Choosing a Cadmium Plate Alternative

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Cadmium plating

Cadmium is a sacrificial coating – i.e. in a corrosive environment the cadmium corrodes preferentially, leaving the underlying steel intact. Even when scratched, the surrounding coating still protects the exposed steel. The only coating materials that have this property are the electronegative elements – Cd, Zn, Al (Mg and Be as well, but we do not use those as coatings). You can replace Cd with a barrier coating such as Ni or a polymer, but once it is scratched the protection is lost.

Cd plating is forbidden under the European RoHS, ELV and WEEE rules and restricted under REACH, and it is a worker and consumer exposure problem as well as an environmental contamination problem. It used to be used for fasteners in cars and outdoor applications such as decks, as well as for metal items used outside such as padlocks. Now Cd has been replaced in almost most of these applications as well.

It is still permitted as a corrosion resistant coating for aircraft and military components, applications that are currently exempt from the rule. However, since there are a growing number of alternatives, some of which are proving to have as good or better performance, it is unlikely that this exemption will last more than a few more years.

Alternatives to Cd plating

There are a number of Cd plating alternatives now available, but which is right for a particular application depends on the details of what the Cd is being used for and therefore what are the critical properties that the alternative must have.

ZnNi electroplating

In order to meet the ELV regulations the automotive industry has replaced most Cd plating on nuts and bolts with ZnNi electroplates. At the beginning of the use electroplates generally contained about 8% Ni. In recent years manufacturers have gone over to a 14 to 16% Ni formulation deposited from an alkaline plating bath, which provides better performance.

The aircraft industry has also used an acid Zn-8%Ni formulation (Boeing ZnNi) for many years, although it has not been widely used because it causes embrittlement in high-strength steels. The Zn-(12-16%)Ni formulation also embrittles high-strength steels. However, the aircraft industry found that this problem can be overcome by removing most of the brighteners from the automotive formulation. This is led to the development of low hydrogen embrittlement (LHE) ZnNi for the aircraft industry. This formulation has now been qualified at Hill AFB for repair of USAF aircraft landing gear, and is being put into use at Boeing, Airbus and other aircraft and aircraft component OEMs as an alternative to Cd plate on components and fasteners.

A number of other alloy electroplates have been either investigated or used in a limited way, including AlMn, SnZn and some ternary alloys. None of the these has become widely accepted for various reasons.

Aluminum electroplating

Although Al cannot be plated from the standard aqueous bath, it can be deposited from an organic (toluene) bath provided air is excluded. This makes it much more capital-intensive to set up than a standard electroplate. Aluminum deposited in this way has very good performance, and is in many ways the best alternative to cadmium. However, it is only available in the US from AlumiPlate in Minneapolis.

IVD Aluminum

IVD aluminum (Ion Vapor Deposited Aluminum, of Ivadizing) was developed by McDonnell Douglas Aircraft and has been in use for aircraft for many years. It is a vacuum process and does not cause embrittlement – hence it can be used on high strength steels. As-deposited IVD coatings are soemwhat porous, and have to be glass bead peened for acceptable performance, and as an adhesion check. Both equipment and coating services are available commercially. Because this is a vacuum deposition method, it is significantly more expensive than Cd plating. There are a number of vendors for this process.

Chamber for IVD aluminum (also known as an Ivadizer)

Aluminum arc or cold spray

Al can be sprayed onto surfaces using an arc or flame spray gun, or cold spray system. Flame spray aluminum has been used on one or two aircraft landing gear for many years. Boeing has demonstrated that this is an excellent way of repairing ZnNi coatings, for example, while the U.S. Army has demonstrated that one can repair magnesium gearboxes by cold spray with aluminum alloys.

Zn-or Al-filled polymer and ceramic coatings

In the automotive industry many fasteners are now coated with polymer coatings filled with Al and/or Zn flakes. These coatings have been found to be one of the best options for threaded fasteners because they provide both sacrificial corrosion protection in the basecoat, and lubricity in the topcoat.

Zn-rich primers on a being used on some vehicles, including the hulls of some military vehicles. While these are not cadmium replacements, they do operate in a very similar way to the metal-filled polymers.

Electroless nickel-PTFE for electrical connectors

As one might notice from the galvanic table above, Ni is not a sacrificial coating – in fact it is one of the most noble materials that one can use as a coating. However, electrical connectors represent a very special case because they must have very low contact resistance before and after being subjected to corrosion conditions. It is been found that EN-PTFE meets all of the requirements for conductivity and lubricity, and it does provide corrosion protection, although that protection is barrier layer not sacrificial. A number of electrical connector manufacturers now offer this option.

This is not an option that one would use for cadmium replacement on most components such as fasteners and aircraft parts.

Metallic-ceramic coatings

Thse coatings (often known by the trade name SemeTel) are filled with Al flake and are often used in the aircraft industry for their combination of abrasion and corrosion resistance. They must be heat treated (typically to 375-700°F, 700-1,300°C), although some can be air-cured or cured at low temperature for use on high strength steels. They used to be very expensive as they could only be applied by one company, but there are now various vendors of the materials as well as the process.

Stainless steels and other Corrosion Resistant (CRES) alloys

Corrosion resistant alloys, such as stainless steels and titanium, are being used increasingly in place of Cd plated steel, and there are now many of these on the market with a range of properties. In addition to the standard low strength 300 series austenitic stainless steels, and higher strength stainless steels used for fasteners, there are a number of high strength stainless steels that are typically used in the aerospace industry. The most common of these are the precipitation hardened 15-5PH, 17-4PH and 13-8Mo, and a newly developed alloy, S53 (available commercially from Cartech and other producers) that has the strength of high strength aerospace landing gear steels such as 300M and 4340, but has good corrosion resistance and therefore does not usually require the use of Cd plating.

The increased use of C-fiber composites for aircraft skins is leading to increased use of CRES alloys (especially Ti alloys) for fasteners because they are galvanically compatible with the C. Most GTEs now use CRES fasteners because they are compatible with Ni alloys used throughout the engine. Many Al-skinned aircraft now use high strength Al fasteners to connect the skin to the frame.

S53 High Strength Stainless Steel Forging