Real-time control of powder coating

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Abstract

Powder coating on MDF is still largely intuitive and experience-based. Processes are tuned until the result meets the requirements, which currently is assessed visually or destructively. The Swiss company Winterthur Instruments has developed the coatmaster, based on a thermal measuring method called Advanced Thermal Optics, which for the first time accurately measures layer thickness of uncured powder on MDF in a noncontact and non-destructive manner. Thanks to the measurement of the uncured powder early in the process, online quality assurance can be carried out. Faulty production items are detected before they enter the curing process and appropriate measures can be taken. It allows a real-time control of the coating process as well as 100% quality documentation. The quality requirements of the customer are guaranteed for each component.

The current miniaturization of technology and the automation of measurement processes offer even further potential for process control. Overall, the use of this system leads to an increase in the production efficiency and provides significant savings of powder material.

Process of powder coating of wood materials and related challenges

Powder coating is state of the art for many industrial applications, especially in the high-end furniture and interior fittings where beautiful and highly resistant surfaces are demanded. Powder coating of wood-based materials, as well as solid wood, was so far just a niche product. Development in powder coatings for temperature sensible materials and new application technology make these products available to a bigger market.

Current developments are particularly new low–bake powders [1], systems for one-layer coating on MDF and new technologies to apply powder to non-treated MDF. These factors improve the powder coating technology toward a better process stability, reliability and also reduced production cost. These are reasons why market leaders and wholesalers are switching their product portfolio from water-based lacquers to powder coating [2] [3]. In this context new large production lines are put into operation, setting milestones in process cycle time and profitability. The technology now is very competitive. It provides additional advantages in VOC-free building materials and functional characteristics.

However, powder coating of MDF and solid wood is still a very complex process, depending on many parameters (e.g. temperature, humidity, air drafts, etc.). Currently some of them cannot be controlled by the production equipment or by the operator, e.g.:

- Preheating and curing ovens are crucial for the final quality and the durability. They are influenced by environmental factors and fatigue. Therefore, a simple recall of process parameters can only be used as starting point for a new charge.
- Wood based materials are usually conditioned to get an optimal humidity for a high-quality coating. However, conditioning the workpieces is never uniform, especially on edges and specially milled geometries like milled pockets or sloped edges.
- The conditions of the powder are changing over the storage-time and at lower lever over the process-time.
- The climate conditions in the production are changing over the course of a working shift. These climate changes and the absorbed energy of the ovens influence the environment inside the production site.
As result of these fluctuating conditions and the geometry of the workpieces, the thickness of the powder layer is not uniform over the workpiece and also not constant over the time of production. A systematic inspection of the coating is essential to control the process and meet the high-quality requirements. Therefore, a stringent documentation of the quality control by the coater is necessary. The current method for measuring coating thickness after curing requires a destructive measurement technique (see below) with a wide range of interpretation. Furthermore, due to the destructive nature of this technique, only non-shipped items can be tested. Consequently, workpieces with suboptimal layer thickness are not detected before shipping.

Today the process control is based on experiences of the operator and the long-time experiences of the company. The evaluation of new process parameters often requires valuable production time and expensive workpieces to achieve a satisfactory result. Coating thickness is not measured before the powder is cured (for example with the destructive wedge cutting test, Fig. 1). So today the time to get a reading is too long and costly.

![Image of measurement with thickness gauge PAINT BORER](source: Bern University of Applied Sciences)

It is thus apparent that to achieve a constant quality, the coating thickness has to be checked not only on samples but on the whole production, at short time intervals. These measurements can then be used to detect and correct deviations in a closed-loop process.

To realise a short closed-loop for the powder application, Winterthur Instruments AG developed the coatmaster – device to measure the thickness of the uncured powder directly after the application.

**Noncontact inline thickness measurement with coatmaster**

The coatmaster finally allows to measure the layer thickness of uncured powder on MDF and other wood-based materials in a noncontact and non-destructive manner. coatmaster technology is based on the measurement principle of Advanced Thermal Optics (ATO). In this method, the layer to be measured, is heated in a pulsed manner by a computer-controlled light source. The surface temperature diminishes with a characteristic dynamic which depends on the layer thickness and the thermal properties of the coating. A high-speed infrared detector in the ATO optics records the resulting surface temperature profile from a distance. Proprietary algorithms analyse the dynamic temperature profile on the surface and determine the layer thickness and other properties quantitatively and reproducibly [4].

The coatmaster technology is available in the following products: The coatmaster Inline, a device for continuous use in industrial production environments, and the coatmaster Atline, a compact device, suitable for manual measurements in labs and measurement stations next to production lines (Fig. 2).
Measurement Setup

As mentioned above, the coatmaster measuring system is based on Advanced Thermal Optics. After application of thermal energy, the device measures the temperature profile of the surface. Because the coating thickness significantly influences the temperature curve, the layer thickness can be extracted from the temperature curve. The measuring technique is suitable for non-destructive measurement of the layer thickness on finished as well as cured coatings.

This is made possible by calibrating the system in advance to compensate the composition of the powder coating. The calibrating procedure is based on referencing manual wedge cutting measurements with the coatmaster results. Usually, about three examples with various coating thicknesses are sufficient.

Before starting a coatmaster measurement, the corresponding calibration can be selected. Now the device is ready to measure in line, non-destructive and delivers thickness measurements in real time.

While the system is already state of the art in metal coating plants, first industry-oriented studies to use the device in the wood industry have been carried out at Berne University of Applied Science. Especially the non-destructive forecast of coating thickness immediately after powder application turned out to be very valuable. The thickness forecast of the coatmaster measurement is within a range of +/- 10 µm of the subjective wedge cut method, covering the needs of quality control at this stage.

Examples for use of coatmaster for production control and documentation

The coatmaster can be implemented in different integration depths, according to the requirements of the coating production facility. Integration options range from a mobile measurement station, to an installation with automated positioning, optionally connected to the powder coating application equipment for an automated closed-loop production system.

Mobile measurement station for quick-and-easy real-time thickness measurement

An easy and cost-effective integration is to use the coatmaster on a mobile measurement station. The mobile measuring station has the Coatmaster mounted on a manually adjustable lifter. Measurement values are displayed on an industrial touch PC mounted on a swivel arm directly on the lifter frame. Using this measurement station, the operator can either manually measure parts out of the line, or she may position the measurement station at the coating line, directly after the exit of the powder coating booth. In this setup, a sensor detects if a part is in position and accordingly triggers a coatmaster
measurement at the manually fixed height on the panels (see Fig. 3). The system can be setup without interrupting the line. Measurements are taken on moving parts, thus also no process interruption is required for the measurement.

![Diagram of measurement positions with mobile coatmaster measurement station at fixed height.](image)

Figure 3: Measurement positions with mobile coatmaster measurement station at fixed height. The height can be adjusted manually to gather information over the height of the MDF panels.

Swing and movement of the panels have no effect on the measurement. The thickness values are displayed on the screen and can be downloaded for quality documentation and to access process statistics. An optional LED signaling lamp displays if the coating thickness is ok (green), in warning range (orange) or in error range (red). The error signal can be combined with an acoustic alarm to draw operator attention.

Such a system supports the operators in setting up production process and ensuring constant production, detecting out-of-tolerance coating thickness and thus avoiding costly reworks.

**Installation with automated vertical positioning of coatmaster**

In this integration example, the coatmaster Inline measuring optics is mounted on a vertical motorized axis, programmed for continuous up-/down movement cycle. Sensors detect panels in the measuring area for automated triggering. This setup provides thickness data over the entire height of the parts, see Fig. 4.

![Diagram of measurement positions with vertically automated coatmaster measurement.](image)

Figure 4: Measurement positions with vertically automated coatmaster measurement. Height of the position is adjusted automatically.

Using this data, operators can control their production and correct deviations as they are detected. The continuous measurement also can be compiled into measurement reports. These reports can support quality assurance documents to gain confidence in the production, also be end-users of the coated parts. In addition, the data is valuable for analyzing and optimizing production, adjusting the coating equipment and to determine optimal coating equipment maintenance intervals (which may vary according to environmental conditions).
Closed-loop production control

The coatmaster can be connected to the coating application controllers. The manual adjustment of the application parameters is thus replaced by the automatic adjustment of the powder guns. This allows for an autonomous coating line operation, with minimal operator interaction required.

**Figure 5:** Principle of closed loop for the Thickness control (Source: Bern University of Applied Sciences) with a loop “time” of only some meter feed and a measurement time of less than 1 s

Conclusion

The automatic thickness measurement enables to optimize the use of the production capacity. Already in the easiest integration with a mobile measurement station, significant savings in powder coating material is achieved and measurement data is available for quality documentation. Through the closed-loop control of the powder application, the coating continuously corrects deviation and is thus always on target. This leads to considerable savings in the quantities of powder used. Manual adjustments and thus error sources are reduced, and the coating line can operate with minimal supervision for extensive lengths of time.

Outlook

For narrow surfaces/edges and special geometries the coating thickness is often critical but not easy to access with automated inline measurement systems. For very flexible measurement, coatmaster Flex (Fig. 6), also based on the non-contact Advanced Thermal Optics technology was developed. The coatmaster Flex is designed for manually guided measurements, allowing the user to easily scan even complex surfaces. The device is currently being tested for MDF at the Berne university of applied science.

**Figure 6:** coatmaster Flex for wireless and flexible noncontact measurements of powder coatings before curing (source: Winterthur Instruments AG)
Literature

[1] Technisches Merkblatt IGP-RAPID®, IGP Pulvertechnik AG