Coatings that won't let you down

Optimal fluidised-bed coating of wire goods

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Coating of wire goods is increasingly being carried out by the effective and economical fluidised-bed process, in which relatively thick layers can be applied without pore formation. The process is used for shelves, protective grilles, racks, medical and technical articles, and parts for the automotive industry. Coating protects these against corrosion, mechanical damage and external influences. Coated surfaces are easily cleaned and therefore hygienic – an advantage in, for example, dishwasher racks. The attractive appearance of fluidised-bed coated articles is an added plus. As a result, in Europe these coatings are becoming more popular for shopping trolleys done in the corporate design colours of the supermarket chain, although this application is still more popular in Asia.

Commonly used coating powders are PVC, polyolefins (PE, PP and PE/PP blends), PA 11 and PA 12, and duroplastic powder coatings. Over the last few years, thermoplastic polyamide 12 (PA 12) systems such as VESTOSINT® powders from Degussa AG, Düsseldorf, Germany, have increasingly established themselves. PA 12 has the lowest water absorption of all the polyamides and also the lowest melting point (176°C). This reduces the energy costs for the coating process. The powders have better melt-flow properties and form a smooth and highly elastic surface with good resistance to chemicals and hot water. Polyolefins or duroplastic powder coatings, by contrast, either do not have the high resistance required or cannot be satisfactorily processed.

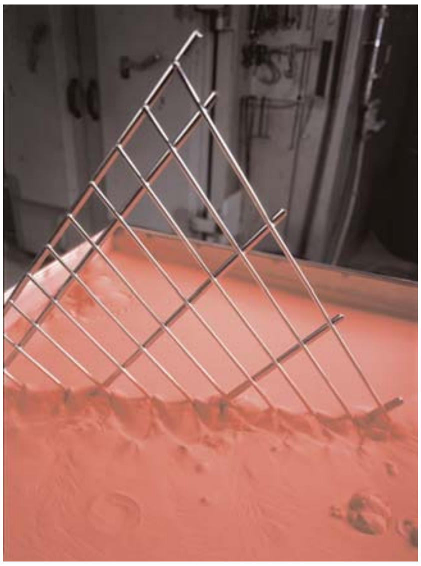

Diagram 0: VESTOSINT® coating powders are available in well over 1,500 colour formulations, including those producing a metallic effect.

The powder

Chemical composition apart, the important physical properties – which are controlled partly by the production process – of a coating powder are as follows:

- melting point: this determines process temperatures;
- density: for a given layer thickness, production becomes more economical as the density decreases;
- relative molecular mass, and its distribution: the viscosity of the melt and therefore its flowability can be regulated, and the elongation at break and edge coverage influenced, through the relative molecular mass;

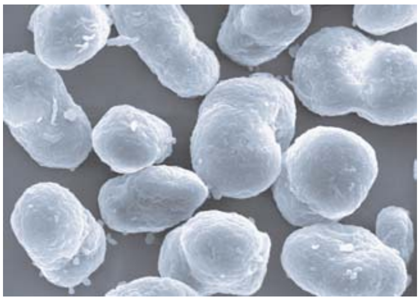

Diagram 1: The grain shape and particle size distribution influences fluidising behaviour and flowability.

- grain shape and particle size distribution: this influences fluidising behaviour and flowability. The more nearly spherical the powder grain, the better is the fluidising behaviour of the sintering powder and hence the better the flow into critical regions such as the crossover points of the wires. Moreover, the fluidised powder should contain only a small percentage of fine particles and no coarse particles, in order to avoid coating defects and excessive dust in the powder basin (Diagram 1).

- pigmentation: Every conceivable colour, including special-effect colours such as those producing a metallic effect, can be obtained by addition of pigments during the production process. Adequately high pigmentation and homogeneous dispersion are important.

Strict adherence to these parameters places stringent requirements on the process capability of the production plant and demands effective process and quality control.

Optimal design for coating

Carefully planned design of wire goods is essential for defect-free coating. To allow the coating powder to flow freely around all parts of the rack in the powder basin, parallel wires and all hanging wires should be at least 10 mm apart from one another. The hanging wires must be so arranged that a projection end of at least 15 mm from the rack is maintained.

Because a certain heat content is necessary for coating, the wire diameter should in general be at least 2.5 mm and the ratio of the thinnest to the thickest wire should be 1:2. With skilled heating (shock-heating) wire thicknesses as low as 2 mm can be processed. In this case the 2:5 ratio of the thinnest to the thickest diameter allows greater freedom in designing the rack.

Production of the racks is usually semiautomatic. Wires that have been cut to length are aligned, placed in templates and connected crosswise into a mat by means of high-frequency automatic welders. After the mat has been bent into the basic shape, the rack is given stability by individual frame wires or a complete frame. The welding and the processing of the ends of the wires influence to a large degree the quality of the subsequent coating. Like all liquid systems, the polyamide 12 melt attempts on account of its surface tension to attain the form of a drop. Sharp edges, caused by wire ends that have not been cleanly cut, or welding beads with sharp points can project through the surface so that this ruptures slightly at the burrs. This may be prevented by chamfering or crushing the ends of the wires, or to form ball-ends. Chamfering also allows a coating thickness of around 200 μm to be achieved in the region of the edge, which ensures adequate protection from corrosion over roughly the entire lifetime of a dishwasher.

For ideal welding, each of the crossed wires is compressed by about 30% so that good contact surfaces are produced. If the welding is faulty so that it fails when subjected to stress, the coating in this region cracks, which may result in underfilm corrosion of neighbouring zones.

In addition to welding beads, adhering spatters can also crucially affect coating quality. These are often overlooked as they are easily covered over. As starting points for underfilm corrosion, they may ultimately necessitate high replacement costs. The danger also exists of such loosely adhering particles falling into the powder basin and appearing in the coating as dirt particles. In this case, corrosion or washing out of the particles during use may lead to pits or even holes in the coating.

Pre-treatment

As with all powders, pre-treatment of the racks before fluidised-bed coating with VESTOSINT® is

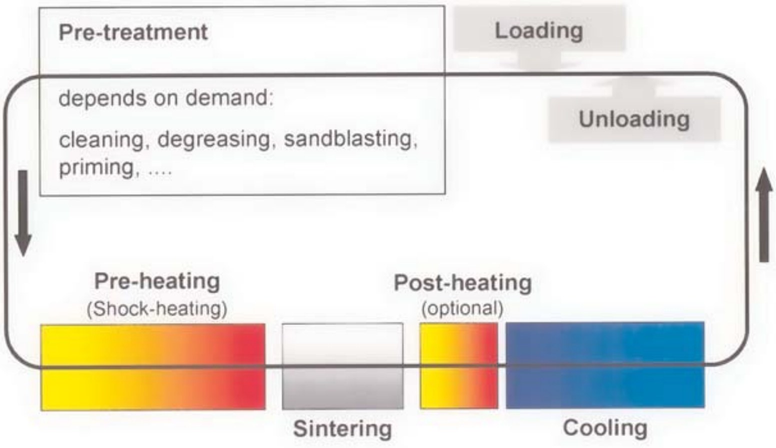

Diagram 2: Schematic drawing of the fluidised bed sintering process

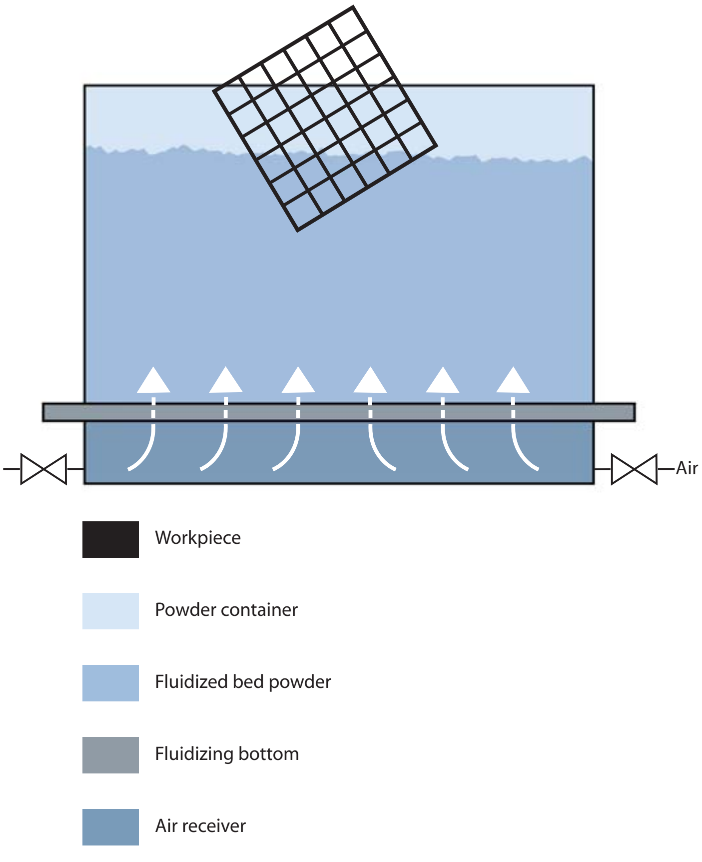

Diagram 3: Schematic drawing of the coating process

absolutely essential to remove any adhering grease, oxide layers and dusts. Greases can crack during pre-heating and contaminate coating or powder basin, and oxide layers and dusts result in poorer adhesion between coating and wire.

The extensiveness of the surface pre-treatment necessary depends on three factors:

1. the metallic substrate to be coated (steel, aluminium, etc.),
2. the condition of the surface (greasy or oxidised), and
3. the required adhesion strength of the coating.

It is therefore impossible to give any general recommendations for pre-treatment.

For optimal coating, the wire surfaces should be subjected to alkaline degreasing and roughened by sandblasting with clean grit. A further degreasing step, temperature-stable phosphating or chemical priming can then ensure good adhesion of the coating.

Coating systems

Continuous coating systems comprise pre-treatment, pre-heating, coating and post-heating (Diagram 2).

Pre-heating

Pre-heating is carried out in ovens with a uniform temperature profile so that the same surface temperature is attained for wires of the same diameter. Air-circulating ovens are generally used in flow-through systems. Even if directly oil-heated, these ovens should not cause the racks to become soiled again. To avoid heat losses during the process, the oven should be as close as possible to the powder basin, but the heat radiated from it should warm the surface of the bath only slightly.

For high flow-rate capacities, pre-heating ovens with 6 to 9 cycles are recommended. They are ideally divided into two zones: the temperature of the first zone – the heating-up phase which comprises two thirds of the total length – is 350°C, and that of the second zone – the final third, known as shock-heating – up to 500°C. In this way, despite the differing thermal capacities of thin and thick wires, uniform surface temperatures can be attained, which are a prerequisite for uniform coatings.

Coating

The pre-heated pieces should be immersed, as far as possible without heat loss resulting from long pathways or draughts, in the PA 12 sintering basin. Here, all the coating powder is uniformly fluidised upwards, with air from the air chamber, through the fine-pored base plate. For large powder basins it is recommended that the air chamber be divided into several zones that can be individually regulated so that fluidising conditions can be optimally controlled. The air used for fluidising must be oil-free, and its humidity should ideally lie between 50% and 70%. Along with the antistatic finish of the powder, this helps prevent electrostatic charging of the powder particles (Diagram 3).

The porous plate of the base plate must be protected by a wide-mesh wire grill against hot parts falling from the hanger. It should be

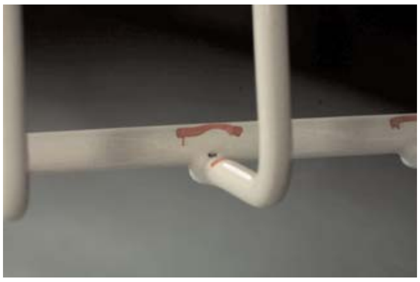

Diagram 4a: To avoid pore formation at the crossover area of two wires, the coating powder must be moved sideways in the sintering basin.

Diagram 4b: Pores may be starting points for underfilm corrosion and may ultimately necessitate high replacement costs.

Defect	Cause	Remedy
Blisters in the coating	• Thermal decomposition of the coating • Emission of water from moist coating powder • Release of gas from the part to be coated	• Reduce pre-heat and/or post-heat temperatures • Reduce moisture content of the powder • Increase pre-heat energy to accelerate gas release
Pitting/pinholes	• Powder application and/or post-heat energy insufficient • Poor fluidisation of powder	• Increase immersion time and possibly also post-heat temperature, or extend duration of post-heating • See below
Strings	• Contact of coating material with base or walls • Contact with an object in the powder basin • Powder level too low • Poor fluidisation of powder	• Change suspension or basin dimensions, shorten hanging wire • Remove object and clean basin • Keep the powder level constant • See below
Orange peel/rough surface	• Unsatisfactory flow of melt • Heat content too low	• Increase temperature and/or duration of post-heating • Shock-heating
Yellowing	• Overheating of the coating • Application of too little powder with too much pre-heat energy • Water cooling absent or too late	• Reduce post-heat temperature Increase immersion period, or reduce pre-heat time for high thermal capacities • Faster cooling in the water bath
Poor fluidisation of powder	• Insufficient fluidising air • Fluidising air poorly conditioned • Electrostatically charged powder • Faulty fluidising bed • Powder temperature too high	• Increase flow of fluidising airCondition fluidising air (optimum: 40 - 50°C, 60 70% rel. humidity) • Discharge powder or use new powder; use conditioned air • Check porous base plate and replace if necessary. • See below
Powder temperature too high (poor fluidisation of powder)	• Powder basin too small for the energy supplied	• Increase basin size • Cool basin • Do not blow in hot air
Poor elasticity of coating	• Degree of polymerisation too low	• Increase temperature and/or duration of post-heating
Gloss too low	• Water cooling absent or too late	• Install water cooling, or water-cool sooner after post-heating
Loss of adhesive strength	• Inadequate or faulty pre-treatment	• Check pre-treatment and optimise if necessary (degrease, sandblast)

Table: Defects arising in coating with VESTOSINT

supported from underneath so as not to sag under the weight of the powder, which may amount to several tonnes, as this would prevent uniform fluidising of the powder.

In flow-through systems with high flow-rate capacity, the operating temperature in the powder basin rapidly rises to values of around 70°C, and in a few cases even to 90°C. With VESTOSINT®, in contrast to other coating powders, temperatures of 85°C are possible, but should not be exceeded for extended periods. If this cannot be ensured, it is advisable to redimension the powder basin to give an optimised surface-to-volume ratio, or to selectively control the temperature of the outer walls. For low flow-rate capacity, the outer walls may also be heated so as to achieve operating temperatures of 40 - 70°C. This measure also counteracts the electrostatic charge on the powder and thus reduces pore susceptibility.

The workpieces to be coated can be immersed in the basin either by lowering the conveyor frame or by raising the powder basin. Both variants are commonly used. The racks should be suspended by a stable wire, ideally of stainless steel. Thin tie wires are hardly ever used because these may cause defects.

The VESTOSINT® powder flowing from below encounters the underside of the wires and, during the slow withdrawal of the racks, strikes the upper side of the wires. It flows along the sides of the wires, and even those parts in the crossover area of two wires lie on the shady side. To avoid defects, the coating material is moved sideways in the basin with the help of pneumatic guides. During removal from the basin, a lever strikes the hanger to ensure that any loosely adhering powder falls back into the powder basin. This measure prevents, for example, pore formation and highly non-spherical coatings that could later lead to problems: In dishwasher racks, for example, a uniformly spherical coating is important for mounting of the rack rollers (Diagrams 4a and 4b).

The immersion time lies between 3 and 5 seconds and has a significant influence on the thickness of the coating. In the first few seconds the build-up of the coating is almost linear so that a layer thickness of ca. 400 μm is attained after 4 seconds.

The VESTOSINT® powder consumed can be continuously replenished, either manually or by means of a fill-level control system. For high flow-rate capacity, automatic powder regulation from large containers has been found most suitable.

Post-heating and water cooling

Many coating systems, particularly flow-through systems, use post-heating ovens (1 - 2 cycles, up to 300°C). This brings about, for difficult designs, the smooth fusing of any powder that has not already melted. Post-heating ovens also serve to increase the molecular weight of the product, which has a significant effect on the elasticity. The coatings, particularly in the case of dishwasher racks, receive a final finish by the water cooling that follows. The articles are immersed in the water bath before the melt solidifies, about 30 to 45 seconds after leaving the post-heating oven or powder basin. The abrupt cooling prevents formation of large polyamide crystals so that the elastic properties of VESTOSINT® are improved by a factor of 10 as compared with air cooling.

Reprocessing of the powder/extraction of impurities

The quality of the coating depends on consistency of quality of the VESTOSINT® coating powder. For automatic filling, therefore, fittings are available that recirculate the powder: these necessarily include, in addition to the filling system, a sieve for continuous extraction of dust and coarse particles, and a metal magnetic separator for small iron particles that could cause corrosion, pores and pits in the coating. Powder basins without powder recirculation must regularly be completely reconditioned. Apart from the unavoidable loss of powder, amounting to ca. 1% of the basin contents, this also entails interruption or reorganisation of production.

Final treatment

After water-bath cooling, the hanging wire is cut off to a length of ca. 1 cm and the cuts covered with, for example, two-component paint and/or an attached plastic cap. This ensures that no downward migration of corrosion occurs that would separate the coating from the metal. The parts are then examined for defect-free coating in a visual quality control check.