THE PREPARATION, POWDER COATING AND CURING OF PRE-CUT METAL SHEETS FOR POSTFORMING

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ABSTRACT

The postforming process differs from the traditional practice of coating metal parts after they have been formed into three-dimensional shapes. Flat metal sheets are sheared with holes punched to exact dimensions, creating so-called "blanks" which are then surface prepared, powder coated, and cured. The fully coated blanks are then mechanically formed into three-dimensional enclosures for final assembly.

The benefits of the postforming process include accelerated cycle times, a high-quality finish, reduced energy consumption and wastewater generation, lower floor-space and manpower requirements, and no hazardous waste.

This paper describes a system for the pre-coating of flat blanks. Substrate selection, material handling, surface preparation, coating application, and thermal requirements will be discussed in this paper. The forming and assembly steps will not be covered in this paper.
INTRODUCTION

The postforming process is an efficient, cost-effective alternative to the traditional method of assembling a complete, three-dimensional part before applying a finish. The use of this process is growing in Europe, the Pacific, and in the U.S. appliance industry. Figure 1 shows a typical postforming process line. In this line and others like it, the quality and environmental benefits of powder coating are combined with the process efficiency of a two-dimensional finishing line.

Figure 1. Typical postforming line.
THE POSTFORMING PROCESS

Substrate Selection and Surface Preparation

The choice of a substrate depends on material cost, corrosion resistance properties, and the formability of the material. Formability is determined by the radius of bending within the range of "0-T" bend to "10-T" bend. Cost issues should be addressed after the specification defines corrosion resistance and formability requirements. The least costly substrate which possesses maximum flexibility is cold-rolled steel. Certain zinc/aluminum-coated steel such as Galfan and Gal-Alum possess moderate to good formability without disturbing their protective zinc coating but are more expensive. For maximum corrosion protection, zinc-coated galvanized steel, which is normally less costly than zinc-alum products, may be used but will show definite limits of formability.

Unlike coil-coating, all cut-outs, holes, and notches are completed prior to finishing. Pre-cut blanks are stored at a feeding station at the beginning of the precoating line. Blanks of up to 16 ft. long and 4 ft. wide are fed into a system with typical spacing of 2-3 inches between them.

Sheet metal blanks move first through a multi-stage surface preparation process to remove oil and residual dirt (Figure 2). The final step within this stage is the application of either a "dry-in-place" type of sealant or a chrome or non-chrome type of sealant to the top and bottom of each sheet.
Figure 2. The surface preparation stage is designed for rapid processing and minimal environmental impact.

Following surface preparation, the sheets are dried before being powder coated. An infrared/convection dry-off oven uses both electric IR and convection heated air as media for rapid energy transfer. Air is heated by natural gas using an indirect heat exchanger. This indirect system minimizes the possibility of combustion byproducts and other contaminants reaching the surface of the cleaned and pretreated sheet. The use of IR as a pre-heater and the high volume of circulated air enable the blanks to be dried quickly at relatively low temperatures.

After the sheets are dried, they enter a cooling zone where high-velocity refrigerated air cools the parts and maintains them below 95F for the powder coating application stage.
Powder Coating

Powder coating of the pretreated blanks is accomplished using standard application equipment. A modular powder booth design allows quick color changes by enabling the entire booth and conveyors to be moved off line. Several booth/conveyor system modules are included in each line depending on the number of colors and the rapidity of color change that are required. Within each booth/conveyor module there are two conveyors -- one conductive belt for transporting blanks during top coating and a special pin-type conveyor for dust coating of the underside (Figure 3). Full bottom coating can also be accomplished with the use of a second, smaller, in-line booth/conveyor module with an integrated IR "gel" oven.

Figure 3. Powder coated top and edge with bottom dust (slide grain) coating.
Applying powder coatings to flat blanks is more efficient and less wasteful than spraying a large, three-dimensional assembly. Blanks typically require a thinner, more uniform, 1.4 - 1.6-mil layer of powder to achieve the same coverage as a 2.5 - 3.6-mil coating on a formed assembly.

The additional dust-coating process involves a light application of powder to facilitate the movement of finished sheets through forming tools. A small amount of waste powder from the primary coating afterfilter is applied to the underside of the metal sheets. While this application is barely visible to the naked eye, it is sufficient to prevent metallic contact between sheets and forming tools. This "slide grain" replaces traditional oil as a lubricant and serves to protect the surface finish and prolong the life of forming tools.

**Curing**

Since line speeds of up to 80 ft./min. are required for postforming systems, IR energy transfer is the only practical method for achieving a high-quality, durable finish in such a short time frame. Because IR radiation heats by line-of-sight, it provides excellent access to surfaces for energy transfer and hence is ideal for flat blanks. Quartz tubes coated on one side with gold serve as primary reflectors, minimizing convective losses by directing approximately 98 percent of IR energy toward the target. The fast but carefully controlled temperature ramp-up provided by medium wavelength IR melts the powder so that it begins to flow almost immediately. The cure takes place in one-tenth to one-twentieth the time required for conventional three-dimensional pre-formed systems.
The curing of coated blanks is also well suited to IR energy transfer systems and to ovens that combine IR and convection. An IR-enhanced convection system begins with a "pre-heat" zone where high-purity electric IR emitters provide an isolated, non-contaminating environment with rapid temperature ramp-up of the coating and substrate. Next, the "equalization" zone combines IR and high-velocity indirect natural gas convection heat to produce temperatures of 500-650°F without the risk of surface contamination from combustion byproducts. The third section, a "holding" zone, consists of convection heating only that maintains all surfaces at a predetermined temperature. The specific cure requirements that are defined by actual time/temperature curves (chart recording) are dependent on the formulation and chemistry of each type of powder coating material.

Cooling

Within the curing oven, peak material temperatures may reach 480°F-550°F. Before these sheets can be safely removed from the line and properly re-stacked, they must be cooled to approximately 100°F. A cooling system similar to what is used following the pretreatment dry-off is employed to lower part temperature prior to exiting the line. An automated vacuum pick-up system and conveyors are used to re-stack the coated blanks and transfer them for shipment.

BENEFITS OF POSTFORMING

Environmental Benefits

From an environmental and regulatory standpoint, the postforming process allows manufacturers to convert to new coating technologies and comply with new regulations
governing solvents. Solvent-free powder coating is an optimal alternative to solvent-borne coatings. Rapid curing by IR energy enables this technology to be used in applications requiring high throughput.

The consumption of water and the need to remove contaminants from wastewater are also sharply reduced. During the surface treatment stage, oil that is removed from the blanks is reclaimed, cleaned, and used again. For a line running at 50 ft./min., typical detergent consumption is less than 0.083 oz/ft² and wastewater requiring treatment is under 50 gal/h (<1 gal./min.).

The use of powder coating eliminates many material disposal concerns associated with paints. Not only are solvents (VOCs) and other hazardous materials removed from the facility, but also paint sludge, filters, masking materials, and painted scrap metal are eliminated. Because the blanks are processed on a flat conveyor system, there are no hangers to remove and clean.

Product Quality Benefits

The postforming process contributes to overall product quality in a number of important ways. Powder coating affords manufacturers wide flexibility in the choice of powders. Compared to liquid coatings, organic powder coatings combine exceptional hardness and flexibility. The use of IR energy in the curing process improves coating adhesion and quality -- key considerations with metal parts that will be formed after they are coated. High-purity IR energy transfer eliminates skin-over, blisters, and pinholes by reacting deeper within the coating, drying or curing the material from the inside out. No premature surface hardening occurs and the result is a smooth, gloss finish.
The overall quality of the part's finish is enhanced by the postforming process. Since blanks are pre-cut to their final dimensions and all holes and cut-outs are stamped before coating, every face and edge can be fully coated for an improved appearance and additional protection against corrosion. In contrast, a fully assembled, three-dimensional part, can be more difficult to cure completely because pockets and corners are not within range of the line-of-sight IR waves.

**Productivity Benefits**

The postforming process allows higher productivity with reduced costs. Initial capital investment can be lower for a postforming line than for a traditional three-dimensional assembly operation. The manufacturing operation is faster and more streamlined and flexible, optimizing production and facilitating just-in-time delivery. Further, material costs for chemicals and powder are reduced, and energy consumption is lower. Table I summarizes material consumption data for a postforming line that has been operating for over three years to produce kitchen and laundry appliance enclosure parts.

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<thead>
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<tbody>
<tr>
<td>Water consumption</td>
<td>0.0036 gal./ft.² - 0.0048 gal./ft.²</td>
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<tr>
<td>Pre-treatment chemicals</td>
<td>0.185 gal./ft.² - 0.232 gal./ft.²</td>
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<tr>
<td>Powder coating (bottom side)</td>
<td>0.232 gram/ft.² - 0.464 gram/ft.²</td>
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<tr>
<td>Powder coating (top side)</td>
<td>6.5 gram/ft.² - 7.43 gram/ft.²</td>
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<tr>
<td>Natural gas</td>
<td>285 BTU/ft.² - 415 BTU/ft.²</td>
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<tr>
<td>Electric energy</td>
<td>0.0325 kWh/ft.² - 0.0464 kWh/ft.²</td>
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<tr>
<td>Production output*</td>
<td>6,500 - 8,600 ft.²/h</td>
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<tr>
<td>Operators:</td>
<td>2 people</td>
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*Substrate thickness determines actual production output.

Table I. Material consumption for typical postforming line.
Postforming delivers faster cycle times in approximately the same floor space, allowing more productivity in the same space or similar productivity in considerably less floor space. For example, one postforming powder coating line is 250 ft. long, 9 ft. wide, and 8 ft. high. The total floor space requirement for the line and storage space for up to three days of production is just 8,600 ft². Because blanks can be stored flat until they are ready to be assembled, valuable floor space is not taken up by bulky parts. Orders based on a particular color can be filled more quickly when pre-coated blanks are available and ready for forming and assembly.

The manpower requirements of an automated postforming line are substantially lower than those of other systems. Use of highly automated technologies enables some lines to operate with only two technicians. Color changes are handled with a minimum of downtime and manpower.

CONCLUSIONS

Environmental issues and the drive toward higher levels of productivity have presented industry with an opportunity. Postforming lines that are now in service demonstrate that postforming of powder coated flat blanks is an efficient, cost-effective, and environmentally beneficial technology. The continuing challenges presented by environmental regulations, productivity demands, and quality objectives open the way for the use of this new technology in a growing number of applications.

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