



## Flash IR pre-curing of the decorative layer in metal-flake powder coatings

M. Barletta\*

Dipartimento di Ingegneria Meccanica, Università degli Studi di Roma Tor Vergata, Via del Politecnico, 1-00133 Rome, Italy

### ARTICLE INFO

#### Article history:

Received 6 November 2010

Received in revised form 16 April 2011

Accepted 20 June 2011

#### Keywords:

Powder coatings  
IR heating  
Morphology  
Scratch resistance

### ABSTRACT

Metal-flake powder coatings are a special class of metallic paint finishes composed of two superimposed layers: a pigmented decorative base coat and an overlaying transparent protective top coat. In the present investigation, a novel curing procedure for such bilayer coatings is proposed. Flash IR pre-curing of the base coat promotes the formation of a surface diffusion barrier and limits movement of the decorative pigments and metal flakes around their initial positions. Oven baking after deposition of the top coat then completes curing of the bilayer coating. The influence of the IR intensity and irradiation time on the final properties of bilayer coatings was investigated. The visual appearance, surface morphology and scratch resistance were evaluated. Experimental findings revealed that the hybrid IR/oven baking curing procedure is a viable method for obtaining bilayer powder coatings with outstanding properties in a shorter processing time and with considerable energy savings.

© 2011 Elsevier B.V. All rights reserved.

### 1. Introduction

High-quality metal-flake powder coatings are commonly deposited on metal substrates in a two-step process. First, a pigmented decorative base coat is electrostatically sprayed on the substrate and oven baked at moderate to high temperature for a rather long time. This cures the base coat and the decorative pigments and metal flakes are restrained to their initial positions, thus preventing their migration from the base coat to the top coat, which is extremely detrimental to the aesthetic appeal of the whole coating system. The base coat is then allowed to cool at ambient temperature. Second, a transparent protective topcoat is electrostatically sprayed onto the cured base coat and the resulting bilayer coating is oven baked again. The coating is allowed to cool at ambient temperature and its full aesthetic and functional properties are established.

The economy of this process is influenced by the cost of the raw materials and the baking procedures for the base coat and top coat (typically 170 °C for up to 20 min), with an intermediate time-consuming cooling stage.

Besides coating performance and quality, energy savings and the need for reduced costs are driving the development of new solutions in the paint and coatings industry, leading to the design of innovative coating formulations, pioneering technological solutions and novel operating conditions [1]. In this respect, Weiss [2] was the first to discuss how the need to mitigate increased material

and energy costs while meeting customer demands for low prices and constant quality provided the drive to use less energy-intensive materials. Paint and coating materials with less or no solvent to volatilise during curing or with a curing process requiring less energy were widely formulated.

The need to reduce energy consumption during curing of powder coatings and environmental concerns have led to the development of paint materials curable at low temperature or by radiation. Richart [3] reported on epoxy and phenolic powders that could be cured at a low temperature of 100 °C in approximately 30 min. Kennedy [4] was the first to introduce powder coatings that melted and flowed at ~80 °C and could be cured by UV radiation. However, significant energy savings in both studies were counterbalanced by several drawbacks in terms of coating quality and performance (poor aesthetic appeal, mediocre durability and limited resistance to wear and corrosion). Since then, the development of new material formulations for fast or low-temperature curing procedures has been a major focus. Recent developments in UV powder coatings have resulted in extremely good film flow-out, yielding very smooth coatings cured at temperatures as low as 100 °C. Maetens [5] suggested that a combination of polyester and epoxy chemistries is preferable for optimising the performance of UV-curable powder coatings. He demonstrated that a suitable polyester/epoxy ratio yields the best compromise on varying substrates such as MDF, metal and PVC tiles, with the formulation of high-gloss clear coats the only limitation for this approach.

However, UV curing is often limited to planar substrates or substrates with simple geometries. Complex three-dimensional objects are still very difficult to cure reliably and evenly by UV exposure. Therefore, a thermally cured powder coating that can melt,

\* Tel.: +39 0672597168; fax: +39 062021351.

E-mail address: [barletta@ing.uniroma2.it](mailto:barletta@ing.uniroma2.it)

flow and be cured at low temperatures in a reasonable time frame would be of great commercial relevance, especially as the range of applications of powder coatings is expanding to non-metal and heat-sensitive substrates.

Merfeld et al. [6] investigated the role of the catalyst in acid/epoxy powder coating systems to optimise them for low-temperature curing. The best overall coating performance was observed for formulations with heavily pre-catalysed resins and further increases in the catalyst level or more aggressive reagent mixing led to a limited window of dramatically improved impact resistance but with a concomitant drop in chemical resistance. At the highest catalyst loading investigated, they found that gelation during melt extrusion and/or systemic degradation of the coating performance could become prohibitive.

Besides the severe technical drawbacks for radiation- and low-temperature-curable powder coatings, it is worth emphasising that such formulations often require high-cost raw materials. This is often unacceptable in the modern paint and coating industry, in which the cost of raw materials can far exceed 50% of the overall cost. Therefore, new technological solutions are required to reduce energy requirements without the use of material formulations that are costly and difficult to manipulate.

Significant savings can be achieved in the production of powder coatings with high quality and performance by using well defined, simplified or faster curing cycles. Barletta et al. [7] reported on the importance of suitable baking parameters for each powder coating system. They accurately mapped the behaviour of electrostatically sprayed and oven-baked pigmented single-layer powder coatings for varying degrees of conversion. They measured the scratch performance of the coatings as a function of the degree of conversion, applied loads and contact conditions to identify the minimum time and temperature required to achieve target coating properties. More recently, Barletta et al. [8] focused on bilayer powder coatings in which a transparent protective coating was deposited on a decorative base coat. The aesthetic appeal and mechanical resistance of the coatings were improved by increasing the degree of conversion of the base and top coats, respectively. Further investigations involved the use of different contact speeds and geometry during scratch testing of bilayer powder coatings cured to varying degrees of conversion [9]. Experimental data were obtained on the relationship between baking time and temperature and the final properties of powder coatings that will be helpful in making manufacturing decisions and might lead to energy savings when setting baking parameters.

Alternative solutions for rapid curing of powder coatings involve the use of a radiative heating source. To date, the use of IR lamps has been restricted to full curing of powder coatings on heat-sensitive or simple-shaped substrates (typically wood, plastic and metal panels) or to hybrid curing of radiation-curable powder coatings in which IR-cured flowing, melting and levelling stages are followed by a suitable UV curing process. Interesting attempts to better understand the mechanisms in radiative curing have been reported. Vechot et al. [10] investigated the modelling of IR curing of a polyester-based coating in an experimental approach, whereas Deans and Kogl [11] built an analytical model for to assess the process efficiency of gaseous infrared heaters. Bombard et al. [12] developed a comprehensive mathematical model using radiative properties of a coating to describe precisely the coating temperature and deduce the degree of polymerisation during curing. However, precise calibration of the model was troublesome and wide industrial application has still not been realised.

The use of combined IR and convective baking has been widely reported in the literature. In general, such combined techniques increase the level of control in pre-heating of substrates of different thickness, thus yielding good temperature uniformity in the overlying coating. This is a stringent requirement for some

powder-coated plastic components and MDF panels for which IR heating or convective baking alone would lead to degradation of some or all of the substrate. No other use of IR and convective baking has been reported. In particular, combined use to accelerate the baking procedure for multi-layer powder coatings has not yet been reported.

Here a sequential curing process is proposed in which an IR heating stage is followed by conventional convective baking of a bilayer powder coating comprising a decorative metal-flake base coat and a protective transparent top coat. A flash IR heating stage was designed to melt and level the outermost layers of the electrostatically sprayed base coat. This limits movement of the decorative pigment and metal flakes around their initial position and thus guarantees the aesthetic appeal of the powder coating at the end of the baking procedure. The protective top coat is then electrostatically sprayed onto the base coat and the whole coating system is subjected to conventional oven baking. This hybrid IR/oven baking curing technique eliminates both baking and cooling of the base coat, thus providing a faster and cheaper curing procedure. Visually attractive bilayer powder coatings with good adherence and wear resistance can thus be easily manufactured in a simple low-cost process.

## 2. Experimental

Metal-flake powder coatings were deposited on 1.5-mm-thick metal sheet. Square samples (20 mm × 20 mm) were precisely cut by fine blanking to minimise geometric variations in the substrate and provide a uniform starting surface.

Each sample was subjected to a seven-stage zinc phosphate treatment. In the first stage, the sample surface was dipped in a bath of alkaline cleaner for 90 s at ~70 °C and then rinsed for 60 s in water at ambient temperature. The sample surface was then activated by dipping it in a solution with conditioner for 30 s at ambient temperature. This process removes surface contaminants. A zinc phosphate crystalline coating (consisting of a phosphoric acid base, accelerators and zinc salts), was then applied to the substrate. This generates an inert surface to promote optimum adhesion of overlying organic coatings and provides good protection against corrosion. The inert surface also prevents the formation and spreading of metal oxides in case of accidental damage to the surface and overlying coating. The surface was then rinsed in water for 30 s at ambient temperature to eliminate active chemicals and neutralise any residual water-soluble salts. Non-chromic sealing was then performed for 30 s at ~50 °C to stabilize the surface pH at a slightly acidic value and seal potential voids in the coating. The substrate was then rinsed with deionized water for 30 s at ambient temperature, oven-dried and electrostatically spray coated with a commercial metal-flake epoxy-polyester powder (PPG-Bellaria, Alessandria, Italy; mean diameter 20 μm, shape factor 0.80, baking prescribed at 170–180 °C for 20 min). The epoxy-based system consisted of bisphenol-A type epoxy, salts of a polycarboxylic acid, cyclic amidine and other additives such as a flowing agent and UV stabilizer.

Electrostatic spray deposition of the metal-flake decorative base coat was performed at 90 kV voltage with feed pressure (related to the amount of powder passing through the gun tip per unit time) of 1.5 bar and auxiliary pressure (related to the spread of the powder cone from the gun tip) of 1.0 bar for an exposure time at 6 s. During deposition, the samples were located in front of the gun tip, 400 mm far from it, and kept in a fixed position. After deposition, coated samples were submitted to different curing procedures.

A first set of samples was conventionally cured in a methane gas oven for 20 min at 180 °C in natural convection, that is, without any external source to generate the air motion. The samples were

Download English Version:

<https://daneshyari.com/en/article/692851>

Download Persian Version:

<https://daneshyari.com/article/692851>

[Daneshyari.com](https://daneshyari.com)