

## Breakout Session 4

### *“Gun Barrels and Small Components.”*

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\*Note: This meeting largely focused on fasteners. Gun barrels are discussed in Mr. Mike Audino’s white paper on the same subject.

### ***Gun Barrels***

#### **Current Usage**

- Chrome is used in guns for rebuild procedures.
- Mainly used on breeches, mounts, and barrels.

#### **Requirements for a New Coating Material**

- Compatibility of material with substrate.
- Development of hotter propellant.
- Need for a crack-free process.
- Large-caliber gun: 1500-round life for LOS.

#### **Barriers**

- OEM needs a reason to investigate alternatives for medium-caliber weapons, which have different production and purchasing than large-caliber weapons (which are all commissioned and purchased by the government).
- Adhesion problems at various temperatures pose a challenge.

#### **Options**

- Sputtering:
  - o Greater cleanliness before deposition increases the gun life.
  - o Post-treatment diffuses a coat onto the substrate.
- Cladding:
  - o Surface hardness for ammo an issue, to be discussed in upcoming evaluations.

#### **Notes**

- Exposure confined to an enclosed environment where gun barrel chrome lining occurs.

### ***Small Parts: Fasteners, Electrical Connectors, etc.***

## **Current Usage: Cd, Cr, Ni, Cr(6+)**

### *Navy*

The U.S. Navy uses cadmium/chromium(6) as well as zinc coating for general use steel fasteners on almost all of its ships, which were designed in 1960 or earlier and are made of up steel because of its low cost. There are over a million fasteners on a ship. In contrast with Air Force fasteners, which are designed based on the load specification required, Navy fasteners are designed for war-loading. Very few safety precautions are taken when maintenance work is done. For example, materials are not collected.

The Navy's perspective on coatings is that if the fastener is important, it must use an inherently corrosion-resistant material; thus, cadmium and chromium plating are a big problem for Navy. The leadership at Navy is extremely resistant to making any changes to this, and this is not likely to change any time soon. Aluminum vehicles use cadmium and chromium post-treatment; chromium(3) has been explored but was found to be inferior.

Every gun system has chrome lining, particularly in the chamber and sometimes in the bore

### *Army: Aviation and Ground Equipment*

Currently, most weapons systems contain plated fasteners, although the Army is moving forward with examining options other than cadmium, which it uses for profile threading and sacrificial corrosivity inhibition. It conducted some field demos with other electroplating processes, but has not found a technology that performs better. Cadmium in fasteners does not fit the definition of hazardous waste, so environmental reasons are not the main drivers for change. However, there is some concern that cadmium is leaking during maintenance. The Army uses general use specs built around cadmium plating as well as zinc plating. It is switching to zinc-nickel through its spares program.

The DLA would like to get new parts—particularly fasteners—into the supply chain. Concerns about performance involve the effect of different coating on torque tension. Two options that show promise are the Magni top-coat in black or silver. A lab ran an unofficial test of these, and one resulted in no rust. Other potential options include luzimite, tie-dyes, and nylon powder. Zinc-nickel plating with cadmium post-stress treatment has also been considered for fasteners, as well as for electrical connectors, although for the latter this requires nickel strike underneath and a chromate post-treatment (thus defeating the purpose of using this alternative).

### *Marine Corps*

Magni was one of the better options when testing fasteners in amphibious vehicles.

## Requirements for a New Coating Material

- Only corrosion resistance at least as good as that currently used.
- Thread lubricity is equivalent to the current treatment used, unless a secondary treatment is added.
- Coating is no thicker than the current treatment. Cannot put fasteners together if the coating is too thick.
- Treatment is adhesive enough and will not split during use, such as contact with a wrench.
- Can be as easily painted as the current treatment in use.
- Need to develop research requirements based on usage needs, fastener-specific properties.
- Process accommodates complex shapes.
- Need something that can be bulk-processed.
- A major issue is **in-service brittlement**, particularly in flight-critical or mission-critical operations.

## Drivers and Barriers for Development

### *Drivers*

- Due to new OSHA requirements, the use of chromium(6) and cadmium is diminishing, and these coatings will be less available in the future.
- Regulation by the EU and desire by manufacturers to meet requirements for European customers. Companies may also wish to minimize errors caused by the confusion of having two coating systems and products that may not be easily distinguished. They want a single product line.
- The auto and electronics industries are getting rid of cadmium/hex-chromium processes; there is pressure on the electroplating industry to do this same.
- Cadmium plating no longer as cheap → incentive for developing alternatives.
- Very expensive to treat cadmium in wastewater.
- Developing longer-lasting, corrosion-resistant fasteners could save the Navy money.

### *Barriers*

- **Specifications and Entrenched Technology**
  - Fasteners are highly engineered, and their engineering is built into the Navy's specifications for them. Thus, to review or change its specifications for fasteners, Navy would have to address all the engineering issues surrounding fasteners.
  - It is very difficult to make changes on "legacy" technology vehicles.
- **Lack of Data**
  - There is very little data on the risks of cadmium exposures, such as during regular maintenance activities on Navy ships that go undocumented and

that are performed by sailors without safety glasses or other protective equipment.

- Existing research is targeted at commercial industry, not the military.

- **Problem Very Large, Diffuse Across Services and Jurisdictions**

- The different services have different needs for fasteners. The Army views them as more of an expendable resource, while the Navy does not because the fastener provides the primary connection between equipment and the ship and must be designed not to fail under wartime loading. Thus, fasteners are often over-designed for Navy. For Air Force, fasteners are designed based on different loading needs.
- Because the Navy operates beyond 12 miles of national borders, environmental regulations do not apply except when its ships are docking.

- **Existing Options Not Optimal**

- Zinc materials do not interact well in a saltwater environment; zinc also does not have a lot of tolerance for extreme temperatures.
- There are very few materials available that are inherently corrosion resistant, which is a deal-breaker for Navy now, according to current policy. Cadmium is still used in Europe for high-stress steel used by the military because of the lack of options. Similarly, the U.S. Navy relies on cadmium for its lubricity; it is very hard to find something better.

- **Funding and Cost**

- There is a lack of resources to help personnel select appropriate alternatives.
- For electrical connectors; use of free chromium coating as an option is hugely expensive and not as attractive as chromium(6).
- Even though the cost of chromium and cadmium will increase as they become less available, the costs to changing designs are unknown (and probably high).
- There is a lack of incentive among shipbuilders to invest in alternative plating that, while more expensive, has lower life cycle costs because of their higher durability. Rather, need to target marketing alternatives toward the benefits of alternatives after buying a ship—reduced maintenance.

- **Lack of Collaboration and Stakeholder Buy-in**

- Fasteners are “everyone’s problem, no one’s responsibility.”
- Difficult to get squadron skippers down the line to institute change on their ship; similar situation with commander of aircraft.
- There are more than 50 organizations worldwide with many engineers, and there is no vehicle for information-sharing on fastener coating innovations.
- Rotation of top-level staff (admirals, generals) poses a barrier to innovation. For alternatives to be adopted, several consecutive top-level leaders will need to take interest in the long-term and enforce consistency across the service, particularly at Navy, where the current policy is against most alternatives.

- Even where an alternative is specified in a contract, project managers disregard and go with cadmium coating anyway.
- Need for legislative mandate to push for adoption/development of alternatives.

### *Existing Research/Options*

- A Triservice Joint Research Protocol was initiated looking at a number of cadmium alternatives for fasteners, connectors, and springs. However, this research is on hiatus and needs to be continued.
- The commercial automotive industry widely uses zinc-based alloys with a chromium(3) post-treatment instead of cadmium, which is fairly standard in the industry. However, this treatment does not meet military standards because there is too much potential for breakage.
- Current research in progress in the Army is targeted at developing an alternative coating for high stress steel through a process where hydrogen can be baked out to prevent in-service embrittlement. Phase I testing with salt water, propylene glycol, and ionized water went well. Of the options tested, only zinc-nickel was found to do well, although uncertainty remains about lubricity and torque tension. Corrosion is prevented more with increased proportion of nickel, but higher nickel amounts make post-treatment more difficult.
- Sputtering is a possibility for non-composite material, but is not good for complex geometrics.

### **Adoption of Alternatives**

- Army's F35 fighter program: may not to use cadmium or chromium without a mandate. The contractor (Lockheed Martin) must look at alternatives (Ni, Zn-Ni, Teflon, alumiplate, etc.). Lockheed tested alumiplate, which performed well in laboratory test. Composite connectors did very well in salt fog tests. Alumiplate is very expensive.
- The Navy buys a ship to be completed in 20 years: there is not a lot of leverage to buy new technologies because of legacy technologies.
- Army makes changes during maintenance. (Cannot do this with a ship.)
- B-52 Aircraft is similarly based on legacy technology; it is difficult to institute change.
- The DLA (DoD's main custodian of specifications) has the authority to make specification changes without input from engineers if coating is developed.
- Most specification bodies are very slow to make changes. ASTM not as slow as others.
- Gun Barrel research making good progress. There is stakeholder buy-in and is easier to resolve because coating is an enclosed operation.

### **Remaining Needs**

- Need for a set-down mandate requiring a set of precautions to be taken by anyone who could be exposed to cad./chrom., especially at shipyards (wear safety gear, use a respirator, clean up chemicals, etc.).
- There is a large lack of data on alternative coatings. Need for baseline sample of data with cadmium and chromium. Can then test a lot of alternative coatings for fasteners and connectors.
- Need exposure data for people making, installing, maintaining, and removing fasteners. (i.e., switching a fastener in the field)
- Work on finalizing JTP: develop a test plan, conduct testing, and analyze results.
- Because there is no “one-size-fits-all” solution to coating, need to be smarter in selecting the right material for connectors based on needs. Determine these needs and functions (including loading and torque requirements) to educate designers which develop coatings.
- Need to present this issue in terms of cost savings and its benefits in reducing corrosion. Convince services that cadmium coating is diminishing and that there is a need for a replacement. Make the business case for fasteners.
- Among aviation personnel, there is a need to find a driver for technology adoption, as U.S. regulations are not sufficient to drive change. There is a need for a cost-benefit analysis of adoption that not only measures the costs of using cadmium/chromium(6), but also describes the costs of *not* using alternatives. (e.g., Cost to human health—mortality/morbidity due to hazardous cadmium or chromium exposure.)
- Need for a general program across DoD. Existing programs under F35 and Stryker to develop cadmium alternatives are designed for these specific programs.

## Comments

- Sputtering, similar to sputtering on drill bits, may be a very cost-effective alternative for fastener coating. This has been researched, but not thoroughly.
- Zinc plating not good enough for HSS because of steel cracking.