UV-Powder Coating Process for MDF

The Basics from Start to Finish

By Jennifer Heathcote

Introduction

Industrial powder coating, which until recently has been limited to mostly metal products, has grown into a widely accepted technology during the past twenty years. The introduction of ultraviolet (UV)-curable powder coatings, along with recent advancements in their formulation, have now expanded the capabilities of powder coating applications to include materials such as wood, plastic and other heat-sensitive assembled components. One industrial segment that is now benefiting from these latest developments is the coating of medium density fiberboard (MDF) products. In order to promote this UV application to the wood industry and to powder coaters looking to expand their coating capabilities, this article will address the advantages of UV-powder coating and explain the process as it relates to MDF.

Advantages of UV-Curable Powder Coating

As the previous twenty years have demonstrated, there are several advantages associated with conventional-powder coating technology. The powders, for example, contain no solvents and no volatile organic compounds (VOCs). As a result, powder coating is a highly promoted, environmentally friendly technology where up to 98% material utilization is possible due to the recoverable and reusable capabilities of the powder and the powder coating equipment. In addition, powder coatings provide excellent wrap-around coverage and are easily applied. Compared with liquid sprayed coatings, powder coatings can result in a thicker, single coat film build. Finally, the cured coating has an extremely durable finish that adheres well to the substrate.

Once standard powders are reformulated to cure with exposure to UV radiation, several more process, economic and finish advantages are realized. First, with UV-powder curing, the melting and flowing of the powder and the curing of the powder are separated into two sequential steps. As a result, the variables for melting and flowing the powder and then curing the powder can be more precisely controlled and tailored to the respective needs of the individual process. The overall cycle time is also significantly reduced with a UV-curable powder as compared to a conventional powder. In fact, the processing of a raw part to a UV-cured state can occur in just a few minutes. This is a small fraction of the time that it would take to thermally cure the same part. This reduction in cycle time directly correlates into economic savings. An additional economic benefit related to the reduced cycle time is that the processing oven, compared to ovens used for thermal curing, requires less floor space. The speed and effectiveness of UV-curing also makes it possible to achieve a lower board processing temperature and a lower board finish temperature while greatly reducing the percentage of heat-damaged parts. The lower temperatures and reduced dwell times are the key factors that make powder coating possible for heat-sensitive products. In comparison to thermally cured coatings, UV coatings also provide a superior coating hardness along with increased resistance to scratching, impact damage, stains and chemicals. Finally, when a UV-curable powder is applied to MDF, the need for edge banding may be eliminated due to the wrap-around effect of the charged powder particles.

UV Powder Formulation

The appearance, texture and consistency of uncured UV powder is very similar to uncured conventional powder. In fact, both types of powder contain resins, pigments and additives. Resins provide the molecular integrity for the polymerization process and compose the largest portion of the powder formulation. Pigments are employed to provide color, while various additives are used for characteristics such as gloss and texture and to obtain specific coating performance properties. In addition to resins, pigments and additives, UV powders also contain photoinitiators. Photoinitiators represent just a small percentage of the overall powder composition. Photoinitiators, which respond to certain wavelengths of UV energy, are responsible for starting the polymerization process of the coating.

UV powders for MDF are available in a wide range of colors, tones, glosses and textures. They can also be shipped, handled and applied in the same fashion as conventional powders and should be stored in an air-conditioned room with humidity controls. MDF powders are specifically formulated to adhere to the MDF when the surface temperature of the MDF product is elevated to within 130°F and 150°F. Once applied to the MDF, the powders will typically flow out when they are heated to temperatures between 210°F and 230°F. Depending on the process oven and the specific powder formulation, the powder should completely melt and flow out within 1.5-3 minutes when exposed to these temperatures. It will then cure under UV exposure within seconds. It should be noted that the temperatures and dwell times referenced in this article are generalities only. The values will vary slightly depending on the powder supplier's formulation, the desired finish requirements and the capabilities of the process equipment.

MDF

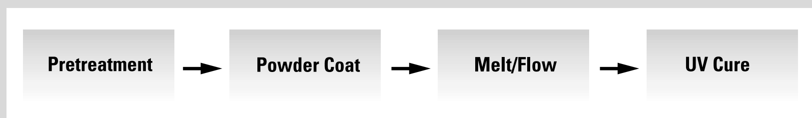
Although UV powders can be applied to both solid wood and engineered wood substrates such as particle board, low density fiberboard (LDF), MDF and high density fiberboard (HDF), the greatest focus has been on MDF applications. The MDF concentration is due to the fact that the best cosmetic finish is presently being achieved with MDF substrates as compared to other engineered woods and solid wood.

The condition of the MDF board plays an important role in establishing the process variables for UV-powder coating. It should be emphasized that it is possible to UV-powder coat most MDF boards; however, there are certain general trends that make some boards easier to coat and better candidates for producing a very attractive finish. For example, the easiest MDF boards to UV-powder coat are lower density, thinner boards. In general, the less dense the MDF board, the lower the risk of cracking, and the less out-gassing to overcome. It is also easier to achieve a more uniform board temperature and, therefore, a better cosmetic finish with thinner boards. The moisture content of the MDF also affects the degree of attraction between the powder and the board. For this reason, the storage of the MDF is very important. MDF should not be stored in locations where it will either gain or lose excessive amounts of moisture. Finally, the edge and surface conditions of the board determine how much pretreatment and powder film build is required to produce the desired finish.

Process Overview

The UV powder coating and curing process consists of pretreatment of the MDF, applying the powder, melting and flowing the powder, and finally curing the powder through exposure to specific bands of intense ultraviolet light. These four stages are illustrated in Figure 1 and explained in greater detail in the next several sections of this article.

Figure 1: UV powder coat and cure process



Pretreatment of MDF

The pretreatment for MDF includes sanding, air blow-off and preheat. Because wood fibers protrude from raw MDF, they need to be eliminated for a smooth surface. The desired smoothness of the coated surface will dictate how much sanding is required. In fact, the more sanding that is administered to the MDF, the smoother the final finish will be. For textured coatings, sanding may or may not be required. If cost is a factor or if there are process time constraints, sanding may be eliminated; however, the cosmetic finish will not be as appealing.

After sanding the MDF, the product is blown off with air to remove all sanding dust and is then preheated. The temperature of the MDF product needs to reach approximately 200°F to 250°F in order to remove excess moisture and produce a substrate condition that is conducive to attracting and holding powder. Parts usually exit the oven with a surface temperature between 220°F and 225°F. Lab experimentation and production evaluations have indicated that convection heating is the most effective method for preheating the MDF. Convection heating consistently raises the board temperature from the inner core to the outside edge. In addition, the air velocity found in convection heating helps to minimize and even eliminate out-gassing of volatiles from the wood.

Variables involved in the preheat stage include the air velocity, the oven dwell time, and the oven temperature. The air velocity is dependent on the oven design while the dwell time is a factor of the oven size and the production throughput requirements. The necessary oven temperature is primarily determined by the powder formulation and the moisture content of the MDF; however, it is important to consider the distance between the preheat oven and the powder application booth along with the conveyor speed. Because the board temperature will begin to drop when exposed to ambient air, it is critical to account for the transport time to the powder application booth.

Powder Application

In conventional-powder coating, powder particles are positively or negatively charged and then directed toward a conductive metal product that is grounded. The charge is applied to the powder through either induced friction, referred to as Tribo charging, or a corona field, called Corona charging. The coated object is then baked in an oven to thermally cure the powder.

Just as a metal object would need to be grounded when powder coated, so should an MDF product. Because wood is not a highly conductive substrate, the process relies on the moisture within the wood to attract and hold the electrostatically charged powder particles. As mentioned in the previous section, it is recommended that the part be preheated so that excess moisture is driven off and the powder will start to melt when it contacts the board.

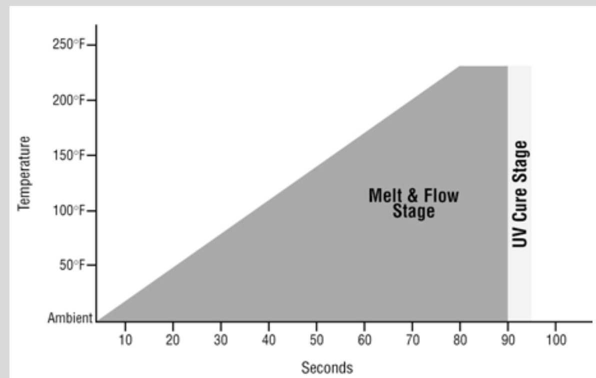
Because the charged particles will tend to wrap-around the part, the best cosmetic appearance is achieved by coating the backside of the product first and then the sides and front. Depending on the substrate type and the surface preparation, it may be necessary to apply a film build that is two to three times as thick on the edges as on the faces. Typical film builds on the faces of the product are three to five mils. As with conventional-powder coating, factors influencing the film build include the powder flow rate, substrate position, location of gun centers, oscillator speeds, nozzle patterns, gun triggering and equipment controls.

UV powders are applied and re-circulated using conventional-powder application equipment, booths and reclaim systems. The details of the equipment and the application and recovery processes, however, will not be covered in this article. Numerous books and articles have already been published in great detail on this subject matter and could not properly be summarized in a few paragraphs. For assistance in locating these publications or powder specific trade journals, please contact a powder equipment supplier.

Melt/Flow Process

The powder will immediately begin to flow once it is applied to the preheated MDF. The melting and flowing of the powder is referred to as gelling and the gelled powder is called the molten film. To completely gel the powder, it is necessary to expose the coated part to a second heat source and elevate the temperature of the powder and product surface to between 210°F and 230°F. The powder should completely gel within 1.5-3 minutes; although, the exact gel time and temperature will depend on the process oven, the specific powder formulation, the film build and the product style. The temperature of the molten powder film with respect to time is illustrated in Figure 2.

Figure 2: UV-powder cure process



The oven employed to melt and then flow the powder is referred to as the gel oven or the melt/flow oven. It can be convection, infrared, or a combination of the two. Convection is effective at heating the inner core of the board first and then gradually raising the temperature of the board all the way to the outside edge. Infrared, on the other hand, will heat the surface of the board first and then work its way to the inner core. Lab experimentation and production evaluations have indicated that combination heating is the most effective method for evenly gelling the powder.

UV Cure Process

For most potential users, the UV equipment, set-up, process and safety issues are probably the most unfamiliar aspects of the UV-powder curing process. A basic understanding of these elements, however, will greatly facilitate the introduction of UV curing into new powder coating markets.

Equipment

An industrial UV system consists of a power supply, lamp head, bulb, reflector, and cooling mechanism. The components can be described as follows:

- **Power supply—**The power supply provides the electrical energy to the UV bulb. Transformer, ballast and solid-state power supplies are all available. For some UV systems, the power supplies are modular and can be networked together to power multiple UV lamp heads. For other UV systems, the power supplies can be combined inside a single electrical cabinet and then independently wired to multiple lamp heads.

- **Lamp head—**The lamp head is an assembly that holds the UV bulb and reflector and is engineered for proper airflow and cooling.
- **UV bulb—**The bulb is a sealed quartz tube that contains a medium-pressure mixture of mercury and inert gas. The mixture emits UV light when it is vaporized by either a voltage arc or microwave energy. A standard mercury bulb provides a certain spectral output. Variations in output can be achieved by adding elements such as iron, gallium or indium to the gas mixture. Although UV bulbs are available in a variety of lengths, combinations of 10" cure bulbs are the most practical for vertical powder curing applications while both 10" cure and longer length bulbs can be used for horizontal curing applications.
- **Reflector—**The reflector is rolled from highly polished aluminum sheet metal or formed from borosilicate into elliptical or parabolic profiles. An elliptical reflector will provide a highly focused and narrow band of UV energy that is concentrated at a specified distance from the UV lamp head. A flood reflector, on the other hand, produces an unfocused, wider band of UV energy. Holes and slots in the reflector or gaps between a pair of reflectors allow cooling air to pass through. The holes or slots are engineered for size and location to provide both optimal and balanced airflow across the length of the bulb.
- **Cooling mechanism—**The cooling mechanism is used to cool components in the lamp head, maintain a consistent bulb temperature for optimal UV output and remove infrared energy, which is a by-product of the UV process. Cooling fans can either be mounted directly on top of the lamp head assembly or mounted remotely and ducted into the lamp head.

Set-up

UV curing is based on line-of-sight orientation of the lamp heads around the part. In other words, the lamp heads need to be mounted around the profile of the part so that a continuous band of UV light is directed onto the product. Because the light only needs to contact the part for about a second, the part being coated is typically passed through the UV light using a conveyor.

The lamp heads should be located between two and eight inches from the product surface. The exact location is determined by the requirements of the powder, the line speed, the part configuration, the lamp head power output and the number of lamp heads.

Intensity, also known as dose rate or watt density, is the amount of UV energy delivered to a particular area of the part per unit time. The units are joules/cm^2·sec or watts/cm^2.

Figure 3: Mercury

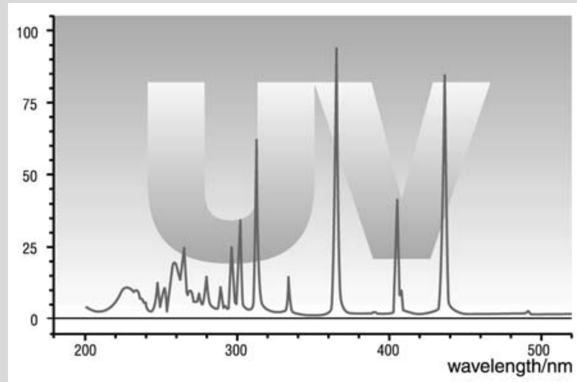
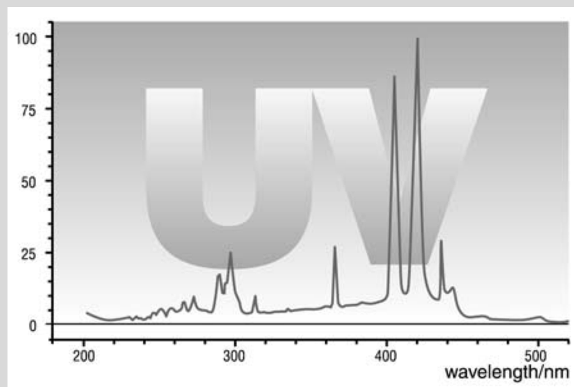


Figure 4: Mercury Gallium



Dose is the total amount of UV energy delivered to a particular area over a period of time. Both the intensity and dose requirements of the powder formulation are important in setting up the UV equipment and determining the number of lamp heads and the power output of the lamp heads.

Spectral output efficiency graphs for mercury vapor bulbs and mercury/gallium vapor bulbs are provided in Figures 3 and 4 respectively. The graphs show the relative percentage of UV intensity (watts/cm^2) at various wavelengths for a particular bulb type. The concentration is provided as a normalized percentage where the energy is integrated over segmented wavelength bands. In other words, the maximum measured intensity from all sampled bands is set to 100%, and the lower intensity values are shown as a percentage of this maximum value.

For powder applications, it has been determined that a gallium and mercury combination of bulbs provides the best curing results; although, some thin powder films and clear coats may require a mercury bulb only. A mercury bulb emits a bright white UV output with a peak spectral intensity around 365 nanometers (nm) and a secondary UV concentration around 254 nm. Mercury bulbs provide excellent surface cure but cannot always penetrate through the thick film builds and pigments used in powder coating.

As a result, longer wavelength gallium bulbs, which produce a violet colored UV output and have a peak spectral intensity around 417 nm, are used for the deeper cure. In general, longer UV wavelengths penetrate further through the coating.

Process

After the powder-coated part passes through the melt/flow oven and is gelled, it can be cured in a matter of seconds using intense UV energy. In general, ultraviolet light is radiant energy in the wavelength band between 200 and 450 nm. During the cure process, the UV light is absorbed by the powder's photoinitiators, which in turn begins the polymerization reaction.

To obtain the optimal cure, the MDF should be passed in front of a lamp head containing a gallium bulb first and then a lamp head with a mercury bulb. As mentioned previously, the gallium bulb will provide a deep through cure while the mercury bulb will provide a hard-surface cure.

Safety

Two safety issues to note with respect to the UV equipment are UV exposure and ozone. Because ultraviolet light is a form of electromagnetic radiation, caution should be taken to safeguard operators from direct exposure to the eyes and skin. The light generated from UV lamps can be harmful if operator exposure exceeds recommended levels. All equipment or areas of UV usage must be adequately guarded, shielded and interlocked to prevent any accidental operator exposure.

Ozone (O_3) is a colorless gas with a penetrating odor that is generated by the reaction of short-wave UV light (≈184 nanometers) with air. Excessive exposure to ozone will cause headaches, dizziness and fatigue. It will also irritate the mouth and throat and, in some cases, can lead to respiratory infections. OSHA requires that the threshold limit value for ozone in the atmosphere of the facility not exceed 0.1 parts per million (ppm).

The ozone generated by the UV equipment is very unstable and will quickly revert back to breathable oxygen when exposed to atmospheric air. Ozone should be removed from the UV oven via a sealed duct and discharged to atmosphere according to local regulations. The discharge location should be away from pedestrian walkways and window openings and should be well above the average human breathing height for the area.

Measuring Finish Quality

There are several testing methods that are employed by material formulators, equiptment labs and end-users as a means of evaluating cure and finish quality. These tests include procedures for measuring gloss and adhesion along with resistance to abrasion, impact, scratching and chemicals. Some of these tests are referred to as cross hatch, boiling water, pencil hardness, ball drop, taber abrasion and MEK rub. Material formulators and customer labs should be able to help in the selection and demonstration of tests most suited to the production application and the finished product's performance requirements.

Material Handling

Material handling methods for transporting the product through the various stages of the UV-cure process consist of monorail or overhead conveyor, chain-on-edge conveyor or flatline conveyor. For parts less than 6" thick that need coating on all sides or on select sides where wrap-around is not an issue, an overhead conveyor works best. For parts that only need to be coated on one face, with or without edge coverage, or for parts that are thicker than 6", a flat line conveyor may be used. For rounder, more complex 3-D parts, a chain on-edge conveyor or an overhead conveyor with part rotating mechanisms are typically utilized so that a full 360° of each part can be exposed to the powder-application equipment and the UV lights.

Typical line speeds for UV-powder applications range anywhere from a few feet per minute up to 30 ft/min. and are dependent on factors such as through-put, powder formulation, oven design and UV-power output. It is highly recommended that all new applications be tested in one of the various customer demonstration facilities located in the labs of material formulators and equipment suppliers.

Conclusion

UV-powder coating on MDF is a relatively new process that utilizes established coating and curing technology in ways that only a short time ago were not possible. The opportunities and advantages of powder coating MDF along with the quality of the finished products being coated are generating incredible excitement in the wood products industry. As new materials continue to be developed and the cure process is further defined, many manufacturers will investigate this process as an alternative to current practices and as a potential for future growth. ■

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