


# ***Evaluation of Alternatives to Electrodeposited Cadmium for Threaded Fastener Applications***

*C. J. Brown, M. W. Smith; Lockheed Martin Aeronautics*

*L. Zeng, L. Haylock, R.H. Gurrola, E. Monserratt, D. Youngblood; Alcoa Fastening Systems*

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Alcoa  
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# *Agenda*

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# ***Background***

- Lockheed Martin Aeronautics (LM Aero) manufactures the F-16 Fighting Falcon in Fort Worth, Texas, USA
  - The world's most popular, most sought-after multirole fighter
  - Over 4300 delivered; over 110 different versions



# ***Background (continued)***

- Part of the F-16 manufacturing process involves removal of primer from the inlet surfaces to accommodate subsequent coatings
- Cadmium dust is generated from the heads of cadmium-plated (Cd-plated) fasteners



# ***Background (continued)***

- LM Aero implemented additional PPE, shower facilities, and more frequent medical monitoring in compliance with the U.S. OSHA cadmium standard
- Cd-plated MS90353 blind bolts were replaced by IVD aluminum-coated rivets as partial solution
- Cd-plated threaded bolts also needed to be replaced
  - Primarily NAS 1580 and NAS 4452 fasteners
  - Several hundred per shipset
  - No plating alternatives available on standard

# ***Program Goals***

- Funding provided to LM Aero by U.S. Air Force to qualify and implement an alternative to cadmium plating on threaded fasteners
  - Identify candidate materials/technologies
  - Develop test plan
  - Solicit partnership from fastener manufacturer
  - Test representative fasteners plated/coated with candidates
  - Implement the best replacement based on test data, cost, availability

# ***Program Goals (continued)***

- Candidates selected based on performance potential, technology maturity, reasonable cost and throughput
  - Alternative substrates considered (e.g. SS, Ti) but cost, weight, and strength issues a concern
  - Secondary coating allowed to enhance lubricity
- Testing to evaluate various alternative coatings for corrosion protection, lubricity, compatibility with substrate
  - NAS 1580A3T12 selected as representative fastener
  - Plan to use NAS 1580 test results for cadmium on NAS 4452, with some possible additional testing

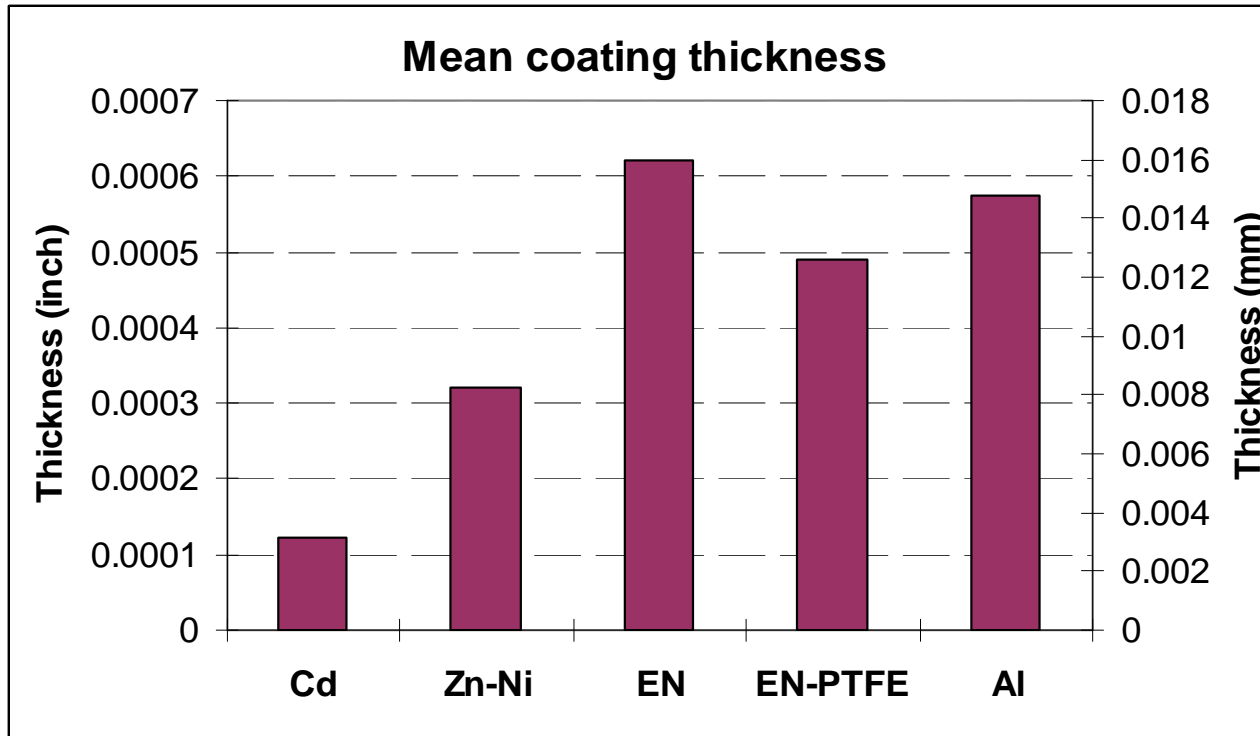
# *Coating Descriptions*

- ***Cadmium:*** baseline, QQ-P-416 type II chromate treatment
- ***AlumiPlate:*** MIL-DTL-83488D High purity Al, Type II chromate.
  - An organic solvent based water-free electrolyte to electroplate high purity thin amorphous aluminum.
- ***Electro-less Nickel:*** AMS-C-26074, 0.0003", no conversion coating,
  - a controlled infusion of P-Ni plating.
- ***Electro-less Nickel-PTFE:*** High Phosphorous, 0.0003" min, no conversion coating.
  - Deposits a durable, and dry lubricating coating that combines the PTFE (20-26%) in a strong, hard matrix of electroless Ni-P.
- ***Surface mineralization Zn-Ni:*** enable an environmentally benign cathodic conversion of a microscopically thin barrier of silicate.

# ***Test Methods: simulate the typical use of threaded fasteners***

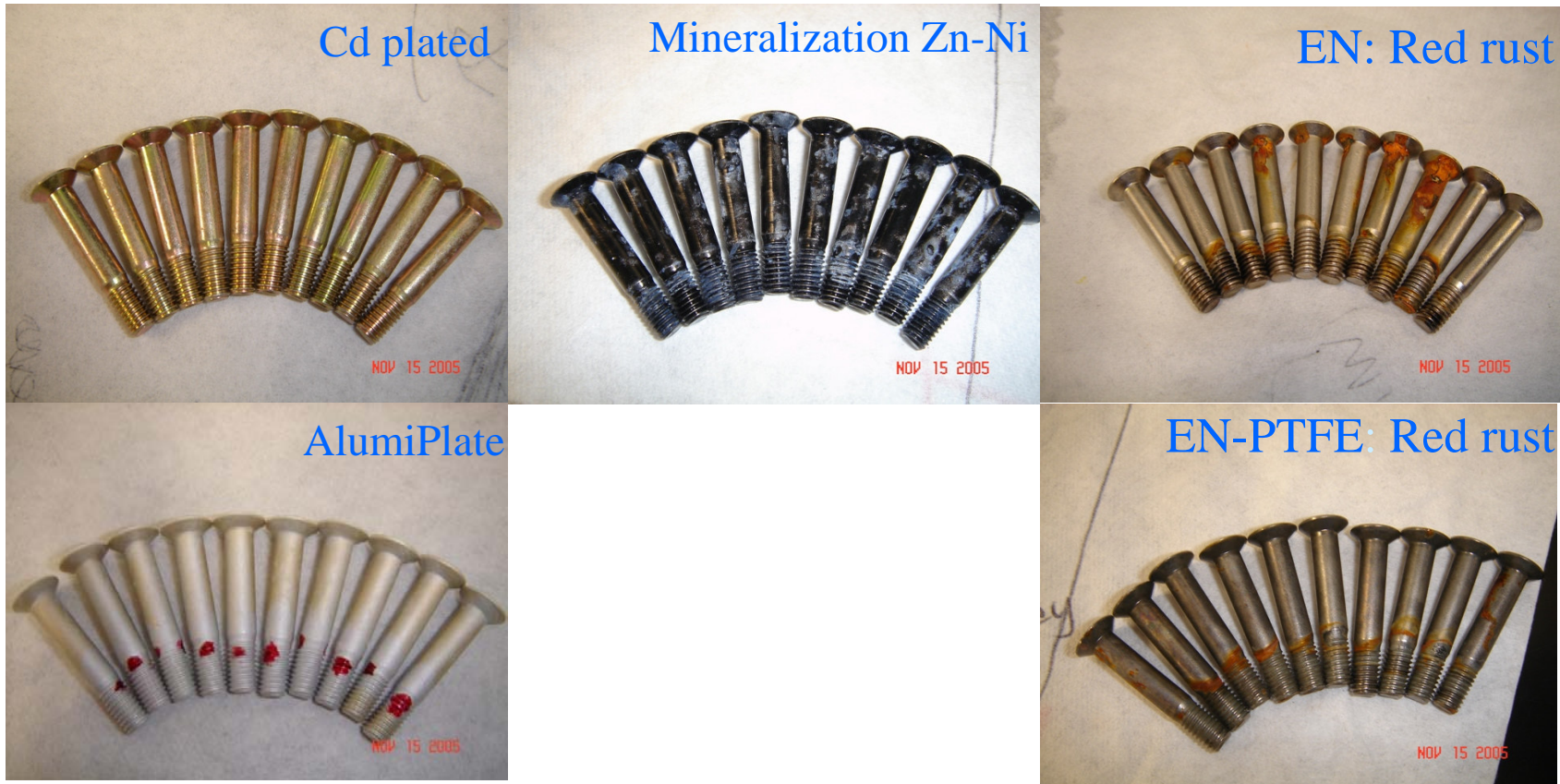
- Coating thickness/appearance (AMS-QQ-P-416)
- Corrosion Protection: Salt-spray (fog) (NASM1312-1 and/or ASTM B117-03)
- Corrosion potential measurements
- Resistance to vibration (NASM1312-31, NASM25027)
  - Run-on
  - Break-away
- Torque-Tension test (NASM1312-15 NASM25027)
- Resistance to insertion: Push-in test
- Resistance to Stress Corrosion Cracking: Stress Corrosion (NASM1312-9)

# Coating thickness/appearance



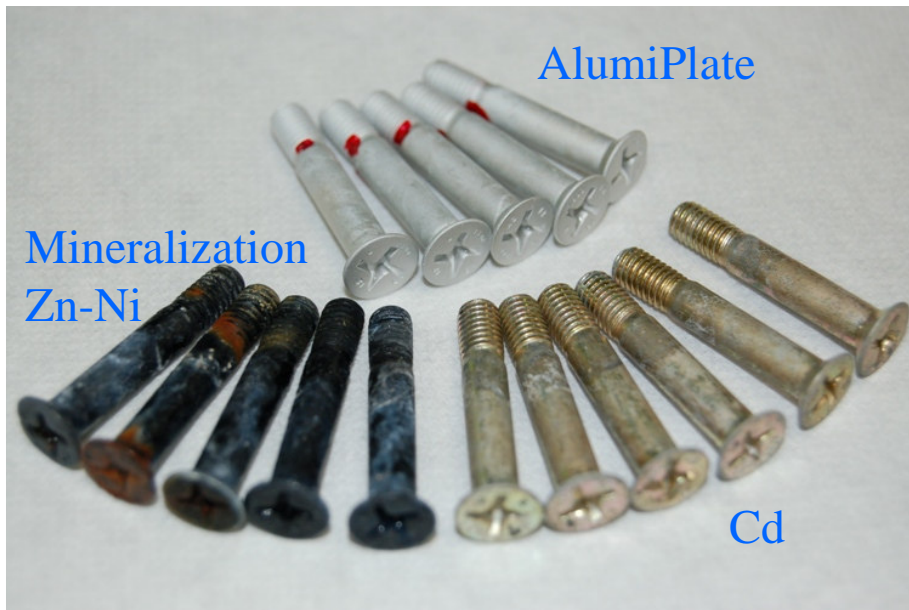
- Coating is continuous, uniform in appearance, and free from contaminants and other apparent defects.
- Different coating thickness among all coatings.

# 96 hours Salt spray tests



- Only AlumiPlate and Mineralization Zn-Ni passed the 96 hours Salt spray tests, in addition to Cd plating.

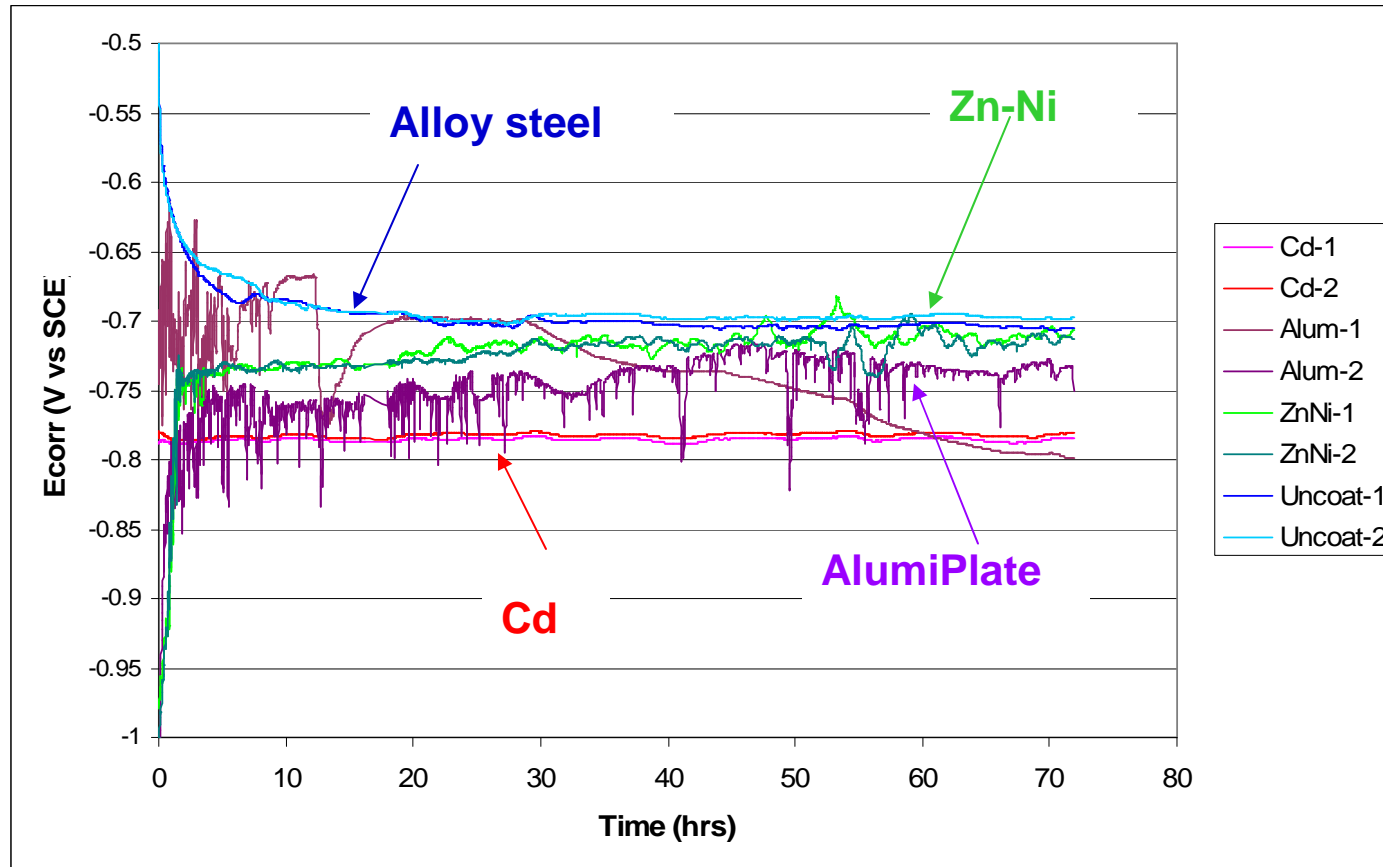
# ***1000 hours Salt spray tests***



- The AlumiPlate performed well. Its surface appearance changed from a light yellow chromate conversion coating color to a metallic white, possibly due to the formation of aluminum oxides on the coating surface.

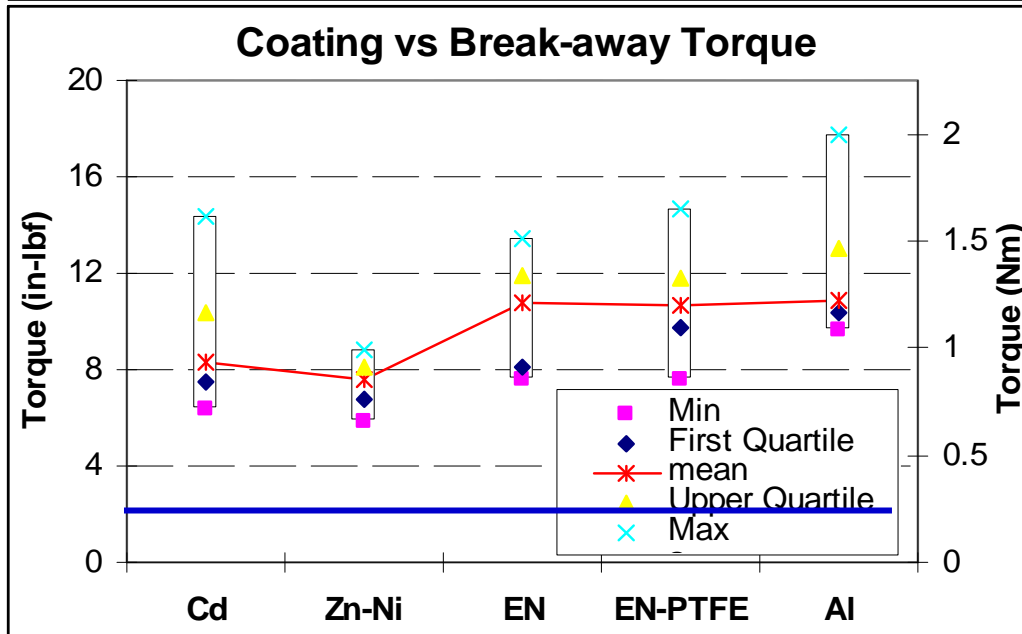
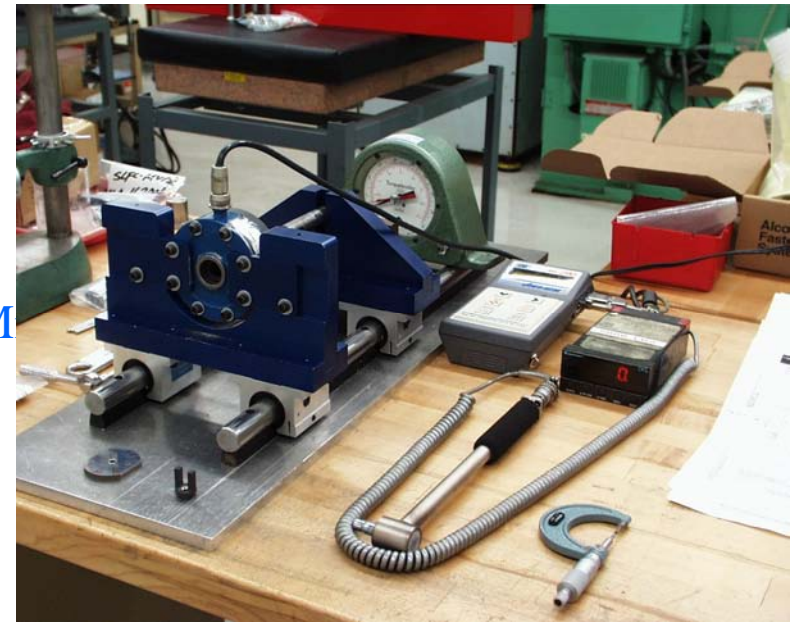
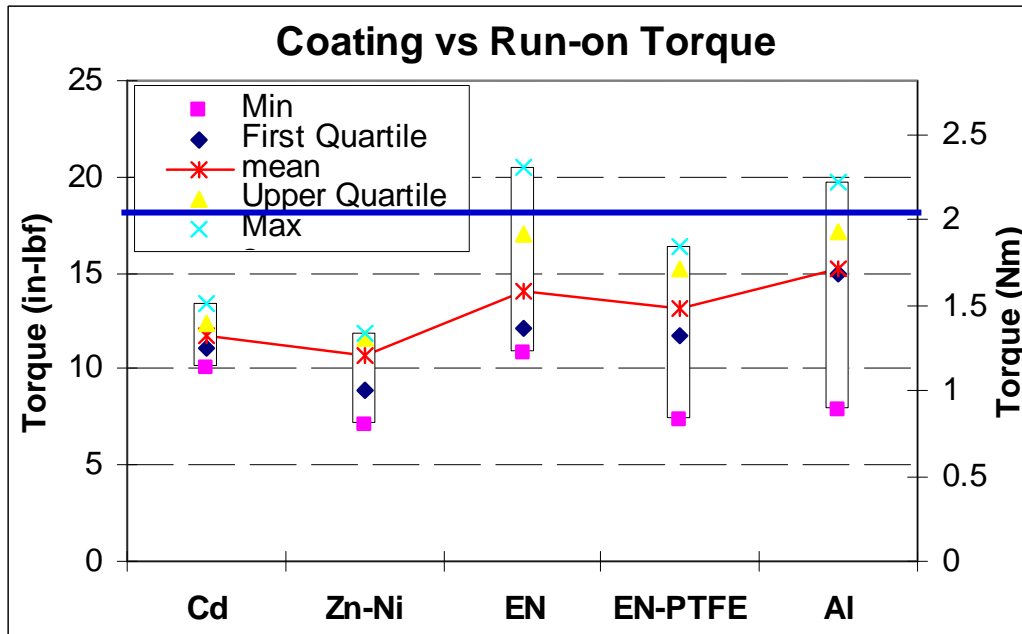
- Mineralization Zn-Ni plated fasteners revealed first evidence of red rust after 550 and 770 hours of exposure.
- The Cd plated fasteners showed slight corrosion on cadmium evidenced by black mottling of the surface.

# Corrosion potential measurements



- Zn-Ni, AlumiPlate and Cd could provide sacrificial protection for 8740 substrate due to lower electrochemical potential.

# Resistance to vibration test results

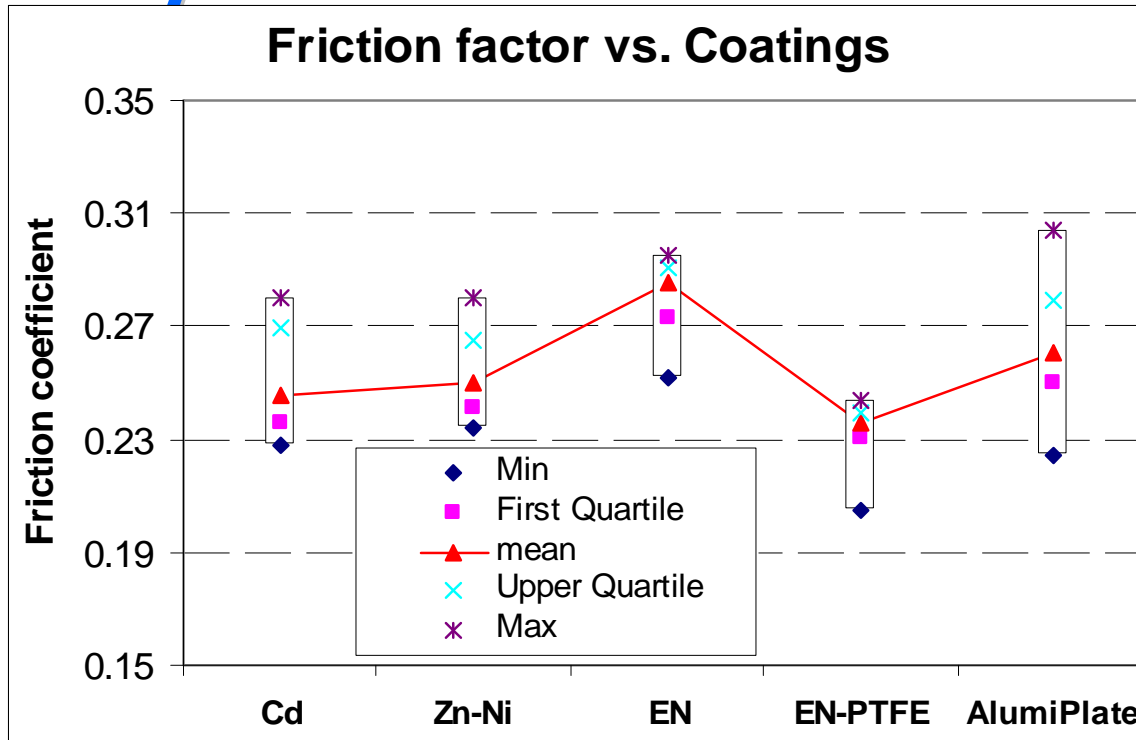


Aerospace KFN541L-3F K-fast locking nuts were used for run-on and break-away testing.

- The Mineralization Zn-Ni, EN-PTFE nut/bolt sets met the specification requirements.

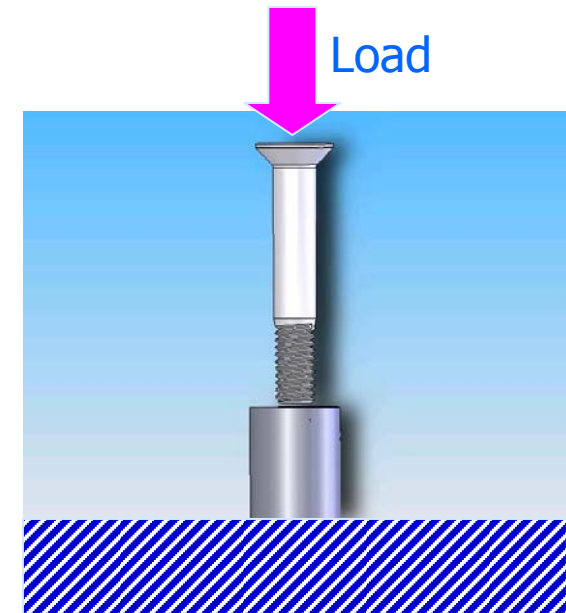
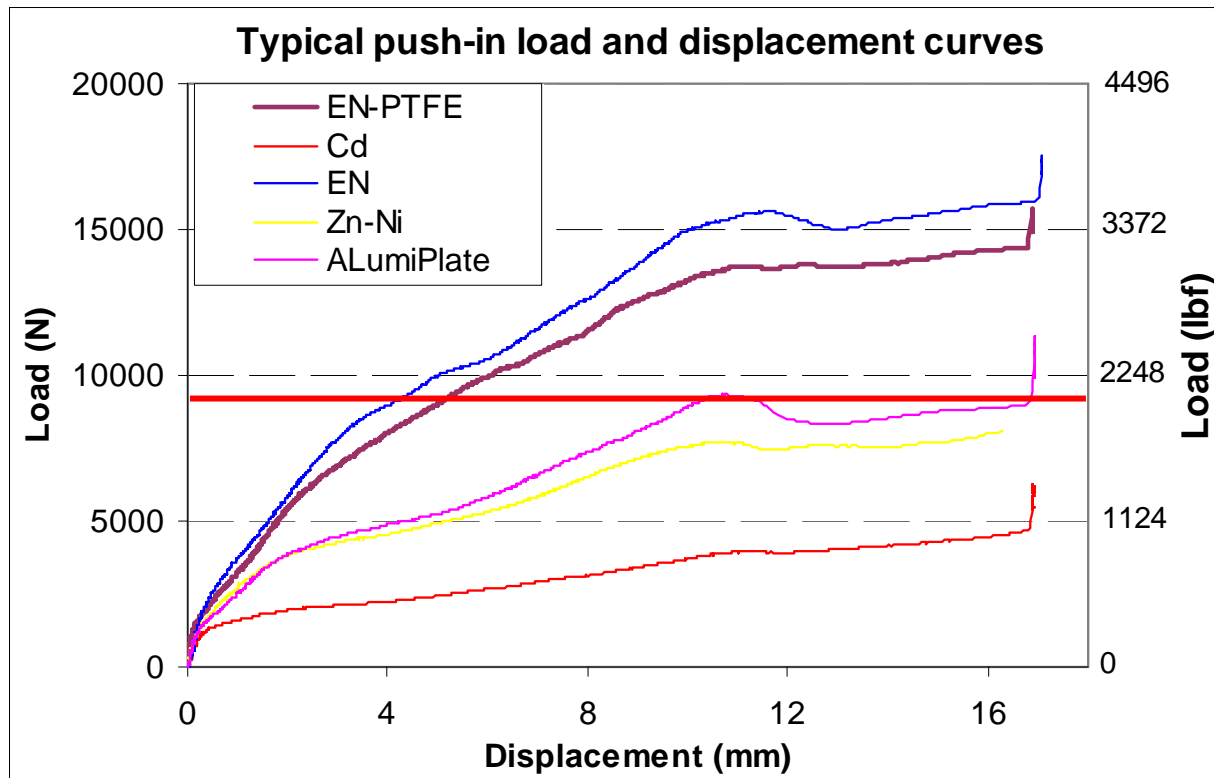
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# Calculation of friction coefficient: Torque-tension test



- EN-PTFE has the lowest friction coefficient and variability.
- Average friction coefficient of Mineralization Zn-Ni showed similar to Cd plated.
- EN has the highest friction coefficient.

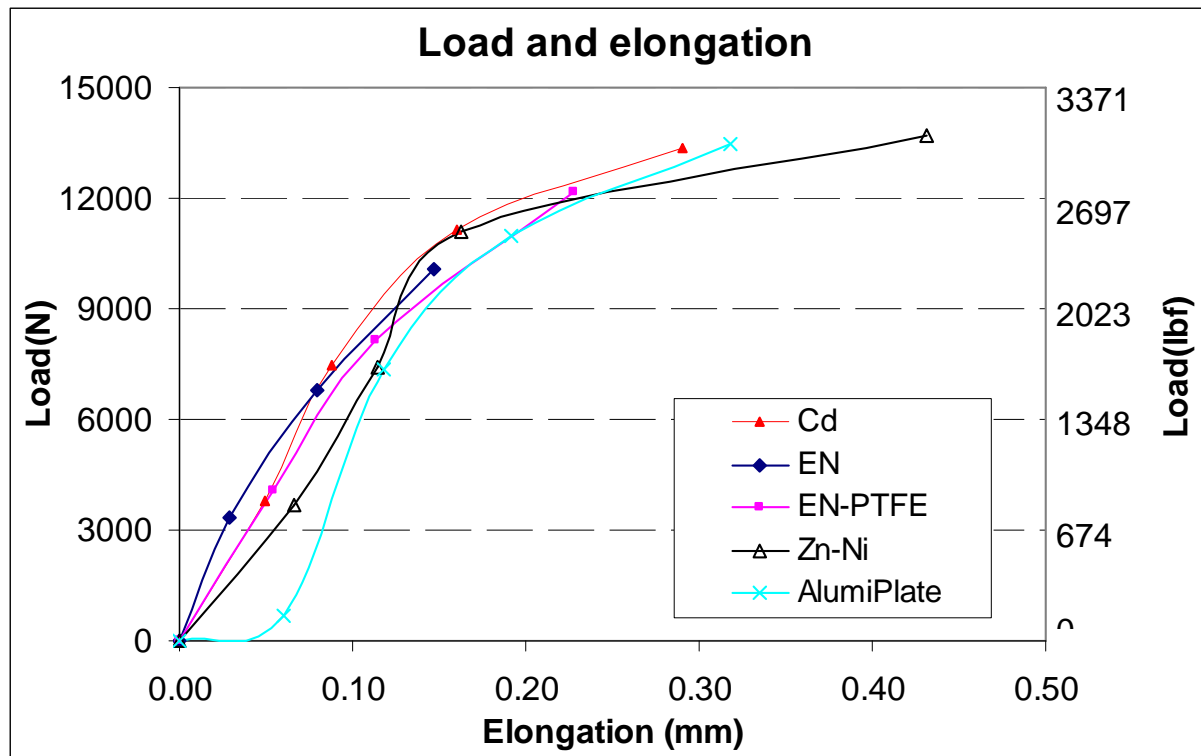
# Resistance to insertion: Push-in tests



The desired maximum installation force is less than 8896 (N) or 2000 lbs.

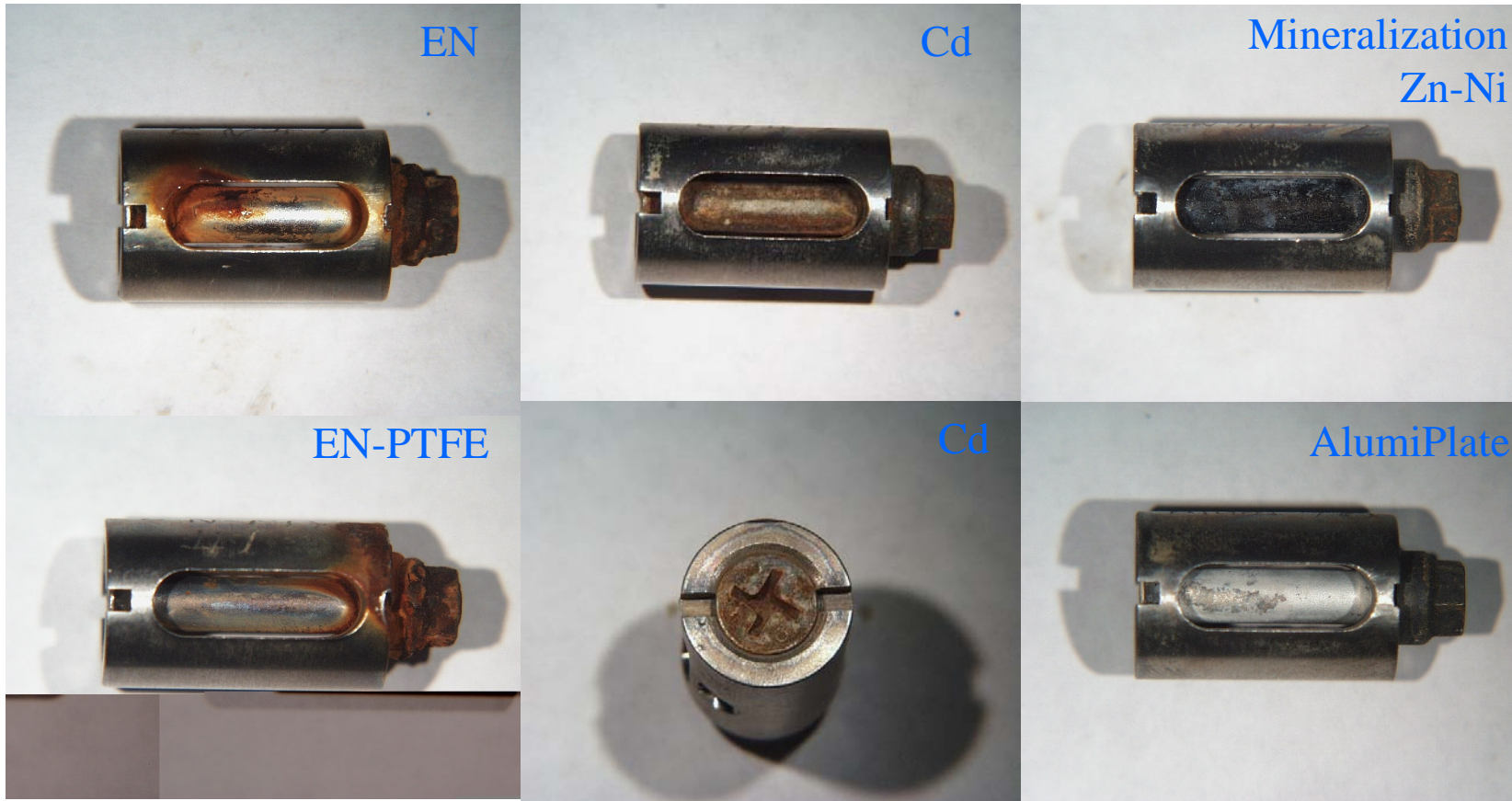
- Fastener was pushed into interference aluminum hole at constant rate of 4000 lbf/min. Thus the required load and load-displacement curves can be measured.

# Stress-corrosion tests



- Fasteners were installed onto NASM1312 defined fixture. The fastener is under tensile stress of 75% of UTS. Based on torque-load-elongation relationship, 75% of UTS tensile stress can be identified.
- The total running time is 587 hours.

# *Stress-corrosion test result*



- Ranking of various coating from the best to the worst as: AlumiPlate, Mineralization Zn-Ni, Cd, EN-PTFE, and EN.

# Summary

	Salt-spray	Torque-tension	Run-on torque	Break-away torque	Push-in load	Stress-corrosion
<b>EN</b>	F	F	F	Pass	F	F
<b>EN-PTFE</b>	F	Ex	Pass	Pass	F	F
<b>Cd</b>	Base	Base	Base	Base	Base	Base
<b>Zn-Ni</b>	Pass	Pass	Pass	Pass	Pass	Pass
<b>AlumiPlate</b>	Ex	Pass	F	Pass	F	Ex

**F:** Fail; **Ex:** excellent

- It appears that no one coating offers the same broad range of properties as Cd plating.
- For the current investigation, Zn-Ni and Alumiplate came closest to the Cd characteristics overall.

# ***Next Action***

- Re-evaluate mineralization Zn-Ni and AlumiPlate under equivalent coating thickness.
  - Repeat mechanical tests plus tensile, shear and fatigue tests.
  - Repeat corrosion test.
- Quantitative measurement of corrosion potentials between fastener material, coatings, and joining alloys to assess galvanic compatibility of given fastener/coating/joining alloy systems.
- Schedule to finish testing by March 2007, implementation by September 2007