Metal Coatings

by Guy Avellon

The original use of a metallic coating was to enhance the appearance of the part it was covering. Such was the use of silver, gold, nickel, chromium and copper. Then it was learned that certain coatings also protected the base metals from atmospheric corrosion; some better than others and by different means.

All steel fasteners have some type of protective coating on them, if even it is only a thin film of oil to protect the bare steel in shipping or in transition to become coated by another process. This is generally identified by the words 'as received'.

Today, there are a variety of coatings that will enhance the part's appearance, improve its corrosion resistance or control the torque-tension resistance during assembly.

Zinc

This is a metal that provides a sacrificial barrier between the substrate (bare metal part) and atmospheric corrosion. In other words, it will corrode first, thereby protecting the steel part. It is applied to fasteners in several ways; hot dip, mechanical deposition, electroplated or by chemical conversion. When corrosion begins, it will produce a white corrosion product.

Hot Dip Galvanizing

During this process, parts are dragged through a bath of molten zinc. Since the temperatures are over 800°F (427° C) for the molten zinc, it would greatly affect the tempering temperature of a Grade 8 fastener more than a Grade 5. Therefore, this process is limited to structural A325 (F3125), A307, dome head bolts and transmission tower bolts, as well as a variety of pipe and iron flanges.

The A325 structural fastener is allowed the hot dip galvanizing per ASTM B695, Class 55. No other fasteners with higher tensile strengths greater than 125 ksi may have a HDG coating. When applied to nuts, the threads are tapped after coating.

Coating thicknesses are very thick; from 10 to 30 times that of an electroplated zinc fastener. Averaging over 0.005 inches its corrosion protection is extremely good in outdoor use by virtue of its heavy thickness. See ASTM F2329.

Mechanical Zinc Galvanizing

This is another process that produces a heavy coating but without high temperatures. Because it is a mechanical process using slurry of zinc metal flakes being impinged onto the parts by glass or metal beads, there is nothing in the process to promote hydrogen embrittlement. Thicknesses can be controlled and vary from 0.0003" to 0.005". The resultant finish will be a dull matte or hammer tone metallic zinc.

This process is used extensively for hardened flat washers to prevent hydrogen assisted cracking. However, it has not been qualified for ASTM A490/490M (F3125/F3125M) structural bolts.

Chemical Conversions

These are also called phosphate coatings and are the only coating that will actually react and combine with the substrate. Dissolved metal ions of zinc, iron and manganese are chemically bonded to the surface of the steel. Typically, thin conversion coatings are used on office furniture, etc. as it is an excellent base coat for paint.

When used on fasteners, higher thicknesses will determine the corrosion resistance of the coating. Heavy zinc phosphate coatings in the range of 1,000 to 3,000 mg. /sq. ft. will provide salt spray corrosion test results from 96 to 400 hours. This depends upon the type of sealer used, such as oil or wax.

Electrodeposited Zinc

Typically, electroplated zinc ranges in thickness from 0.00015 to 0.0003", the median being 0.0002" (5μ). Salt spray tests per ASTM B117 will show some form of corrosion product on unprotected zinc within 24 hours. This will be in the form of red rust.

This is why many zinc coatings receive a supplemental chromate dip, which can be clear or colored. These dips act as a sealer to counter any porosity of the zinc deposit and enhance the corrosion resistance. Therefore, white zinc corrosion product will first appear after 36 hours.

The chromic acid dip can have additives which provide color as well as a thicker film. Naturally, the thicker film provides the greater resistance to corrosion. Commonly used treatments applied hexavalent chromium or trivalent. The hexavalent chromium is thicker but was found to have harmful effects on the environment and public health and has been discontinued for general use. With a colored conversion coating, the red rust resistance is pushed up to 96 hours.

To comply with the EPA and RoHS requirements, trivalent chromium has been replacing the hexavalent chromium for all plated parts. The color of the trivalent parts is not as iridescent as the hexavalent chromium. It produces a more muted yellow color than bright. The corrosion protection is slightly less and the varying surface finishes can disrupt consistent torque-tension relationships. Most of all fastener products are zinc electroplated.

Nut Thickness

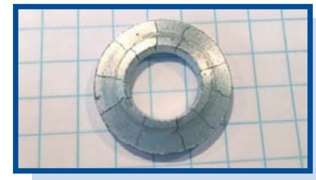
Many specifications require that the nut's thickness should be the same as the fastener. This is unnecessary. For one, it will create thread fit problems. Electroplating creates a 'Christmas tree' effect at the thread crests of the externally threaded fastener. This is a combination of the current density of the electrolyte and the geometry of the part. The crest being closest to the anode, or metal source.

The nut will have similar problems, only the plating will build up at the outside of the first thread. Since plating baths have relatively low 'throwing power', the inside threads will receive little plating deposit. But remember, they mate with their male counterparts who will provide sufficient protection when tightened. Consider hot dipped nuts. They are all tapped after coating and have essentially bare threads. When thread fit problems exist, it is better to reduce the thickness on the nut.

Cadmium

Though basically banned as a carcinogenic substance by RoHS and EPA, products from the Pacific Rim have been known to still be plated with cadmium. Specifically, all-metal prevailing torque lock nuts. Unlike zinc, cadmium does not sacrifice itself but produces a dense barrier layer protecting the substrate. Hexavalent yellow chromate was used to identify cadmium because untreated zinc and cadmium both appeared to be silver in color. Dipped in wax, this coating produced extremely consistent torque values. Corrosion resistance was over 400 hours.

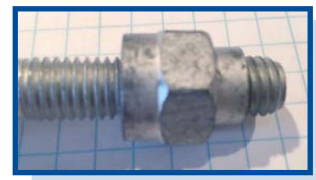
Hydrogen Embrittlement



Hydrogen Embrittlement (HEMB) is a delayed fracture phenomenon that occurs due to the absorption of hydrogen ions from the metal finishing process. This can be induced from the ion exchange during the electrolysis process, cleaning process or chromic acid dip process. Some will contend that some hydrogen absorption can come from the bolt manufacturing process. In any event, strides have been made to assure parts are free from hydrogen embrittlement. For one, zinc plating was changed from having a cyanide electrolyte to an alkaline or acid bath which is far more efficient and therefore produces less hydrogen at the cathode, the part. The metal deposits also have less porosity. It has been standard practice to bake plated parts whose hardness exceeds Rockwell 38 in hardness. Baking is done at 400°F, ± 25°F for four hours, as originally set by Federal Standard QQ-Z-325 and since updated. This method has shown to provide some relief but is not an absolute.

Because the zinc-cyanide deposits were so porous, baking worked relatively well. The chromate conversion coating sealed the porosity. However, with the more efficient non-cyanide deposits, there is less opportunity for the hydrogen to escape. This is why extended baking times are recommended for highly susceptible and critical parts.

Organic Coatings



These are called dip-and-spin coatings and were being developed in the mid-1980s. There was great difficulty with controlling the thicknesses. Now, thicknesses are being applied in layers with different metallic coatings. The organic coatings have had tremendous success with applications in automotive OEM and military parts. Some are now finding many MRO applications. Basically, coatings are impregnated with metallic particles, such as zinc and aluminum. Top coatings over the metallic rich coatings have further enhanced the corrosion resistance. Salt spray tests range from a low of 500 hours to well over 1,000 hours, depending upon the layers and several treatment options. Two such specifications are in ASTM F1136 and F2833 standards, which describe zinc and aluminum organic coatings with top coats. Top coats may provide two or three layers of thickness, so compatibility with nut threads must be considered. Accelerated salt spray tests tout corrosion resistance times from 840 to 1200 hours. However, these corrosion resistance times are only a relative comparison of salt spray testing under controlled conditions. Actual field results may vary with assembly, other types of exposure from acid rain, UV etc. They will also vary from one applicator to another. These hour ratings are not absolute, only a guide. ◘