Coating Challenges for Fasteners in Defense and Aerospace

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Pressure from a variety of environmental and health rules in the US and overseas is driving adoption of new (and often better) coatings for fasteners

Changes since FastenerTech ‘07

- New DoD memo to eliminate Cr\(^{6+}\) from new equipment
- REACH impact becoming clearer
- Army looking to replace Cd-plated fasteners on vehicles
- Several new projects on fasteners
Why Cd?

- Cheap and easy
- Sacrificial, but not too electronegative so lasts a long time
- Low volume of corrosion products
  - Inhibits “freezing”
  - Not electrically insulating
- Lubricious, reliable torque-tension
- No re-embrittlement
- No fatigue debit
Drivers for change
Materials are changing, especially in defense and aerospace

- Composites (carbon fiber, glass fiber)
  - Insulating organic matrix, conducting carbon fibers
- High use of Al, increasing use of stainless steel, Ti, Mg
  - A lot of potential for galvanic corrosion
  - Potentially puts Al, steel, C in galvanic contact
DoD Memo on Cr$^{6+}$

April 8 ‘09 OSD issued memo restricting Cr$^{6+}$ use, unless no cost-effective alternatives with satisfactory performance

Requires Program Executive Officer (PEO) and Corrosion Control and Prevention Executive (CCPE) to certify if no acceptable alternative
Changing environmental and health requirements

The wars of the RoHSes

- European RoHS, China RoHS, CA RoHS
- Severely restricting Cd, chromates on electrical equipment sold in EU – aerospace and defense exempt
- US RoHS, HR 2420 “Environmental Design of Electrical Equipment Act (EDEE) Act”

Hath not thy RoHS a thorn?

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Companies selling electrical equipment and vehicles in the EU must certify RoHS compliance

- With HR 2420 we will have the same here

For many companies the biggest difficulty with meeting the RoHS requirements is with fasteners because they have no control over them

What works depends on the environment in which they will be used

- No homogeneous layer can contain \( >0.1\% \text{ Cr}^{6+} \) or \( >0.01\% \text{ Cd} \) by weight
- “Homogeneous layer” means any layer that cannot \textit{in principle} be mechanically disjointed
- The chromate layer is a homogeneous layer, not the chromated Zn or Cd
What about REACH?

- **Cr⁶⁺** not affected by REACH at this time
  - Sodium dichromate was put forward in first Annex XIV group, but decided not to make it a priority substance at this time

- Cd plating permitted on aircraft and some other applications, but otherwise severely restricted
  - Not permitted on vehicles, and military vehicles do not seem to be exempt
  - Most US military vehicles in Europe use Cd-plated, chromated fasteners

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But aren’t we exempt?

- Military and aerospace are exempt (for now) from WEEE and RoHS but not from OSHA or EPA
  - HR 2420 does not have aerospace or defense exemption
  - Unlikely to stay that way
- **No defense exemptions built into REACH**
  - UK has Defense Exemption, but does not exempt from rules, only from disclosures to ECHA
  - Other EU countries considering similar laws
- Being exempt from REACH or RoHS does not make us exempt from their effects. Military and aerospace users are concerned about
  - Reduced availability of chromated materials
  - Reduced availability of Cd plating
  - Higher prices, longer lead times
  - Selling and maintaining equipment in Europe

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Personnel safety

- All military systems and aircraft need paint touch-up for corrosion control and aesthetics
- When scuff sanding, Cd plated, chromated fasteners and chromate converted Al with chromate primers are a serious personnel hazard
  - Especially bad for uncontrolled areas – flight lines, forward bases, etc.
  - Even in factories and military depots, sanding for touch-up or bonding creates chromate dust
  - New OSHA Cr$^{6+}$ rules require keeping unprotected workers away from site generating Cr$^{6+}$ dust
    - Makes these operations very inefficient and disruptive
DoD and aerospace companies are looking for good alternatives to Cd-plated, chromate converted fasteners. Electrical equipment makers want chromate-free fasteners.
Where do military fasteners come from?

- OEMs if they are special design
- Defense Logistics Agency
  - Most standard fasteners bought by DLA
  - Military users then purchase from DLA
  - But DLA will only stock if there is a demand
    - Catch-22
  - Fasteners must make it onto QPL (Qualified Products List)
    - Must meet user requirements and pass qualification testing
  - Users must be convinced new fasteners will work as well as (preferably better than) existing products

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Military and aerospace requirements for non-Cd fasteners

- Corrosion performance at least as good as Cd
- Sacrificial protection - A barrier can always be breached
- No hydrogen embrittlement (high strength alloys)
  - Either not embrittle or can be baked out
- No environmental embrittlement (re-embrittlement) in typical operational and overhaul fluids
  - Sacrificial coating must not dump H into substrate
- No fatigue debit
- Acceptable primer adhesion
- For aircraft must be lighting-strike proof
- Reliable torque-tension, breakaway torque
  - Looks as though can achieve this through Dry Lubes
  - Enormous cost of changing repair manuals if torque changes

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Barriers to change

- Performance qualification
  - Existing technical data on relevant tests
  - Additional testing required for qualification
- Buy-in from different DoD program managers in different services
- Change costs for drawings and contracts

Data Conversion Laboratory has estimated that converting all the manuals for one aircraft carrier alone to CD-ROM would lighten the ship so much it would sit 3 inches higher in the water.

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Moves afoot to develop DoD alternatives

Army TARDEC hopes to change to AlumiPlated fasteners with permanent polymer lubricant to be available through DLA

- Idea is a single solution to avoid confusion

Several SERDP projects to develop/evaluate fastener coatings

(http://www.serdp.org/research/WP-Heavy-Metal-Elimination.cfm)

- Luna Innovations – vacuum-deposited ZnNiCo
- Akzo Nobel – CVD Al
- Integran – pulse plated ZnNi
- PPG – dip spin metal filled polymer basecoat + electrocoat topcoat

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What works?
In engines most fasteners are now corrosion resistant (CRES) alloys such as stainless steels and high strength Ni alloys such as Waspalloys
- Fits very well with other engine alloys (Inconels, etc)

Not an option for Al aircraft skins and airframes
- Serious galvanic corrosion problem
- When used with Al or Mg both high strength and stainless steels are Cd plated

Good options for aircraft airframes are
- Al coatings – IVD or electroplate
- ZnNi electroplates
Getting the Cr\textsuperscript{6+} off Zn

- There are a great many Cr\textsuperscript{3+} and non-Cr passivates for Zn and Al
- Workshop held in Layton, Utah, 2007 to explore chromate alternatives
  - Workshop report available:
    - http://www.asetdefense.org/PastWorkshops.aspx
NEW SOURCE OF INFORMATION

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Quick information on alternatives

ASETSDefense workshop agendas, briefings, summaries
(HCAT meetings coming soon)

Database

Team Work Spaces

Tools to be added
Chromate Conversion Alternatives

Current Usage
Chromate conversion coatings and chromated sealers are used to create a self-healing conversion coating on Al and Mg alloys that is resistant to corrosion. They are also used for sealing electroplated and anodized coatings. These treatments are typically used prior to painting and finishing, since they generally improve adhesion of paints and sealants.

Typical Applications
- Aircraft skins
- AI frames for aircraft and vehicles
- Mg gearboxes
- Corrosion-resistant coatings (Cd, Al, ZnNi, etc.)
- Anodize sealing
- Fasteners and electrical connectors (Zn or Cd plated)
- Wash primer for steels, armor

Typical Chromate Conversion Coatings
- Conversion and sealing coatings for Al (e.g., Alodine, Indite, etc.)
- Conversion and sealing coatings for Mg (e.g., Dow 7, 17, 19, HAE anodize)

Specifications
- MIL-DTL-81706
- MIL-C-8541
- MIL-M-45202
- AMS 3171
- TO 1-1-8
- MIL-A-8625
- MIL-C-3171
- MIL-C-17711
- MIL-M-45202
- DOD-P-15328
- QQ-P-416

ESOH Issues
Cr⁶⁺ (CrVI, hexavalent chromium) is a known carcinogen that is strongly regulated under

- EPA Clean Air Act rules
- OSHA Occupational Exposure to Hexavalent Chromium (Cr⁶⁺ PEL is currently 5μg/m³)
- European rules (RoHS, WEEE, ELV)

Exposure
Personnel may be exposed during manufacture, depot overhaul, repaint, and operational level touch-up and repair.
Surface Engineering Database

This surface engineering database is a relational database that provides documents and data required for making informed decisions on implementation of clean coatings and surface treatments. This database includes the following:

- Reliable engineering data on the performance of clean alternative coatings and surface treatments from DoD and commercial test programs
- Information and data on coating producibility issues, including production methods, grinding and finishing, stripping, non-destructive inspection, etc.
- Information on what specific coatings have been authorized for DoD and commercial use
- Information on coatings that have been implemented by DoD or commercial organizations

This database is continually growing as more documents are added, concentrating initially on coatings that avoid the use of Cr₆⁺. The documents in the database cover alternatives to the following types of coatings:

- Chromate Conversion
- Chromate Primers
- Hard Chromium Plating
- Chrome Acid Anodize (coming soon)
- Chromate Metallic-Ceramics (coming soon)
- Cadmium Plating (under development)
- Chromate Sealants (under development)
- High VOC Materials (under development)

If you are unable to find what you are looking for in the database, please contact asetsdefense@rowantecnology.com. The information you seek may be available but not yet incorporated in the database. We would also like your feedback on the database structure and content so that we can improve the system accordingly and ensure that we are including the documents and data that you require.

To assist our efforts to expand the database, please also contact asetsdefense@rowantecnology.com if you have additional information such as engineering test reports, service evaluations, authorization documents, and information on where clean technologies are currently in use that you believe should be included in the database.

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Looking for info on what approvals and specs exist for Cd and Cr⁶⁺ alternatives and where they are being used.

Search for specific materials, systems, tests, people, organizations
ASETSDefense ’09: Sustainable Surface Engineering for Aerospace and Defense

Denver, September 1-3, 2009

- Aircraft, ships, vehicles
- Alternatives to chromate primers, sealers, conversion coats, low VOC paint systems, hard chrome, Cd plate
- Stackups, hydraulics, fasteners, electrical connectors

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