Non-Electroplated Fastener Finishes

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This is the final segment of a three part series. In segment one, we investigated what corrosion is and some of the more common corrosion mechanisms. In the second segment we investigated how fasteners are electroplated; focusing primarily on the world's most common fastener finish, zinc electroplating. This final segment will explore other categories and types of finishes that are commonly deployed on fasteners.

By way of review, the majority of all fasteners receive some form of surface finish. These systems are primarily intended to protect the fastener from corrosion or oxidation during storage and handling or from their service environment. However, surface finishes may serve other functions as well. Several of the more common reasons for surface finishing include improving or customizing the part appearance, providing easy part identification or classification, improving the torque- tension behavior, and improving wear resistance. Worldwide, electroplating is the most commonly applied fastener surface finish, but in the last twenty to thirty years many other options have become available, which often addresses deficiencies in electroplating.

Zinc and Aluminum Rich Finishes

These finishes are often referred to as "Dip Spin" finishes, describing the method by which the surface finish is applied. These finishes are essentially a combination of fine sintered metal particles usually zinc or aluminum, suspended in a paint like matrix. The percentage of zinc or aluminum is high so that the finish takes on the protective characteristics of that particular metal. The surface finish is deposited in layers with at least a base coat and top coat layer. The combination of multiple layering and formulation of the layers often results in finishes that far exceed the performance of a zinc electroplated finish. For this reason in recent years they have gained significantly in favor in both automotive and industrial fastener applications.

The application of the coating is conceptually pretty straight forward. The coating material has properties very similar to paint and is, thus, contained in a large barrel or pot. The barrel is loaded into the application equipment. Parts are loaded into a separate mesh or perforated basket. This also is loaded into the application equipment. The basket is then lowered into the barrel or the barrel is raised to the basket fully immersing the parts in the coating material. Enough time is provided to allow the coating liquid to get all around and into any crevices or hollows in the parts. The barrel and basket are then moved apart and the basket is spun at high revolutions to remove any excess material. Following the spinning cycle, the parts are emptied from the basket and shuttled into a low temperature oven where the coating material dries and cures. Larger scale commercial operations will have the parts moving slowly through this furnace on a continuous belt or other equivalent form of conveyance. After completing the base coat, the parts are normally recycled again one or more times through the process to apply the finishing top coats.

These types of finishes started to make a notable entry into the fastener marketplace about thirty-five to forty years ago. Like most technologies that are new or in the early phases of their development cycle there were challenges that needed to be worked out. Primary among these was the tendency for this slightly viscous material to resist evacuation from recesses and crevices during the spinning part of the process cycle. This would lead to a percentage of the finished parts having recesses that were partially or almost entirely filled with the coating material, which hindered or outright prevented full bit engagement during installation. This either barred installation entirely or significantly raised the risk of recess cam-out. To address this issue the manufacturers of the application equipment have made many improvements to the spinning cycles over the years. Today, instead of just spinning in a single axis, the equipment can tilt in multiple axes and directions. Additionally, much of the newer equipment today has arms which hold multiple baskets and spin in one direction while each basket spins in a counter direction. Although coating fill still exists, it no longer is the problem that it was in former times.

Like all surface finishing systems, the success or failure of the coating is often a function of part cleanliness prior to coating. Most dip spin finishes have been developed to provide additional safety against hydrogen embrittlement risk. For this reason they do not incorporate electrocleaning, but rather incorporate mechanical blasting or zinc phosphating to clean and activate the surface for the base coat layer.

These finishes provide medium to high salt spray resistance making them excellent choices for moderate to severe service environments. Salt spray resistance starts at about 400 hours and often goes beyond 1,500 hours in these systems. Coloring is limited. Most of these finishes are a dull silver-gray color, although black is not uncommon. There are several other color options but they are rare. Another significant advantage of these systems is the ease of incorporating lubricants into the top coat. Top coats with integrated lubrication are favored by many manufacturing customers to reduce installation variability and improve torque-tension characteristics.

Mechanical Coatings

Mechanically applied coatings have been around for some time. One of their primary advantages is to provide a reduced hydrogen embrittlement risk alternative to electroplating with the same metal. This is accomplished by cleaning and activating the parts without electrocleaning and then applying the metal coating by "pounding" it onto the surface of the fastener. This application process is accomplished by placing parts, finely sintered metal, glass beads, and some activators into a rotating drum and allowing part-on-part interaction and the glass beads to adhere the powdered metal onto the part surface. The resulting finish, however, is one very different from their electroplated counterparts. Since the finish is developed by pounding small metal particles onto the surface, the resulting surface is not smooth like electroplating but has texture and irregularity. As a result the mechanical finish exhibits greater porosity and is much more matte in appearance. For these reasons it is important to "educate" a prospective customer in what to expect, especially if that customer is accustomed to the appearance of zinc electroplating.

Phosphate Coatings

Phosphates, unlike any of the other types of surface finishes, are crystals. The crystal size and density is a function of the application process. The phosphate crystals are similar in appearance to a pine bough with many branching tendril-like fingers. This configuration makes phosphate finishes ideal as base coatings for other finishes because those tendrils are able to grab and hold what is applied on top of them. Phosphate finishes are, therefore, commonly utilized on fasteners that will be receiving a paint or paint-like coating on top.

Although phosphates are a common fastener finish choice they must be used carefully. As plain, "dry", finishes they possess no real corrosion protection. To achieve some level of corrosion protection they must be subsequently immersed in oil, wax, or receive a more highly engineered top coat. Occasionally individuals are tricked into choosing a phosphate thinking that they will get corrosion protection from it. However, even with a post treatment, phosphate parts rarely exhibit more than a couple of days or weeks of shelf life, depending on the storage environment and conditions. For these reasons, prior to fulfilling an order, it may be prudent to discuss expectations with a customer prior to fulfilling an order whether a phosphate finish is a good choice or not.

There are three phosphate varieties, zinc, manganese, and iron. Each is developed using a different phosphate salt in the application process. Each different variety possesses slightly different characteristics but the most commonly used variant on fasteners is zinc phosphate with manganese phosphate finishing a very distant second. Phosphate finishes are inexpensive and exhibit none of the build-up problems associated with many of the other surface finishes.

At first glance a phosphating line looks very similar to an electroplating line. The line is laid out as a series of tanks in a row with fasteners being shuttled sequentially from one tank to the next in large perforated plastic barrels. Closer inspection, however, would show that the similarities end here. Phosphating does not incorporate electricity into the process. Instead the phosphating occurs in heated tanks of liquid phosphate salts. Like an electroplating line, a phosphating line will also incorporate cleaning, although the cleaning and actuating process may not include electrocleaning.

Oxides

A number of surface finishes are oxides. Perhaps the most common for fasteners is Black Oxide. This is a conversion coating created when certain metals are immersed in chemical solutions of Sodium Hydroxide, Nitrates, and Nitrites. The resulting oxide is Fe3O4 commonly referred to as Magnetite. Black Oxide results in an extremely rich, black colored oxide layer providing a very rich and consistent black color. Unfortunately, Black Oxide does not provide very good corrosion protection in anything but mild service environments.

Another helpful oxide finish is enhanced when stainless steel parts are passivated. There are several different passivation methods. The ones most commonly used for fasteners involve the immersion in a mild, heated solution of either nitric or citric acid. The primary outcome is to make the surface more passive or inert to corrosion and to remove stray iron particles from the surface which may oxidize giving the false appearance of stainless steel rusting.

Aluminum also depends on an oxide for protection. Aluminum naturally forms a surface oxide layer that is hard and nonreactive. However, by anodizing that natural protective layer is enhanced and gives additional corrosion and wear resistance. Anodizing is a process that is the reverse of electroplating, meaning that the fastener acts as the anode during the resulting electrochemical reaction causing oxygen release at the surface which builds up the already-present oxide layer.

Paints

The final coatings we are going to talk about for fasteners are paints. There are essentially two different painting processes that routinely are used on fasteners. The first is E-coating. E-Coat is electrically deposited paint. In Cathodic E-Coating the paint bath is negatively charged and the parts positively charged. In Anodic E-Coating the Paint bath is positively charged and the parts negatively charged. The polarity difference in electrical charge results in the paint being attracted and deposited onto the surface of the parts. Cathodic E-Coating generally is more cost efficient and provides better color control while Anodic E-Coating generally provides better corrosion resistance.

E-Coating is a method often used for large objects immersed in oversize tanks, but for fasteners, parts are bulk loaded into barrels similar to those used for electroplating and immersed in relatively small tanks. E-Coating provides a nice appearance and good corrosion protection.

A second painting method routinely used for fasteners is Powder Coating. In Powder Coating the fasteners are directed past an applicator that is spraying out very fine dry paint powder. This paint powder is attracted electrostatically to the fastener parts. This powder deposits itself evenly on the parts or selected portions of the part. The parts with powder adhering to them are then introduced to an oven. The heat melts the powder into one homogenous paint layer. Often times just the head of a part is powder coated to match the fastener to a specific color treatment. Powder Coating provides excellent corrosion protection and is very attractive.

Summary

In this three part series we have explored how and why fasteners corrode and the importance of providing some form of protection against this. There are many different options available so that designers should be aware of their options and choose a suitable solution dependent on the severity of the service environment. In Part 2 we explored electroplating. Zinc electroplating is, by far, the most popular and common surface finish for fasteners and is used extensively around the world. Zinc electroplating is an excellent choice for mild and moderate service environments. In this last segment we explored other surface finish types. These other options span a wide spectrum of cost and performance. Some of these other types of finishes provide exceptional corrosion protection, appearance, or other performance criteria. No single surface finish choice, however, stands out as the clear "best of show". In fact, when it comes to surface finishes there is no one size fits all. Each choice has its advantages and disadvantages. It is the job of the designer to assess how the parts will be used in service and what performance requirements are really important and then sort through all of these options to find the one that best meets all the criteria.