Dr. Fastener —

Comparing Zinc Plating, Black Oxide, Zinc Flake, Passivation, Anodizing, and Their Corrosion Performance

In this segment of Dr. Fastener, I was asked to compare the corrosion protection performance of the above list of finishing processes. On the surface, this might be a simple task to just rank order them in their corrosion resistance efficacy. However, it really isn't that simple because most of these processes are extremely different from one another and can't just be lined up and categorized as best to worse. Therefore, I will take the approach of trying to answer questions that reveal the strengths and purpose of each of these processes/finishes. In doing so, I hope that I can put into perspective how each assist in combating oxidation or corrosion and those that are better at it than the others.

Q: Considering this list of processes, do they have anything in common?

A: Yes, **they are all plating, coating, or conversion processes that provide corrosion or oxidation protection of the base parts to which they are applied.** It should be understood though, that in each case, these processes may also produce other performance benefits beyond just corrosion protection.

Q: Can you provide a brief description of each process?

A: Yes.

- **Zinc Plating** is actually zinc electroplating. Today's zinc plated parts are well engineered "systems" comprised of several key components. They start with a zinc electroplating, where pure zinc is deposited on the base steel part. The zinc layer can vary in thickness. A "commercial zinc" is likely to be about 5 microns or less while more demanding requirements like those found in automotive may drive the zinc layer as high as 13 microns. Following plating, zinc parts are immersed in a trivalent chromate solution (these days often referred to as passivation). The trivalent chromate generates a conversion layer at the surface, which is more inert than the pure zinc layer, aiding in the overall corrosion protection. Finally, these days most zinc plated parts are finished with a sealer that boosts corrosion protection even higher.

- **Black Oxide** is the generation of iron oxide, Magnetite (Fe_3O_4). It is formed by immersing steel (and other viable metal) parts in a heated solution of sodium hydroxide, and nitrite and nitrate salts. It produces a very rich and attractive black color. However, plain Black Oxide has no real corrosion resistance. If corrosion resistance is desired, subsequent immersion in oil or wax is necessary but only achieves minimal protection.

- **Zinc Flake** refers to a generic family of coatings where sintered zinc (or aluminum) particles are integrated into a binder substance (similar to paint) that is normally applied to fasteners in a dip spin process. Parts are immersed, spun to fling off the excess and produce consistent coating thickness, and cured in a low temperature oven. These finishes are almost always multilayered with at least a base and single topcoat. Some of these systems though may have more than two layers. Because they are multilayered and applied in a paint-like matrix, they tend to be thick, often about 20 microns or more. They are available in silver-gray and black. Corrosion performance is a function of coating choice and application and starts at about 400 hours to red rust in a salt spray cabinet and gives as high as 2,000 hours to red rust.

- **Passivation** refers to a process reserved for stainless steel. Parts are immersed in acid which essentially make the natural oxide layer that forms on stainless steel more passive, thus, protecting them even more from oxidation. Most fasteners are passivated in either citric, nitric, or acetic acid.

- **Anodizing** is a process reserved primarily for aluminum and titanium. These materials form a natural, inert surface oxide. Anodized boosts the strength of that oxide against oxidation and provides for a harder wear surface.

Q: Of the first three, can you comment on corrosion protection ability?

1. Metal Flake
2. Zinc Electroplate
3. Black Oxide

A: Although the answer is somewhat relative because it depends to some extent on the thickness and overall plating system components, in general corrosion protection goes in this decreasing order; metal flake, zinc electroplate, and black oxide. As pointed out above, metal flake coatings are highly customizable with some versions routinely providing 1,500 to 2,000 hours to red rust in a salt spray cabinet. Zinc electroplating is strongly a function of thickness and sealer type. Zinc platings typically range from about 72 hours to about 400 hours to red rust. Some may perform in excess of 400 hours, but you would not expect a zinc electroplate to go to 1,000 hours. There are, however, zinc-alloy finishes such as Zinc-nickel that can go to about 1,000 hours. Black Oxide, as mentioned above, has little or no inherent corrosion protection. In a dry environment black oxide will hold up well, but one would not expect performance in a moderate or severe environment.

Q: Of the first three, do they come in different colors?

A: Yes and no. Of the three, zinc electroplating comes with the most options, although it is basically only three colors; silver, yellow, and black. Zinc electroplating can be dyed to provide alternative colors, like green, blue, or red, although these are dyes and not permanent, especially if exposed to ultraviolet rays from the sun. Metal flake comes in black and silver-grey. Black Oxide comes only in black.

Q: Of the first three, what is the availability?

A: In fastener centric manufacturing regions, it should be no problem to find viable sources for any of these finishes. Commercial zinc electroplaters are likely the most common because zinc plating is, by far, the most common fastener finish globally. Therefore, there are many sources. Metal flake coatings continue to gain popularity beyond just automotive applications. For these, a lot of capacity has been added in the last twenty years, and it should not be difficult to find a competent applicator. Likewise, black oxide should not pose a problem finding a competent applicator.

Q: Beyond corrosion protection, do the first three finishes provide any other unique capabilities?

A: Both zinc plated parts and metal flake routinely are waxed or applied with some form of lubricant to provide friction modification. This is a subject that has garnered a lot of interest in the automotive arena. Zinc parts can be supplied in a variety of colors, so it is popular in industries like electrical components, where zinc plated screws may be dyed green to identify grounding posts. Black oxide can provide a sensational black color. This attribute can make it a good choice when appearance is important, and items are used in dry or very light duty environments. Black oxide also can mask reflection and is, thus, commonly used in the defense industry on exposed fasteners that must not be reflective for fear of exposing a concealed position.

Q: Why are stainless parts passivated?

A: The passivation process does a couple of things. Foremost it boosts the performance of the chromium oxide making the parts more resistant to oxidation and the formation of surface rust from stray iron particles that may get on the surface from contact with steel or iron. In this regard, passivation also provides a cleaning process for stainless steel parts. During processing stainless steel parts are normally collected in steel receptacles. When parts exit thread rolling or forming machines and bump into the side of these steel containers, they pick up small particles of iron. These micro iron particles can then oxidize leaving small rust spots on the surface of the part. Most customers will see this and believe that the parts are rusting. Passivation solves this problem because it cleans the surface along with boosting the oxide performance to prevent any future contamination from causing a problem.

Q: Why are aluminum parts anodized?

A: Once again, anodizing boosts the performance of the oxide. It also has the effect of making the oxide layer denser so that it becomes more wear resistant. Additionally, some anodizing processes create what is called a cellular oxide layer, where the oxide layer has deep wells or troughs. These readily accept lubricants or dyes and explain why aluminum parts can come in so many unique colors.

Wrap-up

In summary, these are all different methods/processes to add corrosion or oxide protection to fasteners. Of course, there are many different options available beyond these five, although these five represent a large percentage of the finishing methods applied to fasteners. Like so many other things related to fasteners, it is important for users and suppliers to understand what the different options are and the advantages and disadvantages that they bring. ■