PROCESSING INSTRUCTIONS VR 218

Use of convection ovens for heat-sensitive substrates

Processing guideline for cross-linking of powder coatings on heat-sensitive substrates using convection technologies

IGP POWDER COATINGS

IGP Pulvertechnik AG
Ringstrasse 30
9500 Wil, Switzerland
Phone +41 71 9298111
Fax +41 71 9298181
igp-powder.com
info@igp-powder.com

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Introduction

The use of infrared technology – with or without additional convection – is a well-established and proven method for cross-linking powder coatings on heat-sensitive substrates like solid wood, plywood, fiberboard, and similar materials. The challenges here lie in ensuring uniform heating of all substrate surfaces and achieving a sufficiently rapid heating rate to prevent thermal overload of the substrate core.
Because infrared technology requires careful control to heat complex shapes evenly, IGP Powder Coatings has developed a process that uses convection as the main energy source. In this process, an infrared heat source is used briefly at the beginning of the curing process.
The implementation of this process in existing systems, as well as its integration into new coating plants, is described below.

Basic Principle

Infrared technology has become the standard for heat-sensitive substrates because it can quickly radiate a large amount of energy onto the surface. This enables a rapid heating rate (about 1–2 K/s) on the substrate's surface while preventing its core from overheating.
In the past, convection systems struggled to achieve sufficient heating rates. However, it was found that effective airflow management allowed these systems to provide more uniform heating of the workpiece.
Therefore, to improve the heating rate with convection systems, we have developed a two-stage curing process:
In the first step, sufficient energy transfer to the substrate is ensured by using a high circulating air temperature and, if necessary, a high air velocity to achieve heating rates between 0.75 and 1 K/s. These rates are sufficient for reliable cross-linking of the powder coatings without overheating the substrate core.
In the second step, the component is moved to a zone with a lower air temperature and/or lower air velocity. In chamber ovens, only the air velocity is significantly reduced.
This prevents further heating of the substrate while still providing enough energy to maintain the required object temperature.
After the necessary retention time, the workpiece can be removed from the oven. In this case, the required object temperature and retention time match the specifications in the technical data sheet.

Advantages / Requirements

The initial costs for infrared technology are significantly higher than those for convection systems.
Therefore, minimizing the need for infrared zones is especially cost-effective for new installations. Infrared ovens contain multiple zones that can be controlled separately, making them complex for operators to manage – especially when coating parts with intricate shapes or using shades with wide variations in brightness.
By contrast, circulation ovens are simpler, requiring only the adjustment of the circulating air temperature and air velocity. These parameters are straightforward and easier for operators to understand. Unlike infrared systems, convection heating does not produce varying results when different powder coatings (e.g., white or black) are cured.
This makes training and setup easier for plant operators.

This process also allows existing systems to be retrofitted to handle both heat-sensitive substrates and metals.
All that is needed is a preheating option (see next section) and, if necessary, an infrared booster zone.
For manual coating applications, a skilled coater with the necessary training is sufficient. For automatic coating, a plastic booth (metal booths do not achieve the necessary electrostatics) with retrofittable counter-electrodes is required. The correct settings must be established, and the coaters must be trained accordingly.

For new installations, cost savings can be realized through lower investment expenses.
Both new and upgraded coating plants can be used to coat metals and heat-sensitive substrates, making this a viable way to open up new markets and spread investment risks.
Additionally, convection systems are easier to operate, as fewer parameters need to be adjusted and monitored, thereby reducing the likelihood of errors.
However, each system should be evaluated individually to determine the optimum setup.

Practical Implementation

General preheating requirements:
Wood substrates or fiberboards generally need to be preheated as part of the coating process. Our experience has shown that infrared technology delivers the best results for this.

General:
When using existing ovens, it is crucial to first check and, if necessary, correct the airflow in the oven. It is essential to ensure a uniform air velocity and temperature distribution throughout all areas of the oven. Uneven temperatures or air velocities will prevent proper cross-linking on heat-sensitive substrates.
Once these parameters are confirmed, measurements can begin using a test plate that matches the material and geometry of the final workpiece. The oven must be fully pre-heated for this process. Additionally, the circulating air temperature must be significantly higher than the required object temperature of approximately 130°C. For MDF substrates (depending on their thickness, e.g., 15–25 mm), we recommend an initial circulating air temperature of around 210–230°C. For solid wood, lower values may be required depending on the type of wood.
Higher air velocities will improve the heat transfer from the air to the substrate, leading to faster heating rates. However, it is important to prevent the unmelted powder from being blown off the substrate. Using a simple IR zone before the circulation oven helps to slightly "tack" the powder to the substrate, preventing it from being blown off and allowing for higher air velocities.
Ideally, a heating rate of about 1.5 K/s should be achieved. However, values between 0.7 and 0.8 K/s are sufficient.

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Example calculation for the heating rate:
The component enters the oven at room temperature (20°C). The target object temperature is 130°C, so the required temperature increase is 110°C (130°C - 20°C). Since a difference of 1°C is equivalent to a difference of 1 Kelvin [K], the temperature difference is therefore 110 K. This 110 K is then divided by the measured time until this temperature is reached. For example, if it takes 2.5 minutes, this is equivalent to 150 seconds. Thus, 110 K / 150 seconds = 0.733 K/s.
This value falls between 0.7 and 0.8 K/s and is therefore sufficient.

If heating rates below 0.7 K/s are measured, the circulating air temperature or air velocity (if possible) must be increased further.
If an adequate heating rate cannot be achieved even at the highest possible air temperature, the use of convection alone is insufficient.
In this case, an infrared gelling or booster zone is required to reach the desired temperature.

In addition to the heating rate, it is also important to ensure that there are no significant variations in temperature (<5°C) or heating time (no more than 10–15 seconds to reach the target object temperature) between the individual sensor positions.

Once the heating rate and a uniform temperature distribution are ensured, the process can move to the second step: maintaining the temperature. For this step, various options are available for both conveyor and chamber ovens:

Chamber ovens:
Due to the slow response time when controlling the air temperature in chamber ovens, the quickest way to adjust the temperature profile is by reducing the air velocity, which in turn decreases the heat transfer rate. It may also be necessary to simultaneously lower the set target temperature.
This adjustment should ideally be done via a programmed control system to ensure a consistent process.
For initial trials or simpler ovens, it might be sufficient to turn off the oven once the necessary object temperature is reached. However, in this case, you can no longer influence the temperature profile.

Conveyor ovens:
Conveyor ovens that do not allow different circulating air temperatures or air velocities to be achieved in the first section compared to the rest of the oven are unsuitable for this process without the use of the aforementioned gelling or booster zone. Without control over the air temperature or velocity, heating cannot be stopped and overcuring of the powder cannot be prevented.
In conveyor ovens with multiple temperature or air velocity zones, the heating rate must be adjusted in conjunction with the conveying speed. It is important to set the conveying speed so that the object reaches the target object temperature at the required heating rate when transitioning between different temperature or air velocity zones.
Once this is achieved, the air temperature and velocity should be significantly lower in the subsequent zones.

Regardless of the oven type, the settings for the second process step must ensure that the substrate neither cools down nor continues to heat up. Additionally, especially in conveyor ovens, the maximum specified retention time must not be exceeded.
During the retention time, the measured temperature of the workpiece should not deviate from the recommended value by more than +/-4°C.
If these conditions are not met, the varnish may be undercured or the substrate may experience excessive stress (causing blisters, cracking, etc.).

Provided that the above points regarding heating rate, uniformity of heating, and retention time are adhered to, this process can produce surfaces that are equal to or, in some cases, superior to those achieved via conventional cross-linking in an infrared oven.

Other Applicable documents

Technical information: TI 111 Technical process recommendations for powder coating MDF

Note

This processing information is provided to the best of our knowledge. However, it only represents non-binding information and does not release the user from the need to perform their own tests.
Application, use and processing of the products take place beyond our control and are therefore exclusively the responsibility of the user.