 V
Al-plated steel (with Ni-prestrike)	-0.99 V
Zn-Magni 565 plated carbon steel	-1.09 V

- Half-cell potentials were obtained.
- **Magni 565** has the closest electrochemical potential to AM60B.

Results (1) Electrochemical Assessment

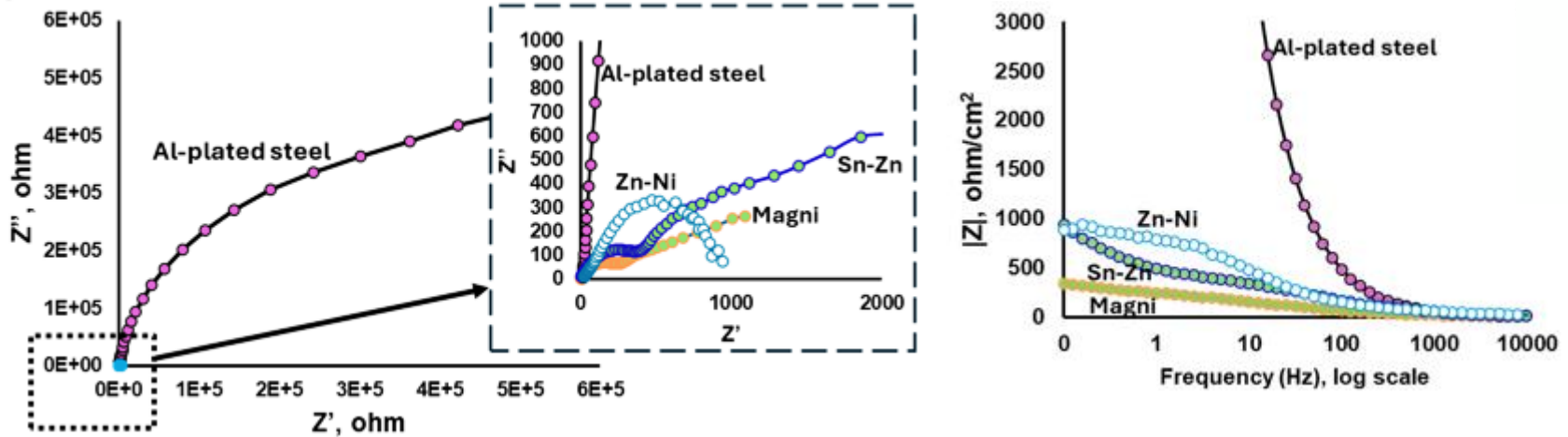
II. Potentiodynamic Polarization



- **Al-plated steel** exhibits the least cathodic current (good for preventing Mg corrosion).
- **Magni 565** coating delaminated during cathodic cycle.

Results (1) Electrochemical Assessment

III. Electrochemical Impedance Spectroscopy (EIS)

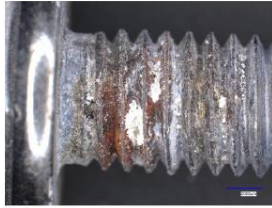


Al-plated steel exhibits the highest electrochemical impedance (good for galvanic corrosion prevention).

Results (2) NSS (Bolted AM60B Coupons)

I. Bolts (Visual examination of type of rust)

Red Rust



Bad

White Rust



OK

II. Mg (Galvanic corrosion pit depth)

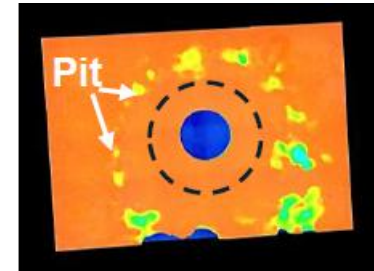
Front (After NSS exposure)



Back (After Sandblasting)

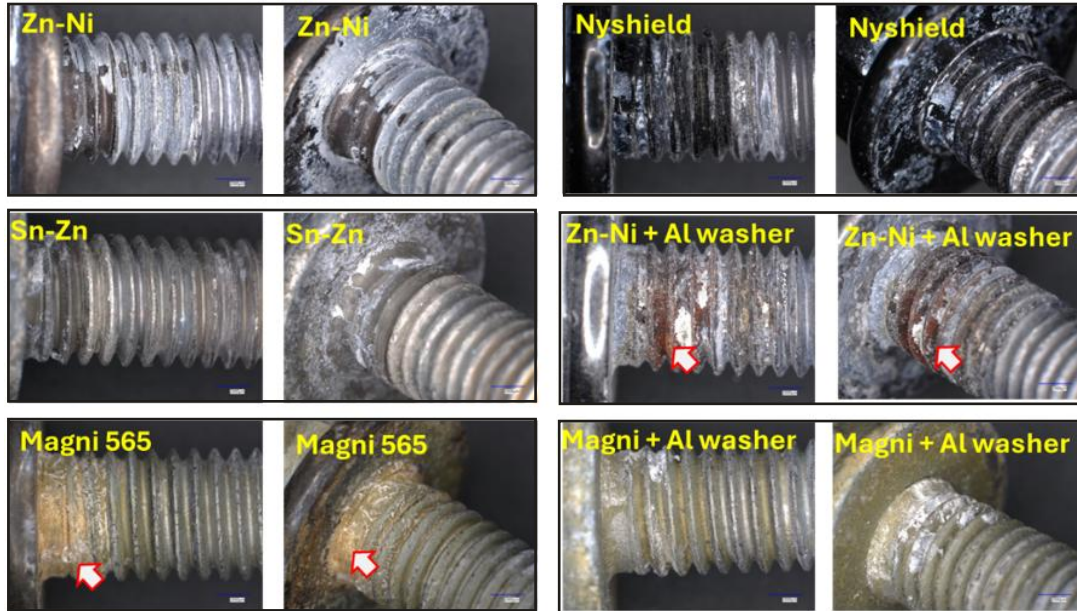


Pit depth analyses



Results (2) NSS (Bolted AM60B Coupons)

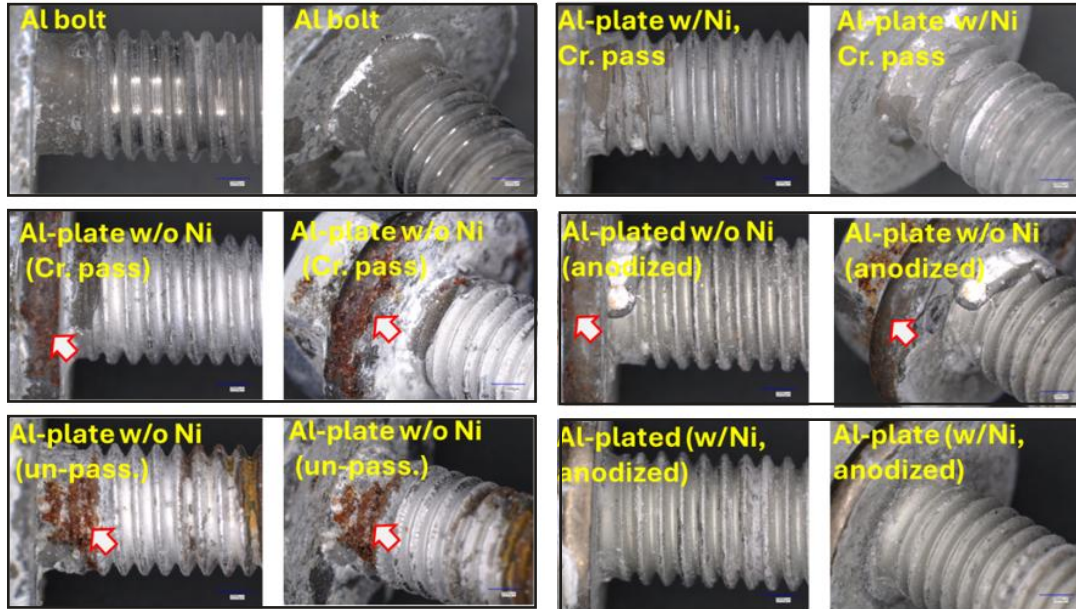
III. Results



- **Zn-Magni** coatings exhibited localized corrosion or discoloration on the threaded region near the substrate interface.
- Some **Zn-Ni** bolts showed red rust, indicating exposure of the underlying steel to the corrosive environment.
- The use of **Al washer** helped mitigate corrosion; however, coating quality is critical.

Results (2) NSS (Bolted AM60B Coupons)

III. Results

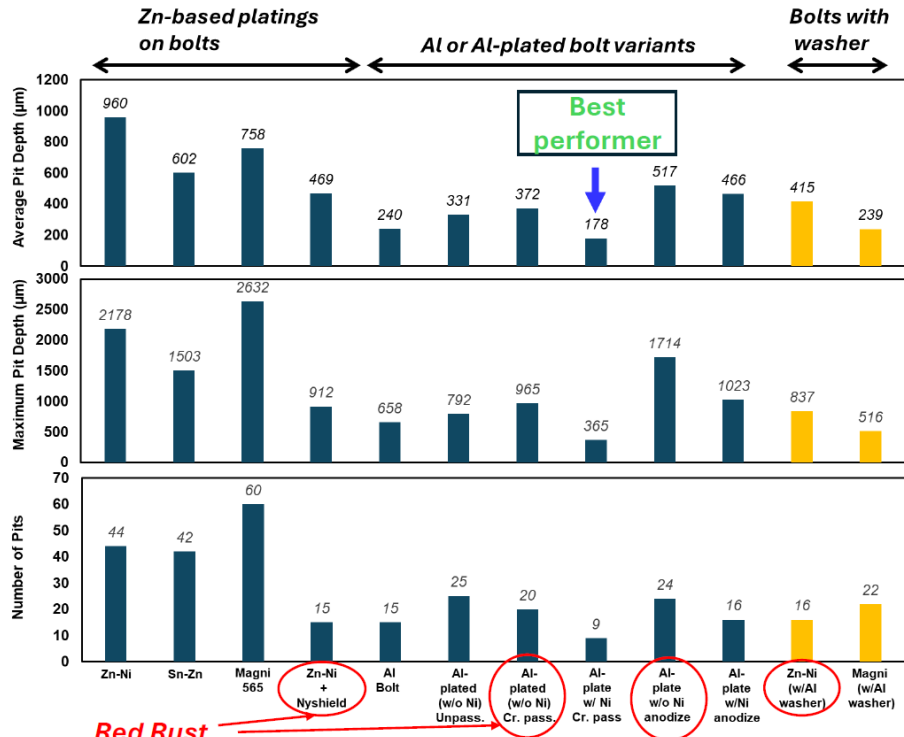


Al-plated bolt variants without a Ni pre-strike exhibited red rust, indicating coating delamination during NSS testing.

→ This suggests that the Ni pre-strike enhances adhesion of the Al plating to the steel substrate.

Results (2) NSS (Bolted AM60B Coupons)

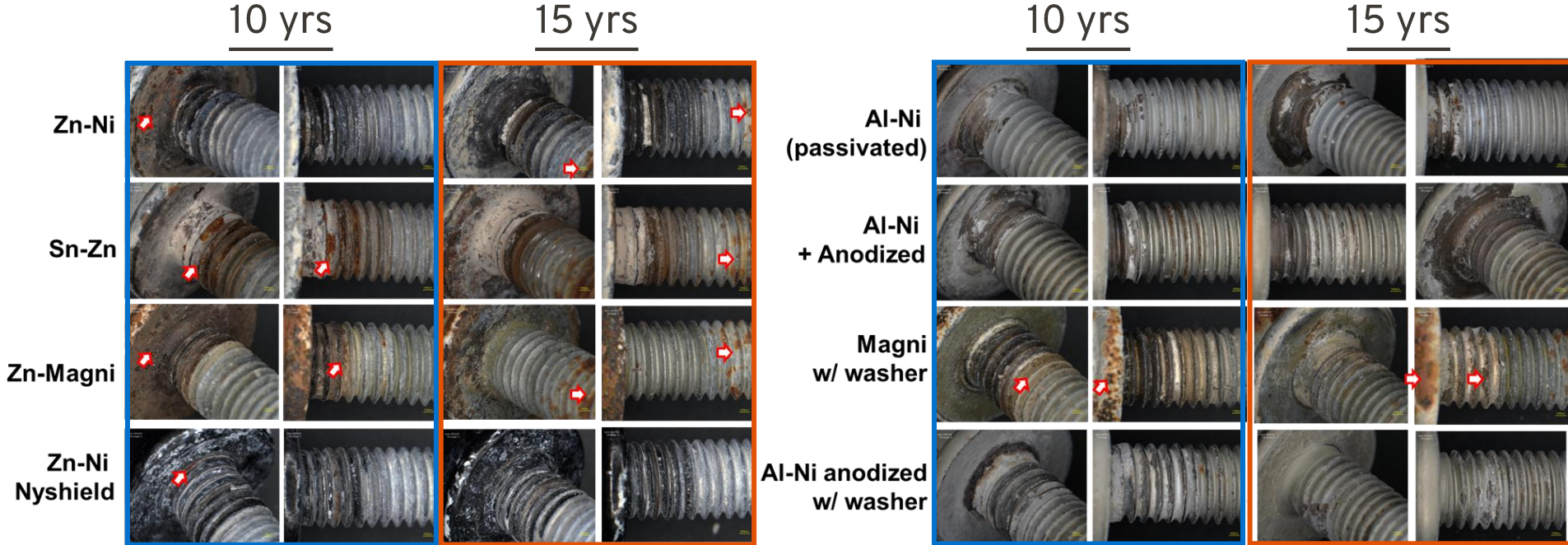
III. Results



- Sn-Zn coating was more galvanically compatible with the Mg substrate compared to the Zn-Ni and Zn-Magni coating.
- The addition of **Nyshield** and **Al washer** mitigated galvanic corrosion.
- Al-plated with a Ni pre-strike layer and trivalent chromate passivation exhibits the best performance.

Results (3) Cyclic Corrosion Testing

I. Bolts (Visual examination of type of rust)



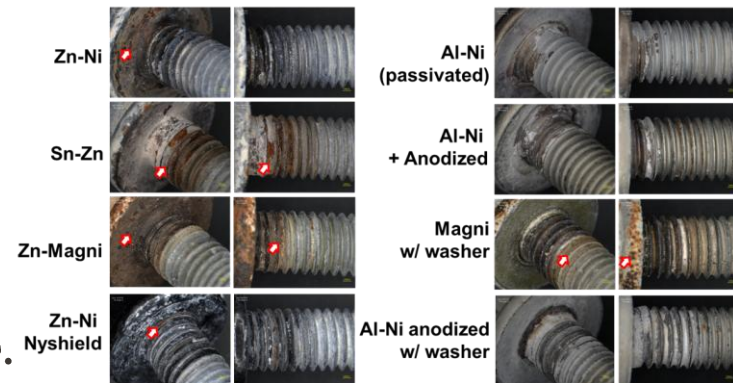
No noticeable difference was observed *between 10 yrs and 15 yrs* based on visual examination.

Results (3) Cyclic Corrosion Testing

I. Bolts (Visual examination of type of rust)

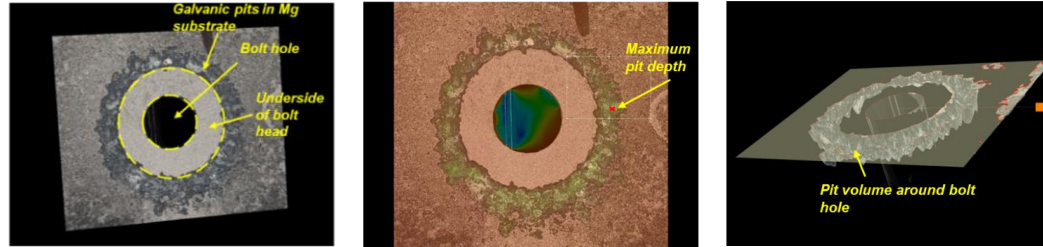
- **Zn-Ni, Sn-Zn, Zn-Magni 565, and Magni with washer** shows visible evidence of white rust with red rust.
- Nyshield-coated Zn-Ni samples showed suppressed rust formation, though localized coating discontinuities were present.
- Among the evaluated bolts, Al-plated steel bolts demonstrated superior visual performance.
- The use of Al washer with Magni mitigated the rust formation

10 yrs

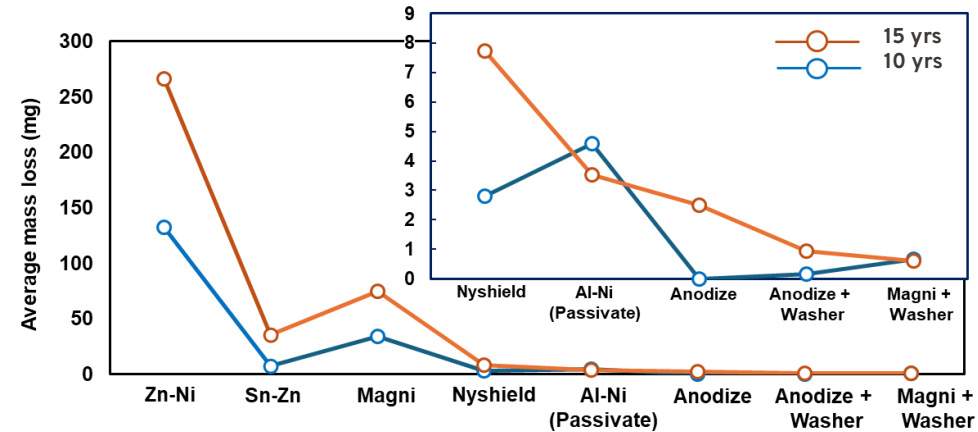
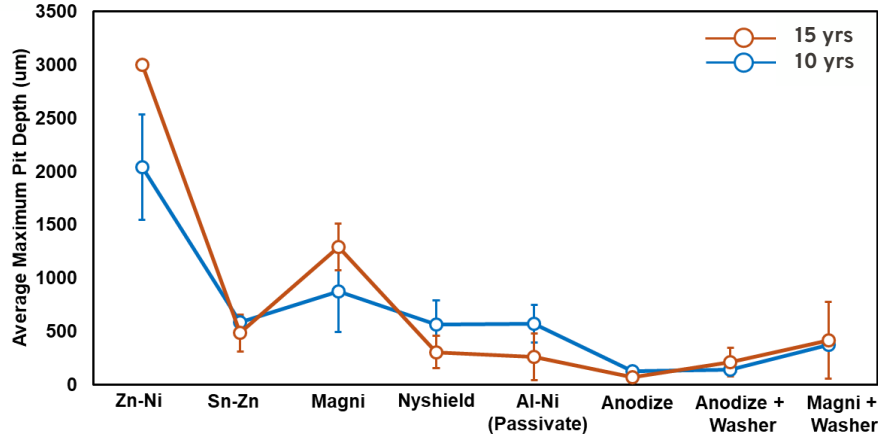


Results (3) Cyclic Corrosion Testing

II. Mg (Galvanic corrosion pit depth)



- **Al washer** mitigate galvanic corrosion.
- **Anodized Al-plated steel bolt** shows good performance without Al washer.



Conclusion

- **Zn-based coated bolts**, especially **Zn-Ni**, caused the most severe galvanic corrosion of Mg.
- **Sn-Zn** and **Zn-Magni 565** performed slightly better, but corrosion damage remained significant.
- A **6061-T6 Al washer** effectively reduced galvanic attack for Zn-Magni 565 bolts, although fastener rusting was still observed.
- **Al-plated steel bolts** outperformed all Zn-based systems with lower pit depth and mass loss.
- The **anodized Al-plated steel bolt** showed the best overall performance by maintaining a protective dielectric barrier after installation.



Thank you for your attention!

