POWDER COATING AND GALVANIZING

TECHNICAL ARTICLE

Powder coating over hot-dipped galvanized steel

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Pairing powder coating with other forms of finishing can allow coaters who combine the processes more variety and versatility for their businesses than if they were to stick with one system. Take galvanizing, for example. When combined with powder coating, it can add to steel's durability over a long period of time. This article explains duplex systems, or those that combine hot-dip galvanizing with powder coating. It outlines the process and explains how to prepare a galvanized surface for powder coating.

In the past, protecting steel from corrosion typically involved either the use of hot-dip galvanizing or some type of powder or wet coating system. However, with greater emphasis on long-term performance (50 to 100 years), more designers and owners are using a combination of both methods of protection in what is commonly referred to as a *duplex system*. A duplex system is simply powder coating steel that has been hot-dip galvanized.

When finishers combine powder coatings with galvanized steel, the corrosion control provided is superior to either system used alone. The galvanized coating protects the base steel, supplying it with cathodic and barrier protection. In addition, the galvanized coating prevents the development of iron oxide under the powder coating system. The outward pressure caused by the iron oxide that has developed on ungalvanized steel surfaces eventually leads to blistering and peeling. Powder coatings, in turn, give barrier protection to the galvanized coating by isolating it from the corrosive attack of chlorides and sulfides in the atmosphere.

The powder coating slows down the rate at which the zinc is consumed, greatly extending the service life of the galvanized steel. In return, once the powder coating has been weathered down or damaged, the zinc is available to provide cathodic and barrier protection so that rust won't form and the powder coating won't peel. With this synergistic effect, duplex systems typically provide corrosion protection that lasts one and a half to two and a half times longer than the sum of the service lifetimes of zinc and powder coating used individually. This results in maintenance-free structures, architectural pieces, and fabrications for 75 to 100 years in most locations.

Galvanizing process includes four steps

Although the process may vary slightly from plant to plant, the fundamental steps in the galvanizing process are

1) Cleaning
2) Galvanizing
3) Finishing
4) Inspection

Cleaning. The cleaning process involves three steps:

1) Soil and grease removal
2) Pickling
3) Fluxing

Soil and grease removal. The first cleanup step involves dipping the steel into a hot alkaline solution that removes dirt, oil (including shop oil), grease, and soluble markings. The hot alkaline cleaning solution is unable to remove some surface residues such as mill lacquer, welding slag, varnish, water-insoluble paints, adhesives, and sands used in the making of castings. Consequently, finishers may need to use mechanical cleaning, such as grinding or blasting, to remove these residues.

Pickling. This second step involves the immersion of the steel into dilute solutions of either hydrochloric or sulfuric acid that remove surface rust and mill scale to provide a chemically clean metallic surface.

Fluxing. In the third step of the cleaning process, steel is immersed in liquid flux—a zinc ammonium chloride solution—to remove oxides and to prevent oxidation before the steel is dipped into the molten zinc bath. In the dry galvanizing process, the item is separately dipped into a liquid flux bath, removed, allowed to dry, and then galvanized. In the wet galvanizing process, the flux floats atop the molten zinc and the item passes through the flux immediately before it's galvanized. Either method (dry or wet) effectively promotes the metallurgical bond between zinc and steel.

Galvanizing. The article is immersed in a bath of molten zinc at temperatures greater than 800°F (427°C). During galvanizing, the zinc metallurgically bonds to the steel, creating a series of highly abrasion-resistant zinc-iron alloy layers, commonly topped by a layer of impact-resistant pure zinc.

Finishing. After the steel is withdrawn from the galvanizing bath, excess zinc is removed by draining, vibration, or, for small items, by centrifuging. The galvanized item is then air-cooled or sometimes quenched in liquid. If the galvanized steel is to be duplex-coated, it shouldn't be quenched following galvanizing. Quench-bath surface contaminants will deposit on the newly coated steel and will interfere with powder coating adhesion. Quenching practices vary from one galvanizing plant to another; therefore, you need to specify whether or not you want the steel quenched.

Inspection. Coating thickness and surface condition inspections complete the process. For purposes of inspecting galvanized steel to be duplex coated, you need to understand that because of the immediate solidification of the zinc upon contact with the air, a galvanized coating occasionally may have runs or drips. In addition, dross or ash inclusions or other types of coating imperfections may also occur. Although these imperfections don't affect corrosion prevention properties, they must be removed and the galvanized surface smoothed out before it's powder-coated.

Galvanized steel divided into categories

The most important component of powder coating over hot-dip galvanized steel is understanding the characteristics of the zinc coating at each stage of its weathering. Although the zinc begins reacting with the environment immediately upon removal from the galvanizing bath, the zinc coating can take as long as 2 years to weather completely, depending on the environment.

For purposes of determining the stage of weathering—also called the *zinc patina development* (zinc oxides, zinc hydroxides, and zinc carbonate; see Figure 1)—galvanized steel is divided into three categories:

1) Newly galvanized
2) Partially weathered
3) Fully weathered

Slightly different preparations must be done for each stage of galvanized steel weathering for duplex coating because the galvanized surface has different characteristics and different surface materials. When you remove steel from the galvanizing bath, the zinc immediately begins to react with the environment. Zinc oxide corrosion forms 24 to 48 hours after galvanizing. Zinc oxide is a powdery, lightly adhering corrosion product and is the first step in the development of the protective zinc patina. Before the zinc oxide forms on it, the newly galvanized steel requires little or no surface preparation and perhaps only slight profiling to encourage powder coating adhesion.

When the zinc oxide is exposed to freely moving air, the surface reacts with moisture in the atmosphere, such as dew, rainfall, or even humidity, to form a porous, gelatinous, grayish-white mixture of zinc oxide and zinc hydroxide. This partially weathered galvanized

The Hudson River Way Pedestrian Bridge, a walkway over the Hudson River in Albany, N.Y., is a showpiece of powder coating over hot-dip galvanizing. The coating needed to withstand the elements of the Upstate New York climate, along with winter road salt and summer skateboarders. The handrails also feature powder coating over the galvanized surface. Hubbell Galvanizing of New York Mills, N.Y., powder coated the bridge, which was fabricated by Riverside Fab, Glens Falls, N.Y., and engineered by Clough, Harbour, & Associates, Albany, N.Y. The architectural firm was Einhorn, Yafee, and Prescott, Albany, N.Y. The design consultant firm was Carol R. Johnson Associates of Boston.

steel forms typically between 48 hours and 6 months after galvanizing. The zinc oxide and hydroxides are ball-shaped particles electrostatically connected to the steel surface that must be removed or neutralized with sweep-blast cleaning or chemical cleaning. I suggest you remove the particles by sweep blasting (with a medium softer than zinc) or with an etch primer to slightly roughen the surface and improve powder coating adhesion. Solvents alone won't remove zinc oxides and hydroxides.

FIGURE 1

Zinc corrosion flow

During the continuation of the weathering process, the zinc oxides and hydroxides react with carbon dioxide in the atmosphere and progress into a thin, compact, tightly adherent layer of basic zinc carbonate. This progression to zinc carbonate enhances the excellent barrier protection afforded by the galvanized coating. Because the zinc patina at this carbonate phase is relatively insoluble, it prevents rapid atmospheric corrosion of the zinc on the surface of galvanized steel. This fully weathered galvanized steel develops between 6 months and 2 years and has a completely formed zinc patina. The patina has a very stable and finely etched surface, providing excellent powder coating adhesion. The only surface preparation needed is a warm-water power wash to remove loose zinc oxide and zinc hydroxide particles from the surface.

Surface preparation key element in duplex coating

Understanding the phase of zinc patina that the galvanized steel components may be in is important. Beyond that, successful surface preparation is the key to producing adherent powder coatings and realizing the benefits of a duplex system.

Specifications. Information on preparing postfabricated hot-dip galvanized steel surfaces for duplex coatings can be found in American Society for Testing and Materials (ASTM)[1] D 6386, "Practice for Preparation of Zinc (Hot-Dip Galvanized) Coated Iron and Steel Prod-

uct and Hardware Surfaces for Painting." In general, surface cleaning and profiling are characterized by the following elements.

Surface cleaning. When cleaning a galvanized surface before applying a power coating, the goal is to remove dirt, grease, or oils. At the same time, you need to take care not to remove too much of the galvanized coating. Alkaline cleaning, ammonia cleaning, and solvent cleaning are the most common ways of removing dirt from a galvanized surface. Some cleaners may react differently with different powder coating systems. As a result, you should consult the manufacturer of your powder coating for specific reaction problems.

You can remove oil, grease, and dirt with an alkaline solution in the pH range of 11 to 12. Solutions ranging from 13 and higher will damage the zinc coating. Most alkaline cleaning solutions are nominally 2 to 5 percent sodium compounds with small additions of emulsifying or chelating agents. You can dip, spray, or brush the solution onto the surface. If you brush the solution, apply it with a soft bristle brush, preferably of nylon, but definitely not copper or steel bristle brushes. If you dip or spray the solution, stay within a temperate range of 140°F to 185°F. For newly galvanized steel, you can use a water-based emulsifier to remove contaminants. After you've cleaned the part, thoroughly rinse the surface with hot water and let it completely dry.

You can use mineral spirits, turpentine, high-flash naphtha, and other typical cleaning solvents to clean galvanized surfaces if you apply them with lint-free rags or soft bristle brushes. You need to change the rags and brushes often to ensure you're not reapplying the contaminants. After you've cleaned the part, thoroughly rinse the surface and let it completely dry.

You can use a solution of 1 to 2 percent ammonia applied with a soft bristle brush to clean galvanized surfaces; however, this method is typically reserved for cleaning parts with *zinc-skimmings* residue. *Zinc skimmings* are residue particles of oxidized zinc particles from the bath surface that may remain on a piece of steel after it's removed from the galvanizing kettle. You need to remove ash residue before you powder coat the steel. After you've cleaned the part, thoroughly rinse the surface with hot water and let it completely dry.

Surface profiling. To get a good adhesion profile for the powder coating, the galvanized surface you're prepping must be flat and slightly roughened with no protrusions to get an anchor profile. During the removal of the galvanized article from the zinc bath, the excess zinc runs down the edges of the part and can sometimes build up on a protrusion or irregular edge. The zinc can also form tears at the edge where it drains off the part. These high spots and tears must be removed before powder coating because they'll be very difficult to powder coat over. You can usually grind them off with hand tools or power grinders. However, be careful and make sure you don't remove the galvanized coating below its specified thickness.

To roughen the typically smooth galvanized surface after cleaning, use an abrasive sweep or brush blast. Make sure you don't remove too much of the zinc coating. The particle size for a sweep blast of galvanized steel should range between 200 and 500 microns. Aluminum-magnesium silicate has been used successfully in the sweep blasting of galvanized steel. You can also use organic media such as corncobs or walnut shells, or minerals such as corundum, limestone, and sands with a Mhos hardness of 5 or less.

The temperature of the galvanized part when blasting can have a significant effect on the finished surface profile. Sweep blasting while the galvanized part is still warm from the galvanizing process (175°F to 390°F) provides an excellent profile for powder coating. The recommended ambient conditions for sweep blasting are a relative humidity less than 50 percent and a minimum temperature of 70°F.

Keep your processes straight. Sweep blasting isn't the same as near-white blasting, a process that's used to clean uncoated steel before applying powder coating. This process would remove the galvanized coating and negate the corrosion protection afforded by the zinc. Sweep blasting is best performed by an experienced applicator. If the sweep angle becomes nearly perpendicular to the galvanized part, the blasting can quickly remove the protective zinc rather than the zinc oxide particle on the surface of the coating.

Penetrating sealers. Finishers sometimes use two-part epoxy-penetrating sealers to form a 50-micron-thick coating on a galvanized surface after it's been cleaned. These sealers can be particularly effective as surface treatment methods on surfaces that have had zinc oxide and zinc hydroxide removed during the cleaning process. Follow the manufacturer's directions for application and always use a topcoat over the penetrating sealer.

Zinc phosphate treatment. Zinc phosphate is a conversion coating that passivates the zinc surface and blocks the formation of zinc oxides. You can apply the phosphate treatment by immersion, spray, or soft bristle brush. Leave the phosphate on the galvanizing surface between 3 and 6 minutes. Then, wash the piece with clean water and let it completely dry. This type of treatment is appropriate for most types of powder coatings; however, it doesn't perform well with zinc-rich coatings.

Wash primers. Wash primers use a metal conditioner to neutralize surface oxides and hydroxides and to etch the galvanized surface. Apply the wash primers to the galvanized surface in a thickness ranging from 7 to 13 microns to form a protective layer. If the thickness exceeds 13 microns, powder coating adhesion can become a problem. Because you need to be precise about the thickness of the layer, make sure you do this process in shop conditions. If you try to apply this treatment in the field, you'll likely get thick and irregular protective layers. Follow the wash-primer manufacturer's directions to get the most effective performance results.

Acrylic passivation. This treatment uses an acidic acrylic solution to passivate the galvanized surface and to roughen the smooth zinc coating. Apply the acrylic passivation at a thickness of 1 micron to a clean galvanized surface. Allow the passivation layer to completely dry before applying powder coatings to the surface.

The proper selection of a powder coating system for a certain engineering need is the province of the architect and the engineer. Many options are available, depending on the following:

- Use of the duplex-coated part
- Application method and place for the powder coating system
- Concerns about the environment
- Aesthetics of the total system

Many powder coatings companies offer good systems designed to work with galvanized steel. Consult your powder coatings manufacturer for advice on selecting a powder coating that meets your needs.

Summary

The secret to excellent performance of powder-coated galvanized steel is surface preparation of the galvanized surface. If the surface is newly galvanized—that is, less than 48 hours old—you can powder coat the surface after roughening the surface. If the surface of the galvanized part has been exposed to the environment for more than 1 year, then you can powder coat the surface after you've removed the dirt, grease, and oils. If you want to powder coat galvanized steel that ranges in age between 1 day and 1 year old, you need a little more surface preparation, which will ultimately lead you to quality duplex-system performance. **PC**

Endnote

1. American Society for Testing and Materials, 100 Barr Harbor Dr., West Conshohocken, PA 19428; 610/832-9500; Web site [www.astm.org].

Bibliography

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Editor's note

For more information about this topic, see the Article Index in the Reference & Buyer's Resource Issue, *Powder Coating* vol. 14, no. 10 (December 2003), or visit [www.pcoating.com] and click on Article Index.

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