Evaluation of Zinc-Nickel Alloy Plating on Fasteners for Boeing Commercial Airplanes

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Evaluation of Zinc-Nickel Alloy Plating on Fasteners for Boeing Commercial Airplanes

Focused Workshop on Cadmium Plating Alternatives, August 30-31, 2011, Baltimore, MD. Sponsored by SERDP/ESTCP.
Background - Cadmium Plating Replacement

- Cadmium plating has been used traditionally on fasteners for its
  - Corrosion protection (sacrificial anodic)
  - Lubricity (anti-galling)
  - Electrical properties
- US and EU Environmental Regulations are mandating the Aerospace Industry to eliminate Cadmium and other toxic materials
- Current BCA Engineering practice allows substitution or replacement of Cadmium with Zinc-Nickel plating except for use on threads
- Use of Cadmium on Boeing commercial aircraft are allowed by Exemptions
BR&T Chemical Technology and Fasteners Engineering have been evaluating the performance of Zinc-Nickel plating.

- Five test programs (Phases I to V) have been conducted to-date to compare the performance of Zinc-Nickel to Cadmium plating.
- Testing to-date has shown that acid and alkaline Zn-Ni plating are an acceptable replacement for Cadmium on threaded parts.
- Additional work is planned for Phase VI for 2011:
  - Optimize coating thickness on threads.
- Fasteners (standard parts) qualifications are planned post Phase VI.
- BCA Programs have been evaluating electrical properties of Zinc-Nickel and found it acceptable for Bonding/Grounding applications.
Six Phases of Fastener Evaluation

- **Acid Zinc-Nickel plating**
  - **Phase I - on 3/8” fasteners**
    - Axial Tensile Strength
    - Corrosion and Fatigue
    - Torque-Tension
    - Torque Effectivity and Reusability (Locking and Break-Away Torque)
  - **Phase II & III - on 3/8” fasteners**
    - Torque-Tension

- **Alkaline Zinc-Nickel Plating**
  - **Phase IV - on 3/8” fasteners**
    - Corrosion and Fatigue
    - Torque-Tension, Torque Effectivity and Reusability
  - **Phase V - on 3/16, 3/8 and 3/4” fasteners**
    - Similar to testing performed in Phase IV
  - **Phase VI - on various size fasteners**
    - Corrosion and Fatigue
    - Torque-Tension
    - Torque Effectivity and Reusability
The following results are available with representative data shown in this presentation

- Corrosion
- Fatigue
- Tensile Strength
- Torque-Tension
- Torque Effectivity and Reusability (Locking and Break-away)
Corrosion Test Results (All A286 Substrates)

- CC30AB5C
- CC30AB5ZnNi
- N10KE3B4CD
- N10KE3B4ZnNi
- LM6K16
- LM6-16
- LM6ZnNi16
- HR162CD
- HR162ZnNi
Fatigue Test Results
(Acid Zinc-Nickel, Phase I)

Engineering, Operations & Technology | Boeing Research & Technology

- Nickel Alloy 718 Bolts – 3/8” diameter
  Cd or Zn-Ni plated
- Test Nuts – MIL-STD-1312 uncoated
- Test setup – Per NASM1312-11
- Test parameters
  - Cycle = 24 Hz, RT
  - Tension-tension at 1090 lbs (low)
    and 10900 lbs (high)
- Requirement
  - Acceptance = 100000 cycles or
    meets statistical criteria
- Results – Acid Zn-Ni plating on fasteners
  performed comparable to Cd

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<th>Bright Cadmium</th>
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Req. Accept if the life of each fastener exceeds 100,000 cycles. Reject entire lot if average life is less than 65,000 cycles, or if one or more individual fasteners fails in less than 45,000 cycles. Take second sample if lot is not accepted or rejected on first sample.
Fatigue Test Results
(Alkaline Zinc-Nickel, Phase IV)

- Nickel Alloy 718 Bolts – 3/8” diameter
  Cd or Zn-Ni plated
- Test Nuts – MIL-STD-1312 uncoated
- Test setup – Per NASM1312-11
- Test parameters
  - Cycle = 24 Hz, RT
  - Tension-tension at 1090 lbs (low)
    and 10900 lbs (high)
- Requirement
  - Acceptance = 100000 cycles or
    meets statistical requirement
- Results – Alkaline Zn-Ni plating on
  fasteners performed comparable to Cd

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Fatigue Test Results (Alkaline Zinc-Nickel, Phase V)

- A286 Hi-Loks – Cd or Zn-Ni plated
- A286 Collars – Cd or Zn-Ni plated
- Test setup – Per NASM1312-11
- Test parameters
  - Cycle = 24 Hz, RT
  - Size 5 – Tension-tension at 51 lbs (low) and 515 lbs (high)
  - Size 10 – Tension-tension at 192 lbs (low) and 1920 lbs (high)
- Requirement
  - Acceptance = 100000 cycles or meets statistical requirements
- Results – Alkaline Zn-Ni plating on fasteners performed comparable to Cd
Tensile Strength Test Set-up (Acid Zinc-Nickel)

- Tensile Test performed in accordance with NASM1312-8
Tensile Strength Results
(Acid Zinc-Nickel, Phase I)

Loads (lbs)

Bolts

220 ksi Nickel Alloy
180 ksi Alloy Steel
180 ksi CRES

Nuts

220 ksi CRES
220 ksi Alloy Steel
180 ksi CRES
180 ksi Alloy Steel

Cadmium Plating
Zinc-Nickel Plating
Torque-Tension Test Set-up

- Performed Torque-Tension Test in accordance with NASM1312-15
Torque-Tension Test Results for 3/8” Fasteners (Zinc-Nickel, Phase III and Phase IV)

- **Bolts** - 3/8” Nickel Alloy 718 with BMS10-85 (Aluminum Pigmented Coating)
- **Nuts** - 3/8” A286 CRES with Cd or Zn-Ni plating and Solid Film Lubricant
- **Washers** - 3/8” A286 CRES with Cd or Zn-Ni plating
- **Requirement** – At 400 in-lb torque, target tension 30% to 60% of Ultimate Tensile Strength (BAC5009)
- **Result** - Zn-Ni plated nuts/washers performed comparable to Cd for both Acid and Alkaline processes

![Torque-Tension Graph](image)

- **Ultimate Tensile Strength** = 20,900
- **31% UTS**
- **56% UTS**
Locking Torque Test Results (Alkaline Zinc-Nickel, Phase V)

- A286 Bolts – 3/8” diameter with BMS10-85 or Zn-Ni coating
- A286 Nuts – 3/8” diameter with Cd or Zn-Ni and Solid Film Lube
- A286 Washers – 3/8” diameter with Cd or Zn-Ni coating
- Test setup per BPS-N-70
- Requirement: 80 in-lbs MAX

- Phase V Results – Meets requirement. Similar to Cd.
Break-away Torque Test Results
(Alkaline Zinc-Nickel, Phase V)

- A286 Bolts – 3/8” diameter with BMS10-85 or Zn-Ni coating
- A286 Nuts – 3/8” diameter with Cd or Zn-Ni and Solid Film Lube
- A286 Washers - 3/8” diameter with Cd or Zn-Ni coating
- Test setup per BPS-N-70
- Requirement: 9.5 in-lbs MIN

Phase V Results – Meets requirement. Similar to Cd.

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Diagram of bolt, bushing, and washer setup.
Conclusions

- **Corrosion**
  - Performed comparable to Cd

- **Fatigue**
  - Performed comparable to Cd

- **Tensile Strength**
  - Performed similar to Cd. Does not affect tensile strength of fasteners

- **Torque-Tension**
  - Performed similar to Cd for the 3/8” fastener system
  - Higher preload with historical scatter is anticipated for Zn-Ni plating
  - Current method (stripping & replating) is not optimized to provide proper plating thickness.
  - Additional testing will be performed in Phase VI with fasteners fabricated by the traditional manufacturing process (not strip and re-plate)

- **Locking and Break-away Torque**
  - Performed Similar to Cd
• **Torque-Tension**
  – BACB30US (size 3, 6 and 16, Nickel Alloy w/ BMS10-85 or Zn-Ni)
  – BACB30NM (size 3, 6 and 12, Titanium Bolts)
  – BACB30LM (size 3, 6 and 16, A286 Bolts)
  – BACB30MR, BACN11Z, BACW10BP (size 3, 6, and 12)
    – Zip chem on bolts thread only
  – BACB30FM, BACC30AB (size 5 and 10)
    – Cetyl alcohol on Zn-Ni plated collars
    – Install on primed surface
• **Corrosion and Torque Effectivity (Ground Stud)**
  – BACJ40AC (35 Amp Jumper Ass’y), BACS12HNS (A286 Screws)
• **Push-in Installation Force of Hi-Loks fasteners**
  – BACB30FM (size 5 and 10, A286 Hi-Lok)
• **Push-in Installation Force with Rivet Gun of Hi-Loks fasteners**
  – BACB30FM, BACC30AB (size 5 and 10)
• **High RPM Installation Force with nuts runners**
Questions and Contact

- Questions???
- What about other Zn-Ni coating?

Thank you for the opportunity to share these data and to be part of your on-going discussion and evaluation of Cadmium plating alternatives

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