Electrostatic Powder Coating

ITW Gema

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1 Introduction

Electrostatic powder coating is one of the most environmentally friendly and economical technologies in surface treatment. Since the early 60's, powder-coating paints have been available on the market and their problem-free production and processing made powder coating a well-established and commonly recognized technique. In fact, powder coatings are

- environmentally friendly
- energy-saving
- safe to handle and process
- highly economical.

New developments focus on thin-film powders, powders for specific applications and radiation curing systems.

2 The basic principle

Electrostatic powder coating is based on the fact that particles with opposite charges attract each other. This is why most of the conductive and thermally stable solids are suitable for powder coating. Today, electrostatic powder coating considerably increases its presence in the domain of metallic objects such as:

- aluminum profiles
- façade elements
- household appliances
- automotive accessories (e.g. rims, roof racks)
- office furniture
- storage equipment
- outdoor furniture
- wire products etc.

Hence, everybody comes into contact with this technology every day.

The powder coating process:

Dry coating powder is filled in a hopper, fluidized or stirred and subsequently transported by means of compressed air via injectors to the powder gun. In this gun, high voltage is created from a low voltage of 10V utilizing the cascade principle. During the spraying process, one or more electrodes charge the powder with 60 - 100 kV.
An electrical field is generated between the gun and the grounded

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workpiece. The powder particles follow the field lines and, due to the residual charge, remain bonded to the object (3). Once coated, the workpieces are either manually or automatically transferred to a curing oven. Plastic powders are cured at temperatures between 140ºC and 200ºC, fusing into a smooth coating with layer thicknesses of 30 - 80µ for decorative and 200 - 500µ for functional purposes.

Enamel powders may be applied in a layer thickness range of 80 - 200µ, requiring sensitively higher curing temperatures varying from 780°C to 830ºC due to their specific chemical properties.

3 The Powder

3.1 The manufacturing

Powder coatings typically contain:

- binders (resins, hardeners, accelerators)
- pigments and colorants
- fillers (extenders)
- additives

Binders and hardeners are solid resins and also additives are solids. All ingredients of the formulation are weighed out and pre-mixed in a special machine. In the subsequent extruding process, the blend is melt at 100°C - 120°C and dispersed, resulting in a homogenous melt. After being conveyed over cooling rollers and a cooling belt for final cooling, the material is broken into small flakes, ground and finally packaged. At this stage, the product is ready for use and will be applied in its dry state by the customer, the end-user of the powder.

3.2 The powder types

3.2.1 Epoxy resin powder

Epoxy resin powders exhibit good chemical resistance to solvents, acids and alkaline liquids.
A predominant disadvantage of epoxy resin powders is their chalking and yellowing tendency when exposed to UV light. Chalking does mean loss in aesthetics, but not in anti-corrosive benefits.

Today, epoxy powder coatings nearly exclusively serve in the functional domain, e.g. in the electrical and electronic industry, for automotive parts, fittings, reinforced iron, pipe coatings, etc.

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3.2.2 Epoxy/polyester powder (hybrids)

Epoxy/polyester powders, as the name already says, are a blend of epoxy and polyester resins. Featuring better resistance to yellowing and a reduced chalking tendency compared to pure epoxies, these powders are preferably used for decorative purposes. Further application fields for hybrids are ceiling elements, lights, metal furniture, shop fittings and shelving etc.
A disadvantage is the poorer resistance to solvents in comparison with pure epoxy resin powders.

3.2.3 Polyester/TGIC

Polyester resin powders are used when superior non-chalking and weather-resistant properties are required. Their advantageous mechanical characteristics as impact resistance and good adhesion allow ulterior processing as sawing, drilling or milling. Polyester resins are typically applied to aluminum or steel for outdoor purposes, in particular in the automotive sector, for façade elements, window profiles or high-quality garden and camping furniture. This type of powder is making increasing inroads into the interior decoration market where superior yellowing and chalking resistance is favored.
As TGIC is classified a toxic substance, mandatory labeling applies to powder coatings with a TGIC proportion of 0.1%.

3.2.4 Polyester/hydroxy alkylamide

As an alternative to the above mentioned polyester/TGIC powders, this type of coating was introduced into the market in 1990. Polyester/hydroxy alkylamide powders exhibit excellent weather-resistant and non-chalking characteristics, representing a valid alternative to polyester and polyurethane powder coatings for all outdoor applications.

3.2.5 Polyurethane

The application fields of this powder category are identical with those of polyester/TGIC powder coatings, though curing temperatures for PUR powder coatings are generally higher and some compounds may have a lower performance in regards to edge coverage. However, it exhibits noteworthy flow and coating characteristics.

3.2.6 Acrylic powder

The weather-resistant acrylic powder coatings are based on acrylic resins and typically contain dicarboxylic acids, isocyanates or anhydrides of dicarboxylic acids. This type of powder coating combines outstanding characteristics:

- flow characteristics comparable to standard liquid coatings in the automotive industry
- excellent weather stability (5 years Florida)
- high gloss level
- emission-free and low waste generation

However, the drawbacks of acrylic powders include special storage requirements and incompatibility with other powder coatings. Their positive characteristics predestine them for application purposes in the automotive industry.

3.2.7 Enamel powder

Enamels are glass-like substances that are obtained by the melting of oxygen-containing components. With metallic base materials such as steel, cast iron or aluminum, these powders form composite materials that withstand temperatures up to 450°C and feature color stability and scratchproof characteristics. Surfaces refined with this type of coating exhibit excellent mechanical and chemical properties.

Further reading:

The above listing is not exhaustive and gives only a rough overview on powder coatings. We recommend the following specialized literature for further information:

Judith Pietschman. Title: Industrielle Pulverbeschichtung.
Friedr. Vieweg & Sohn Verlagsgesellschaft mbH, Braunschweig,
www.vieweg.de
ISBN 3-528-03380-0

4 The plant concept

4.1 The plant design

An industrial powder coating plant for automated coating typically includes the following: pretreatment, dry-off oven, coating area, curing oven and conveyor system. Please refer to the following schematic plant layout as an example. Depending on the specific needs, especially in the field of enamel powder coating, various conveyor circuits and dry-off ovens may be needed. For minor production quantities or special colors, a small booth for manual coating may be sufficient in most cases. This booth needs a minimum of space and fits in every production facility.

4.2 The conveyor system

Conveyor systems for the transportation of workpieces serve to the automation of the coating process. Primarily, these systems are subdivided into two categories: overhead and belt conveyors. Many transportation problems, in particular if light or extremely heavy workpieces have to be maneuvered, may be resolved with a single strand or a circular conveyor. If long, big or bulky workpieces are to be coated or available space is restricted, the power-and-free conveyor is an ideal solution, as it allows alternatively parallel or diagonal travel. Due to its sophisticated design, it is more expensive but offers a more flexible adaptation to continuous and automated coating, in particular as load and unload zone of the workpieces and the coating processes can work in their individual rhythm. Further advantages over other conveyor systems are the modular design for optimized material flow and easy combination with elevator/lowerator stations. Particular attention should be paid to the lubrication of the conveyor system, as dry-off ovens with temperatures up to 250°C require high-temperature resistant lubricants or alternatively ventilated protective channels for the chains.

4.3 The hanger design

Efficient conveyor technology requires a production-oriented hanger design. How the hanger design should look like depends on the specific application. Sufficient stability guarantees trouble-free coating and assures a smooth production process. Most of the time, the hangers are partly coated in the coating process; this is why round materials should be preferred. Efficient production requires two complete hanger sets: when one hanger set gets too dirty, the replacement set is used while removing the coating from the other.

5 Pretreatment

5.1 Cleaning of the parts for plastic coating

Before coating the workpieces, all impurities such as grease, oil, dirt etc. must be cleaned off. This cleaning process takes place in the multi-zone pretreatment system. According to the material, the subsequent step is pickling, phosphating or chromatizing. In general, steel sheets are phosphated, galvanized steel sheets slightly pickled for improved adhesion and aluminum sheets chromatized. By means of the conveyor system, the workpieces are guided through the different treatment sections where chemicals as slightly acid alkaline phosphates, alkaline bases or acids are used. In the spraying tunnel, which is equipped with a nozzle system, the workpieces are sprayed from all angles. As coating results substantially depend on perfect cleaning and a precisely adapted pretreatment, the quantity of nozzles, spraying angle and pump power have to be adapted to the respective workpieces.
Also metal cleaning systems, which are manufactured in modular units, have to be custom-designed solutions accurately adapted to the specific case. Overdimensioning means waste of energy and raw materials. As a matter of principle, measures for efficient environmental care and raw material recycling are to be taken into account in all pretreatment concepts. Dimensions and layout of the cleaning zones may be individually designed according to the workpieces and specific needs of the customer. In the conception of pretreatment systems, economical consumption of water, raw materials and particularly thermal energy should be top priority.

5.2 Dry-off oven

After passing all pretreatment zones by means of the conveyor system, residual humidity is eliminated in the dry-off oven. The latter is comparable to a curing oven but designed in a simpler way, reaching temperatures up to 150°C. Depending on the type of workpiece, blowing off with normal room air by means of nozzles may be sufficient.

5.3 Cleaning of the parts for enamel coating

Basic prerequisite for the successful application of enamel powder coatings are flawlessly pretreated steel workpieces. In order to meet the required quality standards for this specific application, pretreatment lines including up to 20 steps may be necessary. However, this maximum is only required if steel is extremely dirty or rusty. In general, only good quality stainless steel suited for enameling is processed. In this case, the pretreatment zone may be reduced to the following 6 steps:

Bath 1	Degreasing
Bath 2	Degreasing
Bath 3	Degreasing
Bath 4	Rinsing
Bath 5	Rinsing
Bath 6	Static rinsing

For extremely dirty parts, the following steps are required:

Bath 1	Degreasing
Bath 2	Degreasing
Bath 3	Degreasing
Bath 4	Rinsing
Bath 5	Rinsing
Bath 6	Pickling (rust removal)
Bath 7	Rinsing
Bath 8	Rinsing
Bath 9	Degreasing
Bath 10	Rinsing
Bath 11	Rinsing
Bath 12	Pickling
Bath 13	Rinsing
Bath 14	Nickel-plating
Bath 15	Rinsing
Bath 16	Complexating
Bath 17	Rinsing
Bath 18	Static rinsing / Passivating

The above-mentioned procedures clearly illustrate that cost savings in pretreatment depend on the right choice of coating goods. Only high-quality and absolutely rust-free steel allows a pretreatment phase in 6 steps.

6 The charging of the powder

Various systems are used to charge the powder. The choice of the process depends on the application and the desires of the user. Generally, three different charging processes are distinguished: electrostatic charging, charging with low ionization and tribo charging. Virtually all manufacturers attain the reduction of air-ionization by the use of a special centerpiece on the top of the gun (called SuperCorona at ITW Gema).

6.1 Electrostatic charging

The corona discharging is the unrestrained escape of free electrons from an electrical conductor. The electrostatic gun is equipped at its top with an electrode that expels electrons. When exiting the powder gun, the powder particles are charged through the deposition of air ions. The resulting ionized powder particles, similar to the free ionized air particles, are attracted to all earthed objects. In practice, the earthed object is the workpiece, thus the powder remains bonded to it.
The charging principle with constant feed of electrostatic charge allows the use of this gun type in all application cases and for virtually all powder categories available on the market.

6.2 Frictional charging

In this process, also called tribo charging, powder particles are charged by means of friction with other plastic materials. This process can take place in a pipe, tube or over a plate. Ideally, it should take place at high air velocity, as the resulting turbulences in the pipe will increase the number of contacts. The used plastic material is generally teflon with positive load.

For detailed information on powder charging, please refer to the following notes: „Process of Application and Application Appliances“ by ITW Gema AG.

7 The powder circuit

In a powder coating system, the powder has to be forwarded from one place to another, taking into consideration the specific characteristics and safety rules. The most common application is the transportation of the powder from the original container or the powder container directly to the gun. In automatic systems, the powder is transported from the fresh powder container into an intermediate container (e.g. in a powder center) and from there on to the gun. The overspray powder is collected in the booth, recovered and fed back to the intermediate container. The properties of the powder should not be altered by the transportation. Consequently, the powder transportation should be such as to preserve the original powder properties.

For detailed information on powder conveying, please refer to the following notes: „Powder Transportation and Powder Conveying“ by ITW Gema AG.

8 Criteria for the choice of the appropriate plant concept

The planning of a powder coating plant often originates with the desire or the obligation for an environmentally friendly coating process or extensive automation of the coating process. Many relevant parameters determining the choice between various plant concepts and system, cabin and recycling types arise out of the objects to be coated and the plant technique to be chosen. Also the grade of automation to be selected is already determined in this phase.

Parameters determined by the objects:

First of all, essential parameters, which influence the design of the plant, should be determined:

- quantity of the parts to be coated
- workpiece geometry
- type of powder
- requested layer thicknesses
- requested coating quality
- number of shades
- proportional distribution of main colors and special shades
- frequency of color changes

Parameters determined by the plant technique and structural conditions:

Further parameters, which influence the choice of the coating booth, are the following:

- chain conveyor
- hanger design
- pretreatment
- space available
- floor quality and other interfering influences (e.g. air currents)

For detailed information on powder coating plants, please refer to the following notes: „Powder Coating Plants – Concepts and Design“ by ITW Gema AG.

9 Powder coating appliances

Application appliances fall into two categories: manual coating appliances and automatic appliances. Standardized modules are combined according to the specific needs of the customer. Application appliances always comprise a control, a gun and a powder container. In general, one control module individually controls one powder gun. However, PC and SPS controls are increasingly used in automatic plants. With regards to the powder containers, fluidic systems, vibrated containers or stirrers may be chosen. Also the original powder container of the powder manufacturer may be used, for example in powder centers, which is particularly indicated when frequent and quick color changes are requested.

9.1 Manual coating appliances

In general, manual coating systems consist in a control, a manual gun, a powder container, a precision injector for powder transportation, cables and pneumatic ducts. Powerful manual coating systems are particularly indicated for small and mid series productions. As generally frequent color changes are needed, they should always be easy to clean.

9.2 Automatic appliances

The automatic system consists generally in the same elements as a manual appliance. However, in automatic appliances mainly automatic guns are to be found. Additionally, locking and automatic control units are used. High power appliances for the automatic coating have to meet the requirements for large batch productions. Individual modular systems for custom-designed solutions with standard elements ideally suit these demands.

9.3 The powder booth

Powder booths are typically subdivided into different categories, each of them suiting specific needs: single color application, multi color application, quick color changes.
Booths are made of steel or, for quick color change systems, sandwich constructions in plastic are available.
Plastic booths are more expensive than steel booths but offer reduced cleaning times as excess powder hardly sticks to the walls.
Sophisticated installations with round booths and central aspiration located underneath the guns help to keep the powder quantity in the powder circuit at a low level.

Conventional metallic booths are used for single color systems, e.g. for white goods and enamel coating. These are equipped with a direct filter recovery system and in some cases with a blade system, which collects excess powder on the floor.

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9.4 Injectors

The injector transports a pre-defined quantity of powder from the powder containers to the guns. Similar injectors, which are made of abrasive resistant material, are used for enamel powders.

9.5 Reciprocators

Reciprocators move the spray guns evenly in a vertical direction. Depending on the application, different types of reciprocators may be selected where guns are aligned vertically or horizontally. For complex part shapes, a multi-axial design version allows the entire reciprocator to follow over a certain distance or single guns to be moved separately.

9.6 Fresh powder systems

These systems are used in applications with high powder consumption or if quality requirements demand constant entrainment of fresh powder to the recovered powder.

9.7 Separation filters and cyclones

Quick color changing systems always require the use of mono-cyclones. These separate the retrieved powder from the suction air. The separation level of a mono-cyclone amounts to approximately 95% and depends on the specific characteristics of the used powder type.

As to single color systems, separation filters are directly flanged to the booth. The powder separation takes place by means of plate filters with high separation levels or space-saving cartridge filters.

For detailed information on particular appliances for the powder coating process, please refer to the following notes:
„Powder Transportation and Powder Conveying", „Process of Application and Application Appliances" and „Powder Coating Plants – Concepts and Design" by AG

10 Curing ovens

Subsequent to the powder application, the workpieces may be transferred directly into the curing oven. In the end, it is the temperature accuracy of the latter and further factors that determine the finish.

The re-circulating air quantity depends on the required temperature, the heat consumption and the difference between intake and exhaust air temperatures. The temperature tolerance range amounts to +/- 5°C.

The dimensions of the interior parts of the oven such as partitions, reinforcements or thermal insulations substantially influence the duration of warm-up and holding times. Further essential criteria for the oven design are the type of the workpiece, its hanger density and material thickness.

The choice between a continuous oven, a U-turn furnace or one of the numerous design alternatives is determined by the concept the whole installation and space availability. The experienced plant manufacturer will be flexible and adapt his concept to make the most suitable choice in line with the specific customer needs.

A further factor determining the surface quality is the dwell time in the oven. For a continuous oven, this means that a planned workpiece throughput has to be held for a given amount of time at the required temperature that may not exceed the acceptable tolerance rate. Depending on the type of powder, the curing temperature may go up to 250°C.

11 Energy-saving measures

As thermal energy is costly, savings in this field are always an issue of current interest. The responsible-minded constructor will integrate this problem in his concept and know adequate measures to keep energy consumption as low as possible. The plant manufacturer supports you in your decision with regards to thermal isolation, heat recycling systems, the right choice between direct and indirect heating, etc

12 Conclusions

During the last few years, the environmentally friendly powder coating technology has gained increasing importance and is still achieving high growth rates. Compact, modern plant design and the development of fully automated coating processes keep cost factors such as space and personnel at a low level.
No use of solvents, the possibility to retrieve and reuse the powder, efficiency rates that can exceed 99% and short color changing times combined with high-precision control technology make powder coating the most economical technique in surface treatment.

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