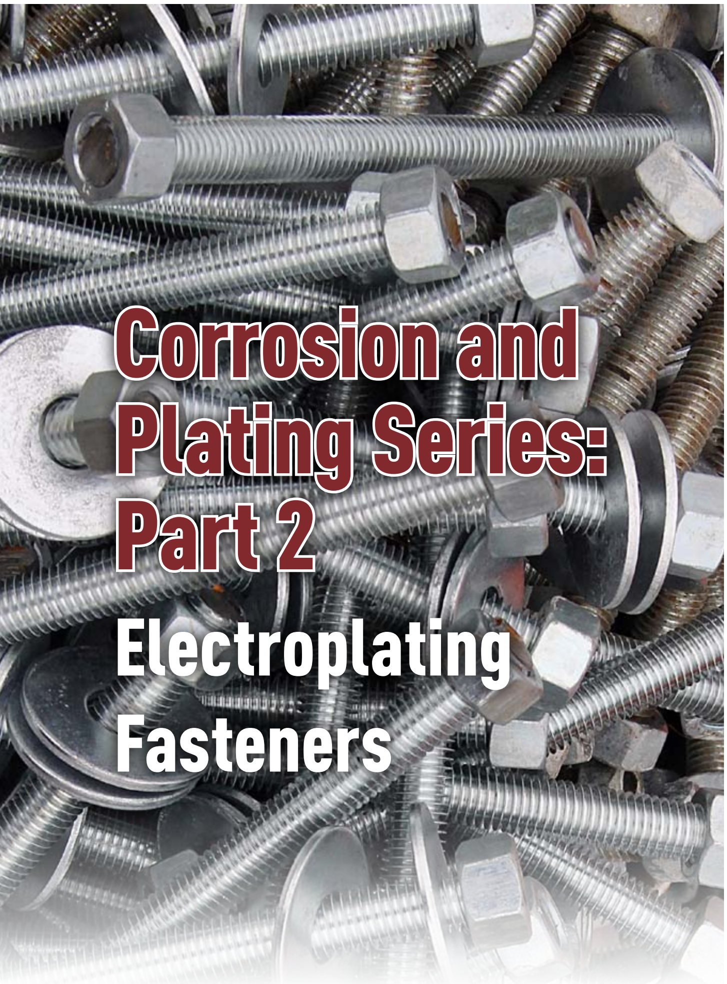

Corrosion and Plating Series: Part 2

Electroplating Fasteners

by Laurence Claus

Most fasteners receive a protective outer plating or coating to protect them from the elements they will be exposed to. Although there are literally hundreds of different options, it is without argument that the most prevalent of all is some form of zinc electroplating.

Zinc electroplating has been successfully applied to threaded fasteners for well over a hundred years. In general, it stands up well to light or moderately severe environments, is easily applied, and very cost effective. Although not without a number of potential drawbacks, zinc electroplating provides an attractive, hard-working exterior finish.

Even though, zinc electroplating is predominantly utilized on fasteners and other similar sorts of small hardware, it is certainly not the only metal that gets applied to fasteners in this manner. In fact, most metals can be successfully electroplated. Many other metals such as copper, gold, silver, tin, aluminum, nickel, and cadmium are routinely applied to fasteners. This article will explore how electroplatings are applied and introduce the most common electroplatings used on fasteners.

Reasons for Electroplating:

One might ask the general question, “Why do we plate or coat fasteners in the first place”? The simple answer to this question is that we do it for several reasons. The number one reason is clearly to provide protection of the fastener’s base metal from the service environment that it is placed in. Rewinding back to the first article in the series, we learned that platings and coatings protect parts in different ways. Some are “Barrier” protectors meaning that they provide a barrier that keeps the corroding medium away from the base metal. Some are “Galvanic” (or Sacrificial) protectors, which mean that they are galvanically more active than the base metal and, thus, sacrifice themselves to protect the base metal. This is the most common mechanism for electroplatings and zinc is, perhaps, the quintessential example. Some create protective oxides or passivation layers that are inert to the corrosive action of the corroding environment. Finally, others are “self-healing”. This means that if the protective layer gets damaged it is able to repair itself. This action is analogous to our skin, when we get scratched the wound heals over and quickly repairs itself. Quite often these mechanisms are combined to improve upon the capability that they possess alone. For example, although electroplated zinc is a sacrificial protector, the complete system includes a finishing chromate passivation which forms an inert, oxide-like layer that boosts the corrosion protection of the singular electroplated Zinc layer. Thus a common zinc electroplated fastener uses a combination of galvanic and protective passivation layer to delay corrosion.

A second common reason for plating and coating fasteners is for friction modification. This is a relatively new development and illustrates the growing need of fastener users to have less torque scatter during assembly or to reduce the effort needed to drive a threaded fastener. Friction modification comes in two basic forms, those that are integral or built right into the finish and those with a separate lubrication layer. Integral lubrication is usually found in coatings and not platings. Platings usually employ separate operations such as wax finish or dry film lubricant that is applied as the final operation in the process sequence.

A third reason for plating or coating is for appearance. Electroplating, even on rougher surfaces, tends to be smooth and uniform. This often makes electroplated finishes more pleasing in appearance than many other coatings, especially those that are paint like or very heavy in weight or thickness.

A fourth reason for plating and coating is for identification. There are various reasons that a user might need to distinguish two similar-in-appearance fasteners from one another. As an example, in the early days of the US automotive industry conversion to metric there were inch and metric fasteners that were nearly identical to one another. It was commonplace to have cases where it was impossible to visually distinguish one from the other. By using different colored electroplating they were able to differentiate these parts. Likewise, today it is still very possible to use different post treatments on electroplatings to provide a different color or hue and allow the parts to be easily distinguished from one another.

Platings and coatings are also routinely utilized to enhance electrical conductivity. Both silver and gold are excellent examples of electroplatings utilized for this purpose. They are sometimes used to provide a base for other finishes. Copper is an excellent example of a finish that often is utilized as a base for multilayer platings or coatings. Finally platings and coatings can be utilized for wear purposes. It is not uncommon to have a plating like hard chrome acting as a wear surface.

Important Concepts:

To understand several important limitations of electroplating, it is important to understand a few essential concepts:

› Electric Current Density:

The electric current density refers to the amount of current flowing through a specific cross section of a part over a given time. The electric current density varies by geometry and location in the parts. Electric current density is always stronger at the ends. Wherever the electric current density is strongest, the resulting electroplating process is fastest and most efficient. The practical implications of this behavior are that electroplated parts tend to plate more quickly on the ends, leaving a thicker deposit in those areas. In some instances, especially on long parts, this results in build-up in the threads and problems with thread gaging.

› Throwing Power:

“Throwing” is the term that describes the electroplating’s ability to reach into recesses and hollows. Most electroplatings do not have good throwing power and, thus, do not deeply penetrate into areas like the bottom of drive recesses or internal threads of a nut.

› Adhesion:

This term refers to how well the plating adheres to the surface of the part. Users do not want the electroplating to either flake or peel off the part, so its adhesion is an important performance characteristic.

The Plating Process:

Electroplating is an electro chemical process, meaning that it requires an electrical current to drive the transfer of electrons between two substances. In the case of electroplating, the application of electric current strips atoms from the plating metal anode (often a solid ingot or bar of the plating material), releasing charged ions into an electrolyte solution, and then redepositing them as plating on the solid fastener workpieces.

Electroplating can be done in bulk or individually in a rack. Since most fastener parts are small and are produced in high quantities, fasteners are almost always processed in bulk. This is accomplished by placing an optimum quantity of parts into bulk plating barrels. These barrels can range in size from relatively small in diameter (about 1/3 meter) to very large in diameter (about 1.6 meters). These barrels are perforated with holes to allow the plating bath to flow in and around the parts.

The first step in the process is to load the barrel. Once again, the load quantity will be a function of part size, weight, and barrel size. Although it is highly dependent on barrel size, the typical commercial plating applicator uses barrels capable of holding a couple of hundred pounds of parts. Parts are immediately moved into cleaning and activation. This is critical as a dirty part, or one whose surface is not properly activated, will not accept the electroplating well resulting in adhesion, appearance, or quality issues. The first cleaning process is normally a strong alkaline cleaner which will remove most of the grease, dirt, and smut on the surface of the part. However, it will not remove scale, oxides, or other stubborn smut or dirt. Parts will then go through an electrocleaning process. In Electrocleaning, electricity is introduced to the process resulting in electrolysis. This is like a deep cleaning process which removes any stubborn grease, dirt, or smut that wasn’t removed in the first soak cleaning process. Parts are finally introduced to a pickling process. This is submersion in a strong acid, like Hydrochloric Acid. This removes any scale or oxides which might be present from heat treating, as well as neutralizing the surface pH from the previous alkaline cleaning steps, and “roughs up” or activates the surface. When parts emerge from this last cleaning step they should be very clean and have a surface ready for plating.

The barrel is then shuttled to the plating tank, where it is submersed into the plating electrolyte bath. An electric current is introduced beginning the plating cycle. In some cases the plating electrolyte is already charged with the plating metal in solution, but more often solid anodes of the plating metal are submerged in the electrolyte and in the presence of the electric current dissociate ions into the electrolyte which are conducted to the workpiece and redeposited. The thickness of the deposit is mostly a function of the time the barrel is submersed into the plating electrolyte.

Following plating, the parts are rinsed and receive any post plating operations that may be stipulated for their specific process. Normally this includes a chromating (or passivating) operation but may also include application of a sealer, application of lubrication, or a hydrogen embrittlement relief bake.

Traditionally most of these electroplating operations have included a chromating step. Chromating is a conversion coating, meaning that when the outer layer of the electroplated surface contacts the chromating solution a chemical reaction occurs converting the outer layer to a very thin oxide-like layer that enhances the corrosion protection. Another result of chromating is that often the conversion coating changes the color or hue of the base electroplated metal. Common chromating color results include yellow, black, brown, bronze, olive drab, and silver (sometimes with a bluish tint).

About twenty years ago the European Union passed some new legislation regulating the way automobiles should be retired at the end of their lives. This included regulations about any hazardous substances that might be present in the auto's components. Unfortunately, one of the substances that has long been the subject of attention is the hexavalent ion of Chromium. Hexavalent chromium was the predominant constituent in most post plating chromating solutions. Therefore, when this material's presence was banned from European automobiles, the world had to make a mad scramble to eliminate it and find an alternative. This led to a significant shift in the plating process because applicators now had to find process alternatives that performed as well as the old hexavalent Chromium containing substances.

The initial solution was to use trivalent Chromium solutions. Unfortunately, trivalent Chromium does not perform as well as its hexavalent cousin, creating quite a conundrum for the surface finishing and fastener industries. In particular the trivalent Chromates do not have the self-healing capabilities that the hexavalent varieties do. This meant that parts processed with trivalent Chromates did not possess as good corrosion protection as they formerly did. The solution was to begin to add sealers after the chromating step.

The other problem was the loss of natural coloring. The trivalent Chromates could not produce the yellow and black colors that the hexavalent Chromates could. Early on this was addressed by adding dyes, but these were never as good as original coloring. In the intervening years the surfacing finishing industry has improved on this problem but there are still cases where the coloring on today's parts is not as good.

Electroplating Options:

› Zinc:

The most predominant electroplating on fasteners is Zinc. It is commonly supplied in clear (or silver), yellow, and black chromated varieties. Trivalent chromated options are today's standard but hexavalent chromated options are still available on a limited basis. Zinc electroplating is a dense, relatively non-permeable finish, giving it a smooth, shiny appearance. Zinc electroplated parts are generally quite attractive. Zinc electroplating works well in light to moderately severe environments depending on the combination of thickness, chromate, and sealer. Zinc electroplating is common so that reputable commercial applicators are found everywhere that there is a significant level of industrial activity going on.

Zinc electroplating, however, is not without its potential problems. The effects of electric current density make processing long parts tricky because they are prone to overplating the threaded ends. Zinc electroplating does not have good throwing power so that recesses and holes may not be well covered. The colors from trivalent Chromates are often not as "rich" or "deep" in hue as the traditional hexavalent Chromates produced and they are often more apt to fade under UV exposure than parts processed with hexavalent Chromates are.

› Zinc Alloys:

In recent years the zinc alloy electroplatings have gained favor. These include zinc-nickel, zinc-iron, zinc-tin, and zinc-cobalt. Zinc-nickel has emerged from this crowd as the "winner", due to significant interest in using it as a Cadmium replacement. All of these alloys are predominantly zinc with about 5-15% of the other metal alloyed with it. Like most alloys, these alloyed combinations provide some performance advantages over zinc alone. In appearance they look just like zinc electroplating and come in basically the same color shades clear (silver), yellow, bronze, and black.

› Tin Plating:

Like the zinc-alloy platings, tin plating is gaining popularity, especially in electrical applications and in the battery packs of electric vehicles. Tin plating is unique in that it smears rather than cracks when parts covered with it are swaged. This is especially advantageous for parts that may be mechanically deflected to provide a better electrical connection or ground.

› Gold and Silver:

Like tin plating, these two precious metal coatings are used for electrical connections. Both of these platings provide exceptional electrical conductivity as well as protection against corrosion.

› Copper:

Copper can be used to enhance electrical conductivity, as a base for other platings or coatings to adhere to, or for lubrication. A number of popular multi-layer coating systems use a Copper strike on the base metal to improve adhesion of the subsequent coating layers. Copper is also used on cold heading raw material that has a tendency to gall, like stainless steel. The copper provides an exceptional lubricant that keeps the raw material from seizing in the tooling.

› Cadmium:

Lastly is Cadmium. In former years, Cadmium was a popular fastener electroplating. In fact, when compared with the others it would probably win the prize for all around best performer. In particular it possesses a natural lubricity that the other platings, such as Zinc, do not have. This is an especially favorable advantage with fasteners because of the consistency and improvement it provides to the torque-tension relationship. Unfortunately, Cadmium, like hexavalent Chromium, is a bad actor and unsafe to humans and the environment. In fact, in some market segments, such as automotive, fasteners with Cadmium plating have been permanently banned and will not be making a comeback.

Summary:

Electroplating is a common and popular way of finishing fasteners. In general, electroplating provides good protection against corrosion in mild and moderately severe environments, is attractive, and is easily accessible. It is no wonder, therefore, that zinc electroplating is found on so many of the world's fasteners. In the last installment in this series, Part 3, we will investigate coatings and other finishes commonly used on fasteners. ■