

Synopsis from RDECOM Metal Finishing Workshop April 2006
POC: John Beatty, Army Research Lab, jbeatty@arl.army.mil

Current Use of Chrome, Cadmium, Nickel and Hexavalent Chromium Metal Finishing Treatment Processes for Ground Vehicles

The present DoD fleet of tactical and combat vehicles consists of approximately 300,000 pieces, and much of the fleet is at least 20 years old. The majority of vehicles are made of low carbon steel, plain or galvanized. Additional important substrates include RHA (Rolled homogenous armor), high-hard steel armor, aluminum armor, composites, ceramic armor and some titanium components. Future vehicles will emphasize high strength steels, high strength aluminum alloys, lightweight composite armor and greater use of titanium and magnesium alloys. Cadmium (electroplated and vacuum deposited) is used on fasteners, small steel components, and electrical connectors. Electroplated hard chrome (HC) is used on hydraulic cylinders and rods, crankshafts, and some engine parts. It is also used in the turbine engines used in the M1 Abrams main battle tank.

Hexavalent chrome (Cr+6) pretreatments are applied as dichromate rinses, chromate conversion coatings, and organic wash primers. The dichromate rinses are used on plated fasteners, including Cd, Zn, and Zn-Ni plated fasteners. Chromate rinses are also used after Zinc Phosphate and anodizing surface treatments. Chromate Conversion Coatings (CCCs) are used as a pretreatment for a wide variety of electrical/electronic boxes on Army ground vehicles, as well as on structural aluminum components.



Bradley Fighting Vehicle
photo courtesy DoD Defenselink

Current Processes

Army metal plating and surface finishing technology processes related to automotive applications are at OEMs and depots (e.g. Anniston and Red River). These processes include metal plating operations such as chrome, cadmium, and strike solutions of copper and nickel. Aluminum finishing uses mainly anodizing, chromate conversion coatings,

and chromate rinses. Even after the use of a non-chromate process (i.e., sulfuric acid anodizing) often a sodium dichromate sealer is used. Zinc phosphate (spray and dip) pretreatments are used on ferrous substrates to promote corrosion resistance (chromium, cobalt and nickel additives). Alkaline cyanide baths are used for plating cadmium. Standard Alodine 1200 processing is used for CCCs.

Most Important Performance Requirements for Processes Used

HC – wear resistance, “rebuildability”, complex non-line of sight parts

Cd - only slight underpotential relative to UHS steels (avoids hydrogen assisted cracking), lubricity, benign nature of corrosion products

Cr+6 – corrosion protection, ease of use, conductivity, color identification, improves processing tolerances

Other aspects - throughput, process robustness, thickness of coating, coating uniformity, wear, metallurgical bond, fatigue life, torsion strength, tensile strength, and surface condition prior to painting and bonding.

Important Specifications, Standards, and Qualification Requirements

These include MIL-C-5541 (aluminum finishing), MIL-A-8625 (anodic coatings for aluminum and aluminum alloys), TT-C-490 (zinc phosphate); QQ-P-416 (typical requirements for cadmium), MIL-C-8837 (vacuum deposited cadmium); ASTM B633 (chromate conversion/zinc phosphate coatings); ASTM B656/ASTM B689 (nickel coatings), ASTM D522/D4145 (adhesion tests), MIL-STD-1500 (cadmium, titanium); MIL-STD-810 (environmental testing); ASTM A153, ASTM B840 (zinc-cobalt), ASTM 841 (zinc-nickel).

Change Drivers

The largest volumes and most serious pollution problems are associated with chromate conversion coatings, chromic acid anodizing of aluminum alloys and zinc phosphating of high strength steels. The Army is concerned with the high costs of compliance. OSHA has issued a new rule decreasing the PEL for hexavalent chrome (all Cr (VI) compounds from 52 to 5 micrograms per cubic meter of air as an 8-hour TWA to reduce worker exposure to mists and particulates. Also, in July 06, the European Union will be banning the use of cadmium and hexavalent chrome in electrical and electronic components. California has already banned the use of cadmium in coatings on automotive components. Army procurement policy for large systems (Stryker) now requires waivers for the use of hexavalent chrome or cadmium for each part. It is anticipated that future significant procurements will be at least as strict.



Stryker Infantry Armored Vehicle

photo courtesy DoD DEFENSLINK

Replacement Priorities

Highest priorities for ground vehicles are cadmium and hexavalent chromium. High strength fasteners are the most prevalent use of Cd. Use of CCCs on electrical boxes and chromate rinses on fasteners are also very prevalent.

Barriers to Adopting Clean Alternatives

Many of the Army systems are older or “legacy” systems. Technical manual changes are expensive, and there is less pressure for change on these systems unless a statutory issue is involved. Additionally, much of the hardware is purchased for multiple customers, both for the Army and for industry, and this complicates implementing incremental changes across the fleet.



One variant of the Family of Medium Tactical Vehicles (FMTV)

Photo courtesy Army Images

New ground vehicle systems are purchased to performance specifications. The Army specifies outcomes, not processes. In the absence of statutory prohibitions, often Cd, HC and Cr+6 will continue to be used, as there is a need for buy-in from commercial

contractors. The ease of technology entry is greatly improved, if new technology is accepted by commercial ground vehicle manufacturers and the commercial automotive industry.



High Mobility Multipurpose Wheeled Vehicle (HMMWV) and the Heavy Expanded Mobility Tactical Truck (HEMTT). Photos courtesy Army Images

There are concerns about the resulting levels of performance with alternatives. Concerns for Army depots include *capital costs* and *process versatility* to plate a multiplicity of parts.

Alternatives Already Adopted

Cd- The use of Zn, Zn-Ni and other Zn-based plating processes to replace Cd on medium to low strength steels has made significant inroads into the use of Cd on steel fasteners. Additionally, Ion Vapor Deposition (IVD) of aluminum has also replaced cadmium plating on some higher strength steel substrates. However, IVD Al is not in widespread use on ground vehicles. Cd remains the coating of choice for high strength fasteners.

HC – Some HC replacement has been achieved through the use of electroless nickel, nickel-tungsten boron and nickel-tungsten silicon carbide composites. HVOF coatings of tungsten carbide/cobalt coating on M1 Tank GTE components (compressor bearing housing) have replaced HC at some Army depots. Additionally, other wear resistance materials have replaced HC in many engine applications.

Cr+6 – Both OEMs and depots have stopped treating more corrosion resistant armor alloys with CCCs. These alloys are now often grit blasted to produce a high surface profile, and then primed and painted with no conversion coating. The Army and Navy have tested non-hexavalent chromate conversion coatings on 5083 and 7079 (the most common Al armor alloys) with good success, but those these processes are not yet in widespread use at Army OEMs or depots. The use of non-chromate alternatives on aluminum roadwheels has also been implemented. Cr+6 “wash primer” has also been eliminated on some high-hard steel vehicles, again substituting increased surface profiling and tighter processing controls.

The use of chromate seals on Zn phosphate is no longer required by the relevant CARC application specifications. A DI water rinse may be substituted.

Uses that are Particularly Difficult to Change

The use of chromate conversion coating on aluminum electronics casings/housings is particularly difficult, as adequate corrosion protection and electrical conductivity requirements must be met simultaneously. These parts are not primed and painted, but used in the CCC treated condition.

Elimination of Cr+6 chromate rinses on Cd and Zn plated fasteners on legacy equipment may often require both specification and technical manual changes. Because of the large numbers of these in use on different platforms, they cannot be easily changed in a piecemeal fashion. Color indicators (as now provided by Cr+6 rinses) are also a desired feature.

Where Changes Could Be Made Easily

Several Commercial Off-The Shelf pretreatment systems can replace CCCs on aluminum alloys, (with the possible exception of 2XXX series alloys) with very good corrosion protection. The use of 2XXX Aluminum alloys on ground vehicles is not common, although the US Marine Corps EFV is currently using 2519 Al Armor. The DoD could continue to facilitate the use of Cr+6 alternatives to CCCs on non-2XXX Al alloys with little risk.

Elimination of chromate rinses on fasteners. The US auto industry, largely in response to European Union regulations, has virtually eliminated Cd and Cr+6 from their vehicles. The US Army and US Marine Corps can adopt many of these processes for their ground vehicles. Again specifications, commercial items descriptions, and performance requirements would be needed.

RDT&E Challenges

Sacrificial coatings – UHS steels cannot utilize Zn-based coatings. Aluminum based coatings produce very abrasive corrosion products.

Alternative Fastener Materials – Use of steels for fasteners that would not require coatings. Biggest challenge in this area is cost, as these applications are usually very low cost items. Life cycle analysis might allow for higher priced fasteners to be specified.

Improved easy to apply pretreatment processes for aluminum and steel – While CCCs have been eliminated from some processes, we are now relying on strict process controls

to gain acceptable corrosion performance of the final products. Many vendors are resistant to using Zn phosphate on steel (capital and process issues), and the reduced usage of the MIL-P-15328 wash primer with Cr+6 has increased the need for easy to apply pretreatments. Preferably, these pretreatments would not require additional capital equipment, and could be applied by painters after proper surface preparation with little or no changes to the current process lines. The pretreatments would have to be compatible with a broad range of MILSPEC coatings, and meet upcoming NESHAP regulations for Defense Land Systems and Miscellaneous Equipment (DLSME).