Surface Technology Innovation and US DoD Strategy

Keith Legg, Rowan Technology Group
NASF Washington Forum
May 2007
Disclaimer

The views presented here are personal, not official DoD policy
All information derived from distribution unlimited, non-ITAR sources
Sources

- Result of two recent DoD/Finishing Industry workshops
  - Metal Finishing Session and Side Meeting, SERDP-ESTCP Partners in Environmental Technology Symposium, November 2006
DoD’s most widely used metal finishes

Chrome plate
Ni – strike, sulfamate
Alloy
Hydraulics, landing gear

Topcoat
Chromated primer
Chromate conversion
Cd plate
Steel

If it moves, salute it. If it wears, chrome plate it. If it corrodes, Cd plate it, chromate it, then paint it.

Aircraft skins, electronic cabinets
Vehicles, hydraulics, fasteners

klegg@rowantecnology.com
Regulatory trends worldwide

From: SERDP/ESTCP Metal Finishing Workshop, May 06. Christian Richter

Growing concerns
- Nanotechnology
- Cobalt
- Zinc
- Other Metals

Already heavily regulated
- Nickel
- Hex Chromium
- Cadmium
- Lead

Next against the wall
- Nickel

Notice: Current regulations hit our current finishes
Future regulations will hit our best alternatives

klegg@rowantechnology.com
Impact of regulations on DoD

- DoD and aerospace exempt from regulations
- But not immune to their effects
  - Weapons system reliability
  - Fewer suppliers of chemicals and processes, higher prices
  - Already seeing these effects in Pb-free solder

- Forcing adoption of modern, more effective technologies that improve performance and workforce health and safety
  - HVOF, Al coatings, CRES alloys, composites

- But, we still have only one periodic table
  - “Green” alternatives are already becoming brown - Zn, Ni, Co, Cr³⁺
  - Need to assure rational approaches that enhance, not impair, our capabilities

F-35 Lightning 2 CTOL first flight Dec 15, 2006

Totally green F-36 Lightning 3 CV carrier landing (circa 2050) Pb, Cd, Cr⁶⁺, Ni, Zn, Co, EHC - free
SERDP and ESTCP have spent a lot on money developing and qualifying metal finishing materials and processes

Where are we now? What remains to be done?

Current state of the art in the Defense sector – OEM and MRO

Emerging regulatory trends – US and overseas

Currently used non-hazardous materials and processes

Barriers to adoption of clean alternatives
  - Performance shortcomings,
  - Cost and other non-technical barriers

Read-ahead papers and briefings
  - Breakouts by application and technology

Materials:
  - Hard chrome
  - Cd
  - Chromates: Conversion coats, pretreats, sealers, anodizing – Not primers
Final Report

- Worked out well, with a lot of detailed information and good discussions
- Final Report
  - Authors: Keith Legg and Christian Richter
  - Available on web
    - Cleared for distribution
    - Link from [www.materialoptions.com](http://www.materialoptions.com)
Alternatives
Materials alternatives or process alternatives?

- Are we looking for alternative materials or processes?
- **Yes!**
- In some cases end product is fine, but the process or effluent is a problem
  - Hard chrome
  - Chromic acid anodize
  - Low Cr$_6^+$ metallic-ceramic (SermeTel) coatings
- In some cases the material is a problem no matter how it is put down
  - Cd plate
    - Still a problem whether electroplated or vacuum evaporated
  - Cr$_6^+$ conversion coatings and primers

**Why do we care so much?**
- Weapons systems must be maintained for many years
  - As long as the system exists, maintainers will be exposed to any nasty materials in it, especially on board ship or at bases that do not have all the manufacturing controls
- Weapons systems must be based all over the world
  - We cannot allow Cd and Cr$_6^+$ and organics to contaminate groundwater
- Weapons systems are sold all over the world
  - Many nations now ban Cd and Cr$_6^+$, Pb, Hg, etc.
Maintenance worker exposure to Cd and Cr$^{6+}$
Engine wash-down

On older engines, wash-down water can be contaminated with Cd from fasteners. Must be captured and cleaned up. **Eliminate the Cd, eliminate the problem**
How can the metal finishing industry and DoD help each other?

- Industrial processes are often very clean
  - To avoid environmental and health issues
  - To be as efficient as possible
  - Many DoD facilities need updating to modern, clean standards

- Commercial materials often meet ESOH rules that do not affect DoD – YET!
  - RoHS, WEEE, ELV rules on Cd, Pb, Hg, Cr\textsuperscript{6+}
  - DoD is exempt now, but for how long?
  - Weapons systems sold all over the world must meet local ESOH regs
  - Need to transition COTS products to DoD primes and contractors

- DoD funds a lot of R&D on new treatments and generates a lot of performance data
Hard chrome alternatives

Thermal spray
- HVOF carbides
- Plasma spray
- Cold spray
- Other alloys, composites

Aqueous electroless, electroplates
- Electro-, Electroless Ni
- nCo-P electroplate
- Trivalent Cr

Vacuum coatings
- Post magnetron sputtering
- Other sputter, arc coatings
- Hollow cathode
- CVD

Weld coatings
- Electrospark deposition
- Explosive cladding
- Laser cladding

Heat treatments
- Plasma and gas nitriding

klegg@rowantecnology.com
Hard chrome alternative adoption in DoD

Alternatives adopted
- HVOF WC-CoCr now specified for all new Landing Gear programs, many aircraft hydraulics
- HVOF baselined for JSF (all)
- Electroplated nCo-P promising for IDs and TDC alternative
- OO-ALC major project to replace EHC with HVOF across depot
- NADEPs JAX and CP use HVOF for engine parts
- WR-ALC, OC-ALC beginning to adopt
- New Army vehicles using electroless Ni, Ni-W-B and Ni-W-SiC electroplate
- HVOF Cr$_3$C$_2$-NiCr beginning to be used for commercial hydraulics
- Gun barrels – sputtered Ta nearing production for large caliber

Remaining needs
- Alternatives mostly identified but adoption rate still low
- HVOF spalling still an issue
  - So far looking good for typical 0.003” thick OEM use
  - Need a better powder than WC-CoCr
- IDs still uncertain
- Gun barrels still under development
- Ni likely next against the wall, so Ni alternatives are only an interim solution
Major plating issues for DoD and aerospace

Critical issues for DoD:
• Most high strength alloys cannot go above 375°F
• Must not embrittle high strength steel
• Must not impair fatigue
Cd alternatives

Vacuum and spray Al
  - IVD Al (vacuum)
  - Sputtered Al
  - Arc and flame spray Al, Al-Zn
  - Cold spray Al and alloys

Aqueous electroplates
  - Acid and alkaline Zn-Ni
  - Sn-Zn
  - Electroplasma Zn-Al

Non-aqueous electroplates
  - Electroplated Al (AlumiPlate)

Alternative alloys
  - Titanium alloys
  - High strength stainless steels
  - Ultra-high strength CRES

Niche products
  - Metallic-ceramic coatings
  - Al- and Zn-filled polymers
  - CVD Al coatings

- Most industries have long since eliminated Cd
- Cd is still the primary corrosion coating for steels and fasteners in DoD and aerospace
US Army corrosion test
Cd alternatives

**Alternatives adopted**
- Stryker has no Cd plated hardware or fasteners
- F35 uses CRES fasteners, AlumiPlated steel or composite elec. Connectors
- IVD-Al used at OO-ALC, CCAD, NADEPs JAX, NI, CP
- F-35 likely to replace LG Cd with AlumiPlate
- Metallic-ceramic (SermeTels) esp. on F-22 LG etc
- Carmakers use Zn-Ni and similar alloys

**Remaining needs**
- HSS fasteners
  - Everyone’s problem, no-one’s responsibility
  - Carmakers use Al/Zn filled ceramic and polymer coatings
  - SERDP has issued RFP for Cd and Cr⁶⁺-free fastener technologies
- LHE alkaline Zn-Ni (Boeing, Dipsol America) test/validation
- Corrosion resistant structural materials (CRES alloys, composites, etc.)
- Cd-free electrical connectors
- Corrosion-erosion resistant coatings
- Brush Cd alternatives
- More options for high density Al coatings

Cd used for protecting steels
Military and aerospace are only remaining coating uses
There are many COTS solutions widely used in industry.

The question is how to qualify those that are viable and find the best solutions where COTS products cannot be used.

Chromate alternatives

- **Al alloys and coatings**
  - Other Cr³⁺
    - Zr (Alodine 5200)
    - Organic (Prekote)
    - Silane (Oxsilan)

- **Zn, galvanize**
  - TCP (various licensees)
    - Permanganate (Sanchem CC3400)
    - Sol-gel organosiloxane, zirconates, Boeing
    - Silicate (EMC)
    - High voltage anodize (Keronite)

- **Mg alloys**
  - Cr⁶⁺ pretreats
    - Inorganic composite (Japanese steel cos)
    - Permanganate (Sanchem CC3400)
    - Phosphate
    - Zn and Al-filled polymers
    - High voltage anodize (Tagnite)

- **Chromate anodize**
  - Cold spray Al
    - Thin film suluric anodize
    - Boric sulfuric anodize
    - High voltage anodize (Keronite, Tagnite)
US Navy corrosion test
Chromate usage

- Chromates (strontium dichromate, zinc chromate, etc.) contain Cr\(^{6+}\) and are used everywhere for corrosion protection and adhesion
  - Conversion coatings and sealers for Al, Mg alloys, Zn, Al, Cd, ZnNi and other corrosion resistant coatings
  - Anodizing, esp. where paint adhesion is essential
  - Primers and bonding primers
  - Fuel tank coatings
  - Wash primers for steels (military vehicles)
  - Metallic-ceramic paints (SermeTels)
  - Passivation of stainless steels

- EU ELV, WEEE, RoHS rules forcing elimination of chromates from galvanized sheet, fasteners, etc.
Cr\textsuperscript{6+} alternatives

**Alternatives adopted**
- Primary alternatives are Cr\textsuperscript{3+} chemistries, Zr, Mn, rare earth inhibitors; also adhesion promoters – silanes, etc.
- NAVAIR TCP (TriChrome Pretreatment) commercially available from several suppliers
  - NAVAIR approved for some Al alloys
- PreKote AF approved for F-16, T-37, T-38
- F-35 Deft non-Cr primer for internal bays
- Many commercial Cr\textsuperscript{3+} options
- Alodine 5200/5700 approved for USMC Expeditionary Fighting Vehicle
- Cr\textsuperscript{3+} on Al road wheels – Army
- NAVAIR approved boric-sulfuric anodization in place of chromic
- Phosphates on steels commercially
- Keronite (for Al) and Tagnite (for Mg) increasingly used as anodize
- Non-Cr or low-Cr metallic-ceramics approved by P&W and others in place of SermeTel W
  - SermeTel, Ceral, Ipcote, Alseal now available

**Remaining needs**
- **Qualify COTS alternatives**
- Fasteners (esp. threaded fasteners)
  - Must have right torque-tension to avoid changing maintenance manuals
  - Must have low volume corrosion products to avoid seizing
- Composites – whole new sets of galvanic corrosion issues
- Chromate alternatives for Mg
- Al electrical boxes and electrical equipment (also coated composite electrical equipment and boxes)
  - Not primed and painted
  - Alternative must work alone and have low electrical resistance
- Technical Database of Surface Finishing Technologies

---

klegg@rowantechnology.com
Getting better technologies adopted
Drivers and barriers to adopting clean alternatives

- Performance is still the strongest driver
- But ESOH regulations are becoming a strong driver as well (especially in commercial products)
- Numerous DoD barriers, including
  - Technical barriers
    - Qualification cost, requirements based on existing technologies
    - Lack of data and specifications
    - Cost of implementation, paperwork and drawing changes
  - Cultural barriers
    - Inadequate depot engineering staffing, lack of management support
    - Lack of specific requirements – policies largely ignored
    - DoD contracts tend to incentivize cost reduction, which disincentivizes implementing new technologies
How can we overcome the barriers to technology adoption?

- **Knowledge**
  - What do we really need?
  - What already exists that we can use?
    - DoD, the commercial world, other countries

- **Experience**
  - What works where?
  - What do others use successfully?
  - What performance and service information is available?
    - Just as important to know what does not work as what does

- **Data**
  - To make good, solid engineering decisions we need good, solid engineering data, and we need it readily available
www.hazmat-alternatives.com

Portal for information on alternatives, regulations, etc., with links to other locations. Includes databases, on-line tools. Surface Engineering Database to be added over coming year as resources available.
Coming up – Chromates Workshop, May 16, 17, Ogden, UT

Workshop will bring together DoD and industry engineers to work out what products are available and what will work best where

DoD Metal Finishing Workshop – Chromate Alternatives for Metal Treatment and Sealing

May 16, 17, 2007
Tour of Ogden Air Logistics Center, Hill AFB, afternoon of May 15
Hilton Garden Inn / Davis Conference Center, Layton, UT

klegg@rowantech.com
Summary

- DoD still uses materials and processes that industry has largely moved away from
- But DoD is developing new technologies and adopting alternatives
- Biggest issue is qualification
- Biggest hurdle to adopting COTS technologies is lack of acceptable data
  - We are putting together and engineering database of coatings and surface treatments to try to remedy this
  - To do this we are hoping to pull together data from DoD projects and commercial data and create an Engineering Database of metal finishing processes

*We are developing all this good stuff – let’s get it used!*
- Info on regulations, including EU rules
- Publicly released reports and briefings
- **Surface Engineering Database under construction**
  - Will contain data as downloadable Excel files, reports, including rig test and service experience
  - Include sources
  - Password protected

www.hazmat-alternatives.com