Temperature Gradients in an Electrostatically Applied Powder Coating Layer While Cured with Infrared Radiation

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***Abstract*— The measurements of the temperature gradients in a charged, thick nylon powder layer coating being cured over a metallic surface with a filtered IR radiation of a cut off wavelength of 2.9µm show that the powder layer close to the metallic surface is initially exposed to a curing temperature lower than the temperature at the surface of the coating. Hence, some of the powder may fall off in the oven. Further work to study the temperature gradients which develop on various powder materials and particle size distribution may help the technology when thick cured powder coatings are required.**

I. Introduction

The considerable increase of the use of powder paints in electrostatic coating has led to industrial interest [1, 2] in applying the energy saving IR technology for curing the deposited powder layer. The electrostatic coating process with powder paint presents substantial economic advantages over the coating with liquid paints:

a. There are no solvents emitted which require special recovery systems. (solvent are recovered by adsorption on a solid adsorbent or absorption in a liquid etc..)
b. Most of the electrically charged powder, which bypasses the target and ends up on the walls and floor of the spray booth, is collectable from specially constructed painting booths with plastic double walls. (Double wall with air space or special dielectric filled space.)
c. With proper colour painting sequence, the mixing of colour powders may be minimized and substantial paint recoveries may be realized.
d. Coating with powders may be also done with Tribo-Electrification guns, which eliminate the need for high voltage power supplies and associated safety precautions.

The fact that powders to date have not completely eliminated the liquid paints is due to the appearance of the cured powder, which in some cases did not match the market's accepted standards for the looks of a cured liquid paint coating. The challenge of matching the cured liquid paint lead to studies of:

- The use of very fine particle powders. In use today, there are more than 300 powder formulations.
- The curing technology, considering that compared to liquid layers, prior to entering a curing oven, the initially deposited powder layer may be thicker.
- The charging of powder particles
- The size distribution of the paint powders. In many applications, the cured film thickness range from under 0.0254 mm to over 0.381mm.

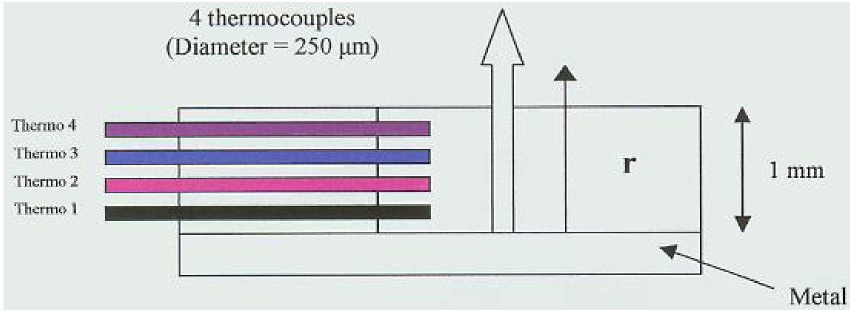
The studies in this paper cover an "in depth" analysis of the curing temperature gradient, in an assumed special case requiring a 1 mm thick layer of powder paint to be cured with infrared radiation.

The electrically charged powder layer held on the surface by Coulomb image forces, must stay in place undisturbed while being conveyed and stopped inside the curing oven. In a high temperature conventional oven tunnel, the entire powder layer, thin or thick, is rapidly cured before the electric charge in the mass of the layer is fully relaxed. In an I.R. ambient temperature oven tunnel, the curing of a thick layer of powder must start with the powder particles which are in contact with the surface to be coated, lest the entire or parts of the charged powder layer may fall off. For this reason, the development of the temperature gradient inside the powder layer is a key factor in the curing process. One must also consider that the temperature of the powder layer may also affect the relaxation of the electric space charge in the powder mass.

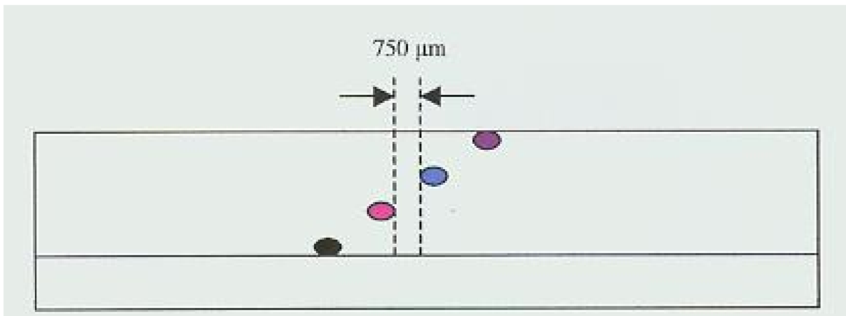
II. THE EXPERIMENTAL APPARATUS AND PROCEDURE

Figures 1 show the details of the mounting of the thermocouples inside of 1 mm thick coating with paint powder over a metallic plate.

The tested coated plate, 10 X 6 cm^2, was made out of 1mm thick aluminium. The four thermocouples were placed as shown in Figure 1. The instrumented plate was coated with a 1 mm thick nylon powder (10-70 μm distribution) in a fluidized bed. For the experiments with IR curing, a filter was introduced, as shown in Figure 2, to minimize the absorption of the radiation on the surface of the coating. The penetration of infrared energy is a function of its wavelength. The shorter the wavelength, the greater the penetration power. The filter had a cut off wavelength of 2.9 μm. It was expected [5], that energies below this wavelength can only be transmitted or reflected, but not absorbed in the coating powder, allowing an initial heating of the metal plate surface.



Vertical Displacement



Horizontal Displacement

Fig. 1. Placement of the 4 thermocouples. Note: Thermocouple #1 is the one in direct contact with the metal. Thermocouple #4 represents the surface temperature of the coating.

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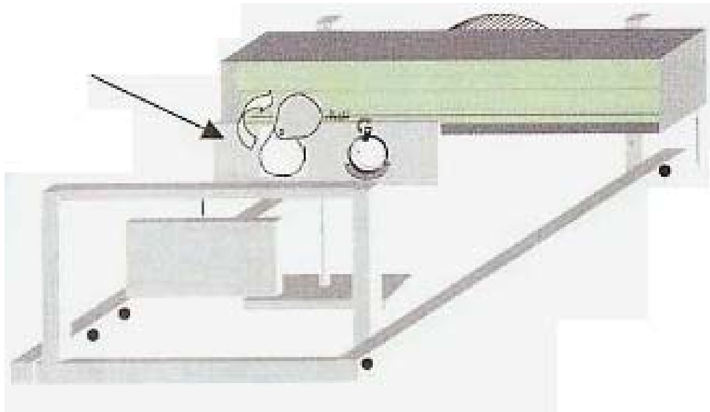

Fig. 2. Experimental assembly.

III. Results

Figure 3 (a, b, and c) shows the results which were obtained in a convection oven at a 120^{o} C. Figure 3a gives the increasing temperature versus time for each of the four thermocouples. Figure 3b permit to visualize directly the temperature variation, in time, across the powder coating. The temperature at the surface increases first, then goes up very slowly. The thermal gradient across the coating reaches only 5 ^{o}C/mm, in the first 50 seconds, as shown in figure 3C.

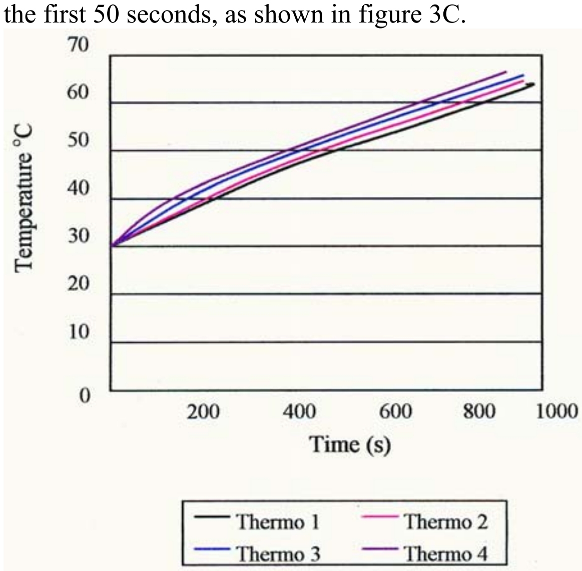

Fig. 3a. Temperature versus Time for each of the four thermocouples.

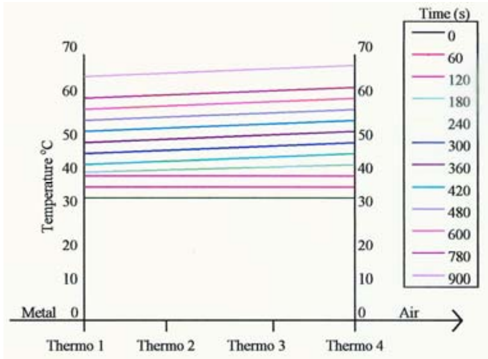

Fig. 3b. Temperature variation across the powder coating.

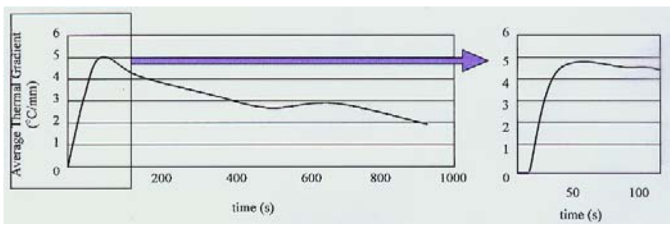

Fig. 3c. Average thermal gradient for the traditional oven.

The thermal gradient °C/mm ($T_4 – T_1$) is always positive and consequently there is no appreciable inversion of the temperature.

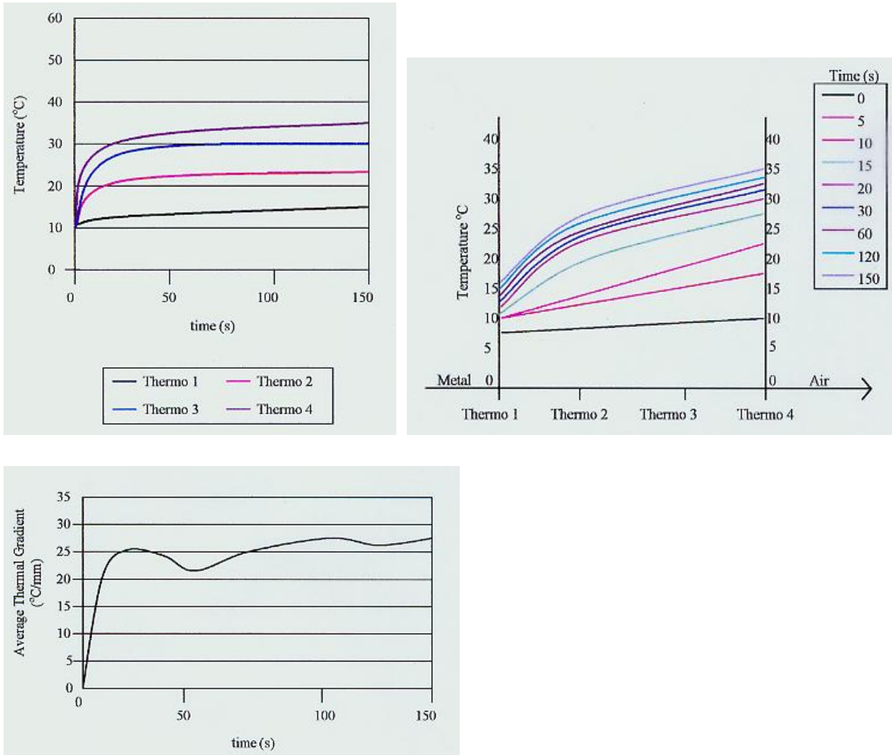

Fig. 5. (a) Temperature versus Time for each of the four thermocouples. (b) Temperature variation across the powder coating. (c) Average thermal gradient (T_4-T_1) versus time, in the coated layer cured with filtered IR radiation.

IV. Conclusion

The measurements of the temperature gradients in a charged, thick nylon powder layer coating being cured over a metallic surface with a filtered IR radiation of a cut off wavelength of 2.9µm show that the powder layer close to the metallic surface is initially exposed to a curing temperature lower than the temperature at the surface of the coating. Hence, some of the powder may fall off in the oven.

Further work to study the temperature gradients which develop on various powder materials and particle size distribution may help the technology when thick cured powder coatings are required.

V. ACKNOWLEDGEMENTS

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