Journal of the Arkansas Academy of Science

Volume 56 Article 6

2002

Reduction of Dendrite Formations to Improve the Appearance of the Powder Cured Films for Automotive Industry

Alexandru S. Biris
University of Arkansas at Little Rock

C. U. Yurteri
University of Arkansas at Little Rock

Malay K. Mazumder
University of Arkansas at Little Rock

Robert A. Sims
University of Arkansas at Little Rock

P. H. Williams
University of Arkansas at Little Rock

Reduction o endrite Formations to Improve the Appearance of the wder Cured Films for Automotive Industry

A Biris, C. U. Yurteri, M. K. Mazumder*, R. A. Sims, and P. H. Williams
University of Arkansas at Little Rock
Applied Science Dept. ETAS 501
2801 South University Ave, Little Rock, AR 72204

*Corresponding Author

Abstract

The appearance of powder-coated films is dependent upon powder chemistry and spraying parameters. One of the most important physical factors controlling the powder film appearance is the microdeposition of the powder particles on the grounded substrate. During the electrostatic deposition of powder, the formation of dendrites and agglomerates was observed; these formations have an adverse effect on the final film appearance and their elimination may result in smoother and glossier films. Dendrites are generated due to bipolar charging and inter-particulate electrostatic attractive forces. The corona charging technique is mostly used in industrial powder coating applications. At low corona voltages (- 40 to – 60 kV) a greater degree of bipolar charging was observed compared to that at higher voltages (– 80 to – 100 kV). At the higher voltages, the increase in number of ions produces a more unipolar charging and higher charge-to-mass ratios. As the film builds up, the powder transfer efficiency decreases as the repulsion forces between oncoming charged particles and the already deposited powder layer increase. By controlling the deposition patterns, the final film appearance can be improved. The smoothest films were obtained when the voltage was ramped from – 60 to – 100 kV. Another method to reduce dendrite formations was to deposit powder particles charged unipolarly by first separating them from the oppositely charged ones by using a charge separator.

Introduction

Generally, the appearance of the powder-coated films is dependent upon the chemical properties of the powders but also on the deposition parameters. The charging technique is important because it is responsible for the charge level of the powder particles and also for how bipolarly the particles will charge. The particle size distribution of the powder, the charge level, charging mechanism, electrical and geometrical aspects, and flow characteristics dictate the microdeposition of particles on the grounded workpiece (Adamiak, 2001).

Highly packed powder layers generate very smooth films with very glossy finishes, a conclusion previously shown by Mazumder et al. (2001). Unipolarly charged particles result in more uniform powder deposition on the substrate because of the mutual repulsion, while bipolar charged particles agglomerate and form dendrites due to particle-particle attraction. Agglomeration and dendrite formation is of concern to the automotive industry because dendrite formations degrade the appearance of cured films by generating an orange peel like surface texture (King and Thomas, 1978).

This paper investigates the generation of dendrite formations and agglomerations on the surface of powder layers due to the bipolar charging characteristic of the powder. Some alternative charging and powder layer deposition methods are also presented. The effect of the dendrite formations on the film appearance is analyzed based on the charging and the deposition processes involved.

Materials and Methods

The experiments were performed in a computer controlled powder-coating booth, where the humidity and the temperature were monitored. The corona gun used for these studies is commercially available from Nordson Inc. The substrates were 10 cm x 30 cm electro-coated steel panels. The steel panels were electro-coated with a 25 μm thick polymer layer in order to emulate the automotive coatings for the clear coat particle deposition.

The powder that was studied is an acrylic with a narrow particle size distribution (PSD) of $d_{10} = 12$, $d_{50} = 28$, and $d_{90} = 40$ μm and is typically used for the top clear coat in the automotive industry. The powder was fluidized for 15 minutes before each experiment and was transported pneumatically to the corona gun through a 1.0 cm diameter rubber hose. A charge separator was employed to measure the mass ratios of the positively and negatively charged or uncharged powder. It consists of two copper plates arranged in a V-shape. A voltage is applied between the two plates. The charged particles are fed from the top, and they move downward between the two plates. The positively charged particles move toward the negative plate, while the negative particles move toward the positive plate. Assuming that the air flow has low turbulence within the separator and with particle Reynolds numbers less than one (Stokes regime), the horizontal and vertical settling velocities of charged particles can be calculated by equating the weight and the electrostatic force of the particles with their drag forces.

The powder mass flow rate was 80 g/min, which allowed the deposition of 60 μm thick films in about 13 seconds. Once the powder was deposited, the panels were cured at 145°C for 30 minutes. The appearance of the coatings was tested with a BYK Gardner wave scan plus instrument which gives short (SW) and long (LW) wave and subnote parameters. SW and LW (on a scale from 0 to 99.9) are a measure of the film roughness and waviness, whereas subnote (on a scale from 0 to 600) is a parameter that integrates the first two and characterizes the overall appearance of the coating. The smaller these values, the better the film appearance. For each experiment 10 panels were sprayed, and the values reported are the averages.

Results and Discussion

Corona is the most common charging method used in the powder coating applications mainly because of the stable and consistent level of charge the particles acquire during this process. Once the particles become charged, they move to the grounded deposition system, driven by the electrostatic attraction forces.

In addition to the electrostatic forces, the aerodynamic forces produced by the air flow through the system are of great importance. These two forces cause the particles to move to the substrate. As the powder layer builds on the substrate, the electrostatic driving force is reduced because of the charge of this layer.

Besides the negative ions and electrons in a corona discharge there are also some positive ions generated. This along with tribocharging produces some positively charged particles. For higher negative corona voltages, the number of negative ions is much higher leading to a greater bulk charge-to-mass ratio (Q/M). The deposition pattern is highly dependent upon the charge polarity of the particles. If the powder is charged bipolarly, the particles with opposite polarity will tend to attract each other and form dendrites. Due to the fact that the deposition process is very dynamic, the airflow at the surface of the powder layer will probably retard the dendrites growth by causing them to break and to generate agglomerates.

As the voltage of the corona gun is increased, the number of negative ions increases with direct effect on the powder Q/M (Sims et al., 2001). The values of Q/M and ion current measured at –60, -80, and –100 kV corona voltages are plotted in Fig. 1.

The powder charge level variation with the corona voltage shows that the powder charge is higher as a larger

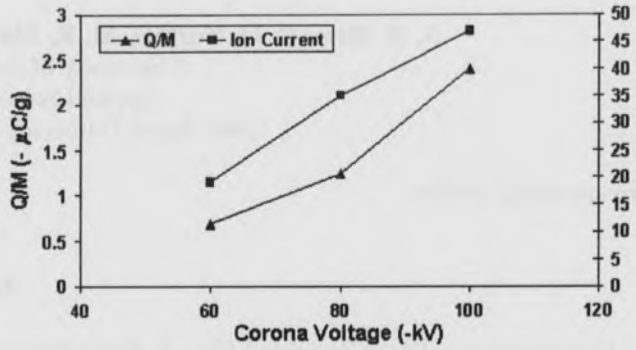

Fig. 1. The influence of the corona gun upon the powder Q/M and ion current.

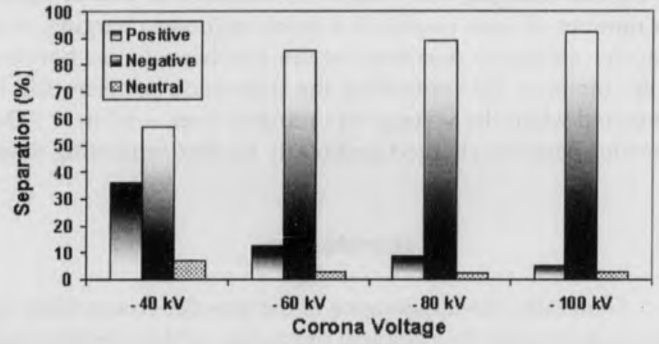

Fig. 2. The charge separation data for powder charged at different voltages.

number of ions are generated. The ratio of positive and negative particles was found for powder charged at different voltages, from –40 to –60, -80, and –100 kV. To determine the extent of unipolar charging, powder collected on electro-coated panels (2.5-3 grams) was blown off inside a charge separator, and the masses of powder deposited on the positive and negative plates and neutral are plotted in Fig. 2. The large amount of positively charged particles at –40 kV is believed to be caused by tribocharging during transport through the hoses. The low negative ion current generated by the corona gun at – 40 kV is not enough to completely overcome this positive charge. Even at high voltages, some of the particles remain positively charged.

Some typical dendrite formations are shown in Fig. 3. Although it is very difficult to quantify the number of dendrite formations, an indirect measurement of the powder film layer unevenness can be made by analyzing the long wave and the short wave parameters of the cured films.

Figure 4 shows that the film roughness decreased as the voltage was increased. The best films were obtained at – 100 kV. By increasing the negative voltage, the packing density increased with positive effects on the film appearance. As previously shown (Biris et al., 2001; Banerjee and Mazumder, 1996), the powder layer became coarser with time because only the large particles will have a high enough charge (charge of a particle is dependent on the diameter square) and momentum to overcome the electrostatic repulsion forces generated by the powder layer. In order to force the fine particles to deposit and to generate smoother films, the electric field between the corona gun and the plate was gradually increased. A 60 µm thick film was produced by spraying for a time period of 14 seconds while gradually increasing the voltage from – 60 to – 100 kV. The resulting field and the increased charge level of the fine particles allowed them to deposit on top of the powder layer. In another trial, the voltage was ramped in two steps. For the first half spraying period (7 seconds), the voltage was kept at – 60 kV, and for the last 7 seconds, the voltage was rapidly increased to –100 kV. Fig. 4 shows that the films with the smoothest surface and best appearance were those generated while the voltage was uniformly ramped.

From Figs. 1, 2, and 4, it can be concluded that the appearance of the cured films improves as the particles are more unipolarly charged, which can be related to a smaller number of dendrite formations. A method of depositing unipolarly charged particles is by using the charge separator. The powder was charged at – 100kV inside the booth and blown off inside the charge separator. The surfaces of the powder layers deposited on the electro-coated panels, which were attached to the separator's plates, were very smooth, and no dendrite formations or agglomerates were observed. Results mean that by depositing unipolarly charged particles the roughness of the powder layers decreased. The experiments were carried out at three different voltages between the separator's plates (10, 15 and 20 kV) and the appearance results are shown in Fig. 5. It can be observed that by increasing the voltage difference between the plates from 10 to 15 kV the films generated were smoother and had a higher packing density. A correlation between high packing densities and the improvement in the film surface smoothness has previously been shown. However, if the packing density of the particles is too high, the electric field within the powder layer can exceed the breakdown value, and back corona can occur. When the potential difference between the separator's plates was increased to 20 kV, the appearance of the generated films was not as good as in the previous cases. Back corona onset and craters and pinhole-like formations were visible on the powder surface.

Conclusions

The microdeposition of powder particles on different substrates is an important factor for the appearance-related properties. At low voltages (- 40 and – 60 kV) a higher bipolar charging of the powder particles was observed. After the voltage was increased to – 80 or – 100 kV, most of the particles were unipolarly charged. The level of charge acquired by the powder particles was directly related to the free ion current generated by the corona discharge, therefore the voltage directly influences the microdeposition of particles and indirectly affects the appearance of the cured powder films. The particles were shown to form dendrites and agglomerates when charged at low voltage because the powder is bipolarly charged.

By ramping the corona voltage from – 60 to – 100 kV during the powder layer formation, the appearance of powder cured films was improved compared with the static spraying conditions (-60kV). When ramping the voltage, the fine particles acquire a high enough charge to deposit on the powder layer and to overcome the repulsion forces due to the already deposited particles.

The best appearance was obtained when the powder deposition was performed in a charge separator. The separator ensured the deposition of unipolar charged powder and reduced the dendrite formation process. It is believed that unipolarly charged particles, due to the mutual electrostatic repulsion, deposit uniformly over the surface of the grounded panels. The voltage between the charge separator's plates that generated the smoothest powder films was found to be around 15 kV. Further increasing the voltage between the plates resulted in back corona onset that destroyed the fine film appearance.

ACKNOWLEDGMENTS.—This work was partially supported by a EPA/EPSCOR grant.

Literature Cited

Adamiak, K. 2001. Numerical investigation of powder trajectories and deposition in tribocharge powder coating. IEEE Trans. Industry Appl. 37:1603-1609.

Banerjee, S. and **M.K. Mazumder.** 1996. Adhesion of charged powders to a metal surface in powder coating process. IEEE Transactions on Ind. Appl. 32:1243-1249.

Biris, A.S., M. K. Mazumder, R. A. Sims, C. U. Yurteri, J. Snodgrass, and **S. De.** 2001. Glosss and texture control of powder coated films. Partic. Sci. Tech. Jour. 19:199-219.

King, M.J. and **T. R. Thomas.** 1978. Stylus measurement of microgeometry of coated surfaces. J. Coatings Technol. 50:56-61.

Mazumder, M.K., A. S. Biris, R. Sharma, D. Kumar, S. Trigwell, and **R. A. Sims.** 2001. Measurement of surface topography, packing density, and surface charge distribution of an electrostatically deposited powder layer by image analysis of fluorescent latex spheres. Partic. Sci. Tech. Jour. 19:239-257.

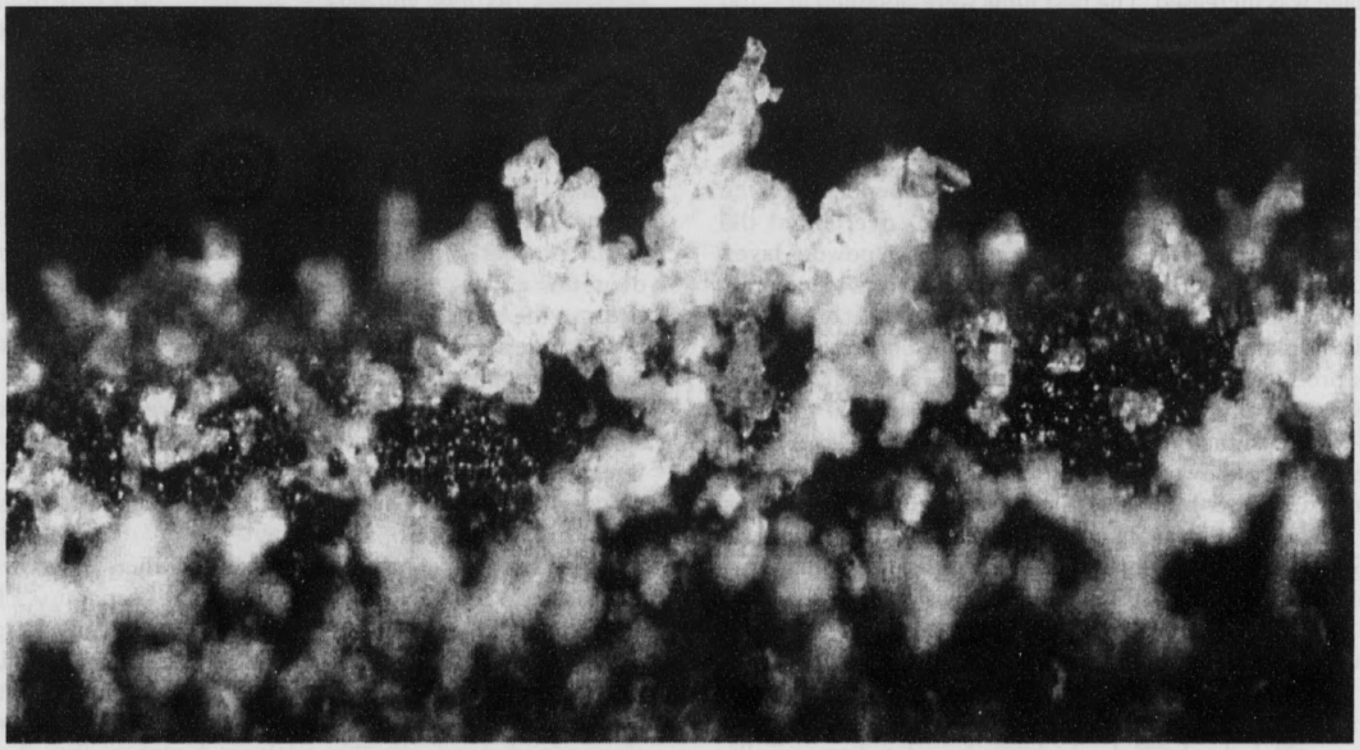

Fig. 3. Typical dendrite formations.

Sims, R. A., M. K. Mazumder, L. Xiaohoung, W. Chok, J. R. Mountain, D. L. Wankum, P. Pettit, and **T. Chasser.** 2001. Electrostatic effects on first pass transfer efficiency in the application of powder coatings. IEEE Trans. Ind. Appl. 37:1610-1616.

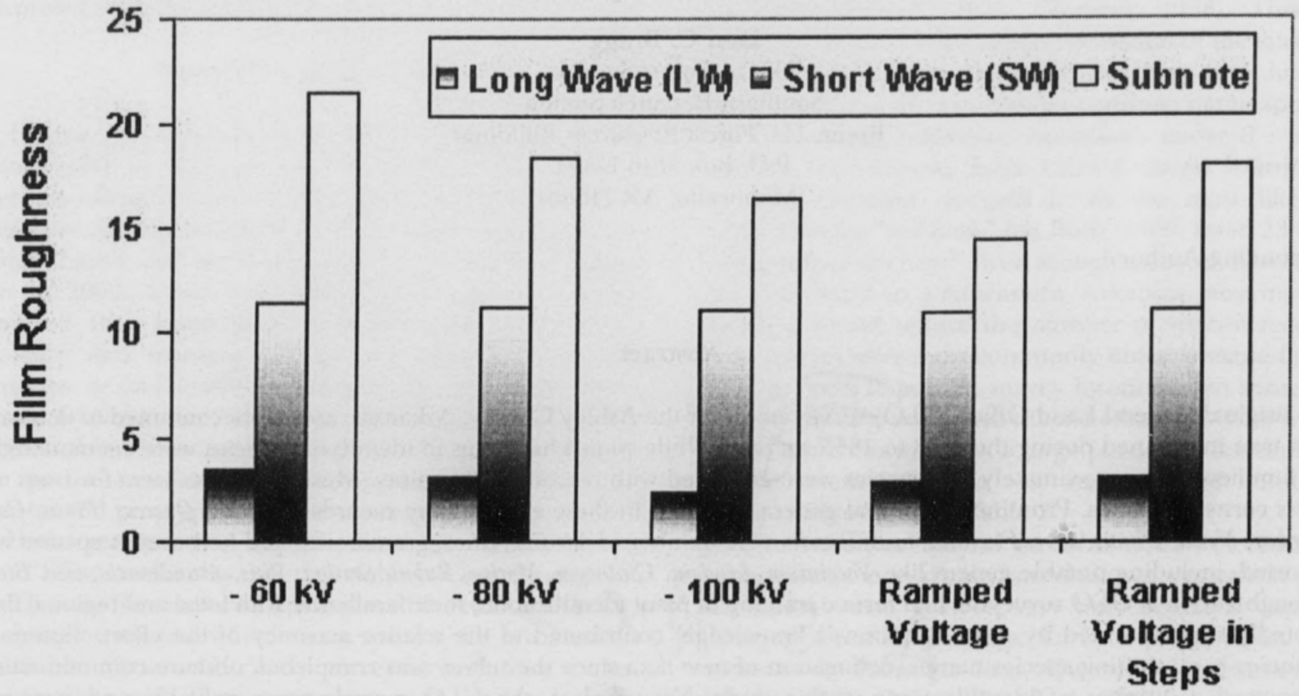

Fig. 4. The appearance data for films generated at different voltages.

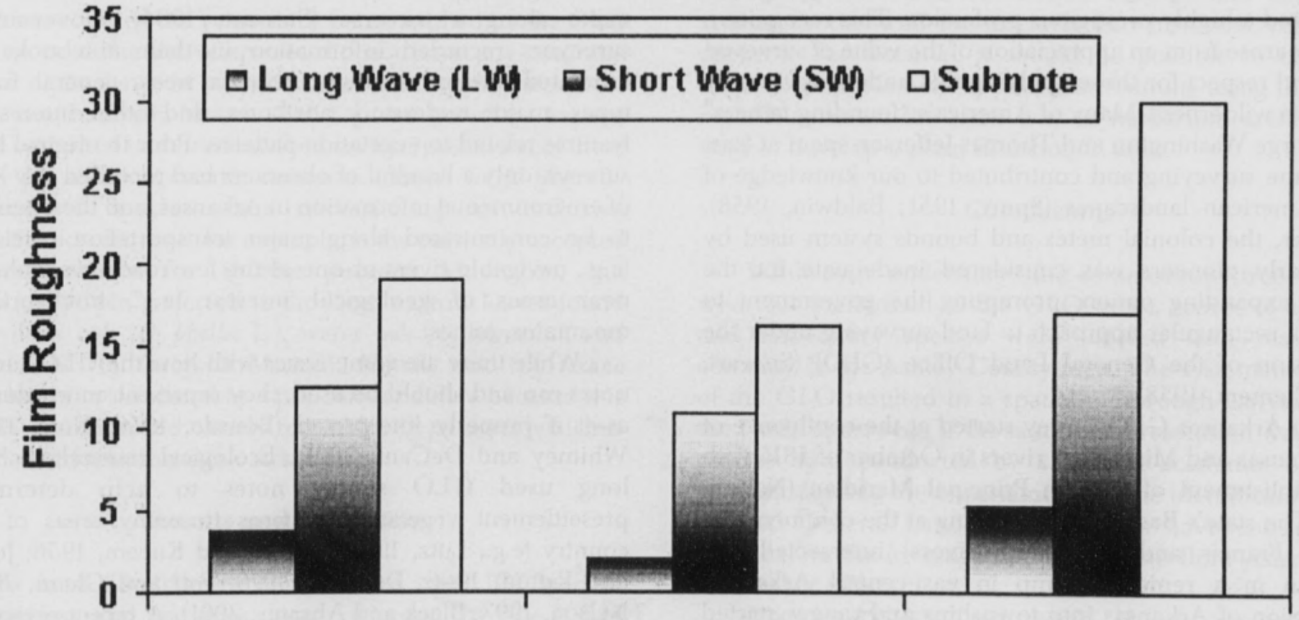

Fig.5. The appearance data for films generated using the charge separator at different voltages.