Cadmium Replacements for High Strength Steel Fasteners

Anthony Eng
NSWCCD-SSES
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<th>5d. PROJECT NUMBER</th>
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<td>Naval Surface Warfare Center Philadelphia, Carderock Division-Ship Systems Engineering Station, 5001 South Broad Street, Philadelphia, PA, 19112-1403</td>
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Naval Surface Warfare Center
Carderock Division
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Background

• Cadmium commonly used on steel fasteners
  – easy deposition, corrosion resistance, low CoF, solderable
  – probable human carcinogen
  – can cause anemia, emphysema, and bone, kidney & liver diseases

• Chromium (VI) commonly used as a post treatment on Cd
  – enhances corrosion resistance of cadmium
  – human carcinogen
  – can cause ulcers and lung cancer

• Cd & Cr impact on life cycle costs
  – satisfactory performance
  – operator exposure, environmental emissions
  – waste related processing
Objectives

• Eliminate the use of electroplated Cadmium in high strength steel fastener applications

• Reduce and/or eliminate the use of Chromium in high strength steel fastener applications
JTP Tests

• General Properties
  – appearance (visual inspection)
  – coating thickness (ASTM B487)
  – max temperature (24 hr exposure-visual inspection)

• Corrosion
  – SO₂ salt fog w/ & w/o defect (500 hr ASTM G85-A4) [fastener & panel]
  – cyclic wet/dry corrosion w/ & w/o scribe (160 cy GM9540P) [fstnr & pnl]
  – galvanic bi-metallic (GM9540P)
  – fluid w/ & w/o scribe [coupon]

• Adhesion
  – water boil (modified ASTM D3359 - A)
  – bend (ASTM B571) [pnl]
  – paint (dry & water immersion) (ASTM D3359 - B) [pnl]
JTP Tests (continued)

• Assembly
  – breakaway torque w/ & w/o corr expos (ASTM G85-A4 & GM9540P)
  – fastener COF (1/3 & 2/3 YS, 3 cycles)
  – torque tension (30, 40, 50, 60, 70, 80, 90% YS, 5 cycles)

• Longevity
  – fatigue (NASM 1312-11) @ 70±30 ksi mean stress w/ & w/o corr expos
  – stress durability (ISO 15330) @ 96 hr w/ & w/o corr expos
  – slow strain rate (ASTM F606) @ 0.001”/min w/ & w/o corr expos
  – strippability (MIL-S-5002D) [fstnr & pnl]
    • bend test after coating reapplication
    • stress durability (ISO 15330) @ 96 hr before & after ctg reappl
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<th>Other Samples</th>
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JTP Status

• Draft issued 17 Mar 2004 and sent to 39 technical stakeholders/contributors
• 291 comments received and adjudicated
  – Eric Brooman (AFRL)
  – Joe Osborne (Boeing)
  – Harry Archer (NSWCIHD)
  – Ralph Adler (ARL)
  – Tim Tenopir (PHD NSWC)
  – Michael Kane (AMCOM)
  – Patrick Doyle (NAWCADLKE)
• Selected Issues
  – Zn vs Cad as control
  – Grade 8 (150 ksi) vs 180 ksi or 220 ksi fasteners
  – Use of dry film lubricants
  – Mandatory and service specific tests/requirements
Preliminary Field Demo

- Fastener: 1.25” (length), 3/8” - 16 UNC grade 8, hex head cap screw
- Nuts installed/removed 5 times
- Fasteners torqued to 90% YS on 4142 plate
- 1 hr dwell, torque reapplication
- Installed on MTVR (Lejeune, NC; Kaneohe Bay, HI; Okinawa, Japan)
Candidate Coating Systems

- Zn with Cr post treatment
- Zn with proprietary non Cr treatment
  - Cd originally planned
- Zn/Al Flake in inorganic binder with friction control TC
- Zn/Al Flake with Cr in inorganic binder with friction control TC
- ZnNi per SAE AMS2417E
- ZnNi with silicate surface conversion and black UV TC
Materials Engineering Branch, Code 622

HCAT/JCAT Program Review
15-17 Mar 2005

KB #205
OK #201
KB #100
CL#118
## Torque Data

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<tr>
<th>Material</th>
<th>DFT (mils)</th>
<th>COF</th>
<th>Initial Torque (ft-lb)</th>
<th>Unexpos BA Torque (ft-lb)</th>
<th>1 Yr Fld Expos BA Torque (ft-lb)</th>
<th>BA Torque % Change</th>
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<td>0.11</td>
<td>46</td>
<td>38</td>
<td>60</td>
<td>159</td>
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<td>0.13</td>
<td>53</td>
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### Slow Strain Rate Data

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<th>DFT (mils)</th>
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<th>UTS % Change</th>
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Note: thread stress area based on ASTM F606, \( A_s = 0.7854 \cdot \frac{D-0.9743}{n} \)^2
Conclusions

- Draft JTP issued
- Draft JTP reviewed by technical stakeholders
- Draft JTP comments adjudicated
- Field exposure test on operational USMC vehicles initiated
- 1 yr field exposure samples collected (analysis ongoing)
- Based on data collected to date:
  - ZnNi and modified ZnNi coatings appear to maintain lubricity
  - Zn w/NC and Zn/Al coatings are displaying the most surface corrosion
  - Hydrogen embrittlement has not been detected wrt coating application nor during field service
- Further JTP coordination on hold until endorsement by DOD