Powder Coating: The Dry Paint

By J. David Adams

Since it was first introduced in the 1950s, powder coating has made significant gains as one of the most resistant finishes available. Although revolutionary in chemistry and application, there is nothing "magic" about powder coatings. The easiest way to think of them is as simply as dry paint. Though there are a few major differences between powder and liquid paint, there are also similarities.

Conventional paint is composed of blended pigment, resinous base and solvent. The pigment imparts color and hiding power. The resin forms the backbone of the paint and the solvent makes the resin flow and "wets" the surface to be covered. Eventually, the solvent is evaporated or driven off, either by allowing the coated object to dry in air, or with the addition of heat. Wet paints are applied using a brush, dip or spray process.

The powder coating process occurs in much the same way. The powder contains pigments, resins and, instead of solvents, additives and extenders to help with the flow, "wetting" and binding of the coating. Powder can also be applied by a dip process, called a "fluidized bed," or can be applied by electrostatic spraying. Instead of air drying, as is the case with wet coatings, powders must be heated to produce a paint-like coating.

Many of the problems, processes and uses are seen to be similar when comparing wet painting, powder coating and even plating. For example, the surface to be coated must be clean—sometimes prepared with an etch or conversion coating—and there must be an attraction between surface and coating.

Powder coating can be applied, though unproductive, simply by directing the powder toward the part. Efficiency is greatly improved, however, by electrostatic attraction, especially in corners and on sharp edges. To understand how heat produces the final cured powder coating, it is necessary to consider the various classes of powders and some simple chemistry.

Powder Coating Classes

There are two basic types of powder coating: Thermoplastic and thermosetting. The first type used was thermoplastic, introduced in the 1950s, and used exclusively until the introduction of thermosetting powders in the 1970s. Thermoplastic coatings include PVC, nylon, polypropylene, vinyl and others. These are high-molecular-weight compounds that melt and flow with the application of heat, but retain the same chemical composition. This is the important difference between them and thermosetting powders.

Thermoplastic coatings generally require a primer and are used mostly where a very thick coating is required (over 10 mil). Typical applications include: Electrical insulation, sliding load-bearing surfaces, chain link fencing, wire racks for dishwashers, chemical-resistant linings, etc.

The thermosetting powders are the choice of the automotive, appliance and construction industries. They are as resistant to chemicals and rust as the thermoplastic coatings, but can be applied as thin films, in the range of 1 to 4 mil. They impart an attractive, even finish, have excellent adhesion and do not require primers. Thermosetting powders are low-molecular-weight compounds. As such, when melted, they "wet" the surface of the workpiece. "Wetting" means the ability to flow on and into rough imperfections on the surface and bind to it. After the powder has melted and wetted the surface, it begins to cross-link, forming very large molecules. This nonreversible chemical reaction produces a coating that has the chemical properties of paint. When cooled, the result is a tough, resistant coating that has almost been fused onto the surface.

Powder Types

There are four main types of thermosetting powders: Epoxies, polyesters, polyurethanes and acrylics. In addition, some very successful powders are made from combinations of these types. An example is the hybrid, polyester and epoxy and TGIC (triglycidylisocyanurate).

Decisions to use particular types of thermosetting powders are based on the end use, characteristics and requirements of the workpiece to be coated. In general, epoxies provide the greatest chemical resistance and adhesion. They "chalk," however, when exposed to ultraviolet rays, as in sunlight. The chalking does not affect coating resistance, but does adversely affect the appearance. Polyesters, on the other hand, offer good weatherability and retain good appearance when exposed to sunlight, but lose some of the strong chemical resistance of epoxies.

When a coating requires good chemical resistance and adhesion, yet will be exposed to UV light, a combination of coatings, called a hybrid, is often used. Hybrids and TGICs offer some of the advantages found in both epoxies and polyesters.

Polyurethanes are also used as powder coatings. They offer good chemical resistance and exterior durability. They can also be applied at lower thickness (0.8 to 2 mil). Acrylic urethane powders have good appearance, hardness, and excellent resistance to alkali. They, too, are good for items requiring low film thickness.

Powder Components

Coating powders comprise four basic components: Resins, pigments, extenders and additives. The resins include the epoxies, polyesters, acrylic or urethane bases. Pigments provide color and hiding properties. Extenders are added to give such properties as low gloss flow, edge covering, etc., as well as aiding in keeping powder cost down. Additives are used in very small quantities to help reduce or extend cure time and temperature, improve or reduce flow, and raise or lower gloss, among other effects.

Substantial research by powder manufacturers has produced a wide variety of combinations of the above components, providing powders for almost every application. As examples, there are low- and high-temperature cure powders, powders that allow post-coating bending, crimping and forming, and powders that can be applied at less than none or more than 5 mil thickness for a good tough coating and good adhesion. Powders can be formulated for any color, gloss range, some textures and many thicknesses.

Powder Manufacturing

As mentioned earlier, powders are composed of dry resins, pigments, extenders and additives. These components are mixed thoroughly, ground into fine powder, melted, remixed, extruded as flat sheets, broken into fine powder and packaged for shipment.

All powders are used exactly as received from the manufacturer. Unlike wet coatings, it is not possible to "tweak" or adjust a powder for a particular application. All testing, formulation and changes must be done at the factory.

Powder Coating Systems

Powders can be sprayed or dipped, but much more is necessary to obtain a strong, attractive finish. Unlike conventional coatings that may contain solvents to aid flow under rust, dirt and films, powder requires an extremely clean and often treated substrate. Consequently, a good coating system must provide:

- A way to clean and pretreat surfaces.
- Good powder delivery, booth and reclaim.
- Curing oven system.

If there is a problem with any one of these, a good powder-coated part cannot be produced.

Metal Pretreatment

The two most common pretreatments in powder coating are zinc or iron phosphate conversion coatings. The phosphates act to form a coating of metal phosphate crystals on the metal surface. These crystals are porous, allowing powder to soak in and produce an exceptionally good bond. In addition, the phosphate layer acts to insulate a variety of "electrochemical corrosion cells" present on the metal, and formed by peaks and valleys in the metal surface and by stress. Insulating these cells with a metal phosphate contributes significantly to rust resistance.

Powder Coating Booth, Delivery & Reclaim System

One of the great advantages of sprayed powder coating over conventional wet coating is that excess powder can be reclaimed for further delivery to the work. Typical transfer efficiency for wet electrostatic coatings may run as high as 80 percent, but for powder coating it is commonly 95 to 98 percent.

As discussed earlier, powder can be applied in a "dip" process. In order to obtain an even, well-dispersed coating the powder must be infused with air. This is the fluidized bed process," which consists mainly of a tank with a porous membrane base through which controlled low-pressure air is fed. This serves to "fluidize" the powder in the tank, giving it flow properties much like those of a liquid. Objects to be coated are preheated and, when brought into contact with the powder, cause the powder to begin melting on the objects Depending on object size, additional heating may be required for complete curing after immersion in the tank.

Electrostatic Spray

In this method, the powder is fluidized in a small hopper and fed through a venturi to a powder coating gun. The powder is positively charged as it leaves the gun to be deposited on an oppositely charged (grounded) workpiece. Rather than having the powder directed onto the workpiece, as in conventional wet spray applications, it is easier to think of the workpiece as passing through a "fog" of charged powder. The fog aids in coverage of tight areas, wraparound, and coating of sharp edges. This method is well-suited to automation.

Reclaiming undeposited powder is accomplished by having the spray booth attached to a vacuum system having either a cyclone or filters to collect the powder. This arrangement collects the larger powder particles and traps the smaller "contamination" particles in a waste receptacle. Generally the air is clean enough to be exhausted into the production area, or into the atmosphere without further treatment.

Changing Colors & Powders

One significant drawback to powder coating is the amount or time necessary to clean the spray booth, the gun(s), and the reclaim system when changing colors or powder type. This can take as much as 20 min, because the entire system must be clean, free of contaminants and other powder.

Powder Curing Ovens

After powder is applied, it must be heated, during which it begins to wet and flow. As it reaches a critical temperature, cross-linking begins and the powder changes from a low- to a high-molecular-weight compound. Curing is both time- and temperature-dependent. Powder manufacturers specify both parameters, usually as "part" temperature (not air temperature) for proper curing.

Heating is normally by convection or a combination of convection and infrared ovens. Most powders cure in about 15 min at temperatures from 325 to 450 °F. Once the part has cooled well below the curing temperature, it is ready for use or packaging for shipment. P&SF

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