Dry Toner Based Electrophotographic Printing of Extrusion Coated Packaging Boards

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Abstract

Digital printing is suitable for short runs of highly personated packagings. The obvious benefit of digital printing is low waste amount and print-on-demand. The status of digital printing, at least in packaging sector, is still quite moderate, but the future is bright and it has been estimated that this method will increase more than the traditional printing techniques. The quality of digital printing will also approach that of offset.

The aim of this study was to evaluate printability of various extrusion coatings used for packaging boards and to map out important material and process parameters.

Introduction

Xeikon Based Web Electrophotography

The extrusion coated board grades were printed in this study on Xeikon DCP/50-SP digital printing machine. The printing method in the Xeikon is based on dry toner web fed electrophotographic process. Printing is performed on one side and four process colors, i.e. yellow, cyan, magenta and black, are used. Fig. 1 displays the machine configuration.

The image creation process in the Xeikon based printing process consists of six steps, which are

1. Photoconductor charging
2. Latent image creation (LED-array)
3. Latent image development
4. Toner transfer to the print media
5. Cleaning of the photoconductor
6. Fusing (non-contact IR-fusing).[7]

In figure 2 is shown an image of a color head and a development unit. All color units are similar.

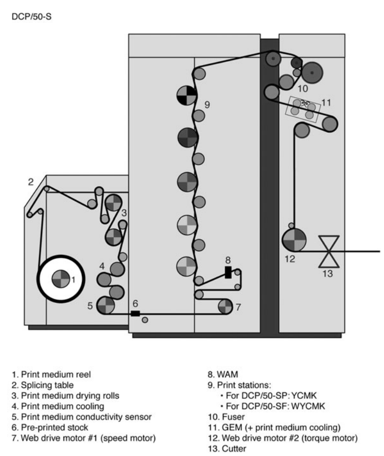

Figure 1. Xeikon DCP/50-SP digital printing machine.[7]

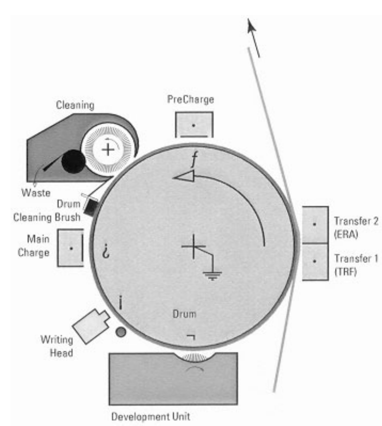

Figure 2. Operation of a single print unit.[7]

The most crucial phases in the process are toner transfer and fusing. Several properties of the substrate affect the success of these stages, e.g. electrical properties, moisture and roughness.[7]

Printing of Extrusion Coated Board

Extrusion coatings in general have an impervious, chemically inert, non-porous surface with low surface energies that causes them to be non-receptive to bond with toners. The most common method for obtaining good toner adhesion is to oxidize the surface. This will increase the surface energy and also provide polar molecular groups necessary for good bonds between toner and polymer molecules. The most widely used method to accomplish this is the electrical corona discharge treatment.

Corona Treatment

As mentioned above, corona treatment is used to increase the wettability and the adhesion properties of extrusion coated boards. During the corona treatment the surface of a plastic coating is oxidized, which leads to increase in surface energy by introduction of polar functional groups on the surface.[2, 9]

Corona treatment breaks the molecular bonds on the coating surface forming very reactive free radicals on the surface. At the same time, ozone and oxygen radicals form that react with the radicals on the surface. Polar functional groups which can form and enhance bondability include carbonyl (C=O), carboxyl (HOOC), hydroperoxide (HOO-) and hydroxyl (HO-) groups. Even small amount of these reactive groups incorporated into plastic coatings can be highly beneficial to improving surface characteristics and wettability.[2,6,10,11]

According to Stenlund,[8] these functional groups form mainly in the amorphous part of a polymer into which oxygen can diffuse. In the crystalline areas the oxygen diffusion is very restricted because of the limited movement of the polymer chains. This means that the oxidation may occur only in the surface areas of the crystalline parts. Based on these conclusions, it can be stated that the effect of corona treatment on plastic surface depends, among other things, on the crystallinity of the plastic.[1, 8]

Corona treatment can also cause a permanent electrical charge on the plastic coating surface. This phenomenon is called the electret effect. The theory of electret behaviour is quite complicated, at least when paper/board is concerned. Usually the electret is induced under powerful DC-voltage area and above the glass transition temperature (T_g) of the polymer. During the corona treatment the plastic coating surface is polarized with an electrode and two types of charges of contrary sign form. So called heterocharge is induced on the surface, but this charge will vanish when the voltage is removed. At the same time a homocharge is induced on the surface. This surface charge has the same sign as the polarizing electrode, whereas the charge induced into the polymer matrix has a contrary sign. The charged polymer matrix acts like a permanent magnet. These charges may last several years depending on the polymer type.[3-5]

Materials and Methods

Coating Procedures

Commercially available plastic coatings were used in this study. They were applied to Cupforma 170 gsm from Stora Enso Oyj in two different extrusion coating pilot lines at Tampere University of Technology (TUT) and Borealis Polymers Oy. Corona discharge treatment was used to modify surface energetics and chemistry.

Digital Printing

The extrusion coated boards were printed on Xeikon DCP/50-SP digital printing machine at Stora Enso Research Centre.

Toner Adhesion

Toner adhesion was determined with a tape-peel method and a rub-off measurement. In the tape test an adhesive tape is pressed on the printed surface for 5 minutes after which the tape is pulled off at 180° angle. The measure of toner adhesion is a percentage (%) which equals to ratio of density of the printed area before and after the test.

Rub-off means the abrasion durability of the dry printing image. It is determined by rubbing the image against an unprinted surface. The amount of toner that has been transferred is measured by change in brightness (%).

Electrical Properties of Plastic Coatings

Surface energy of the plastic coatings was defined with contact angle measurements which were made with Panasonic AG-7355 device using 2-liquids method. The electret properties were determined with polar powder (Porapak® Type Q). This powder consists of polystyrene particles which have particle size of 80-100 mesh.

Print Quality

Print quality, mainly mottling, was analyzed both visually (ranking list) and numerically (mottle value). The visual evaluation was made by six different persons trained for these kind of evaluations. Numerical evaluation was done with Umax PowerLook II scanner and analyzed with Mottling Viewer -software.

Results and Discussion

Toner Adhesion vs. Surface Energy

Preliminary tests were made in laboratory scale with Xeikon magenta toner. Toner was spread out by hand on the plastic coated board samples and toner adhesion was defined with the tape-peel method. These tests indicate that when the surface energy of a plastic coating is above that of toner, the toner adhesion approaches 100% (Fig. 3). As Fig. 4 presents, some coatings have the required level already without corona treatment.

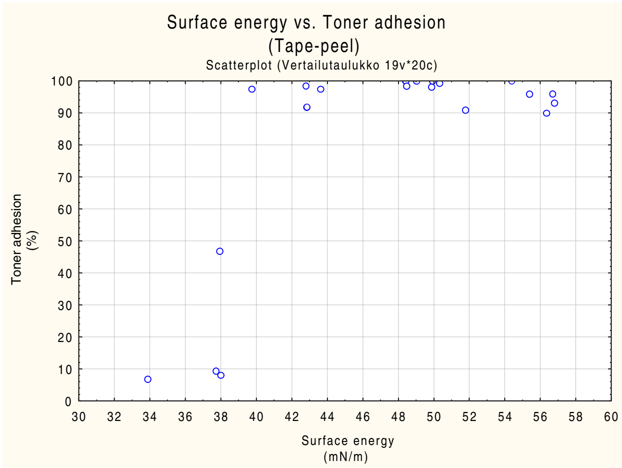

Figure 3. When surface energy of a plastic coating is above that of toner (~38 mN/m), toner adhesion approaches 100%.

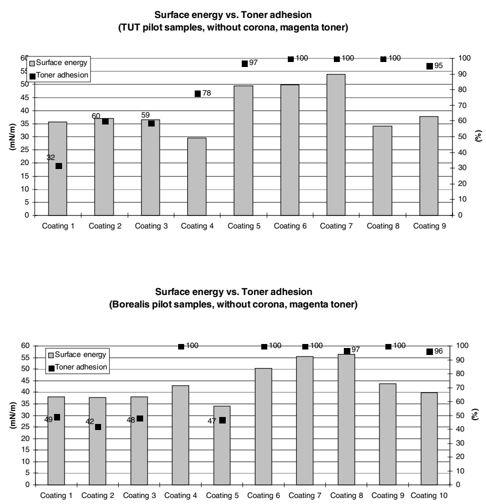

Figure 4. Surface energies and toner adhesion of separate plastic coated boards. Top: TUT Pilot samples, Bottom: Borealis pilot samples.

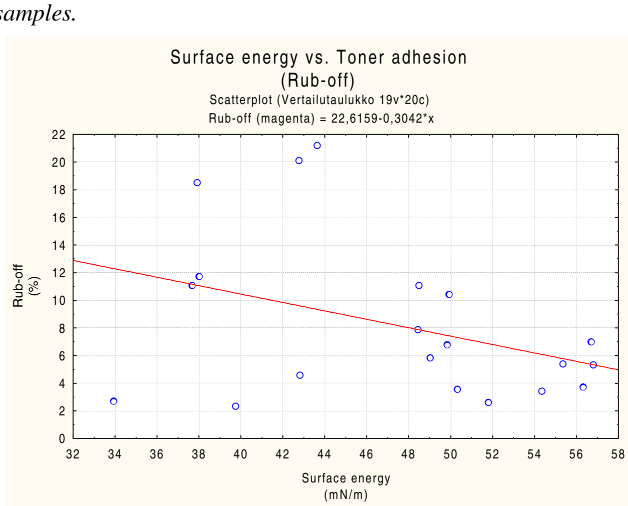

Figure 5. Abrasion durability increases when surface energy increases. (The lower the rub-off value, the better the abrasion durability).

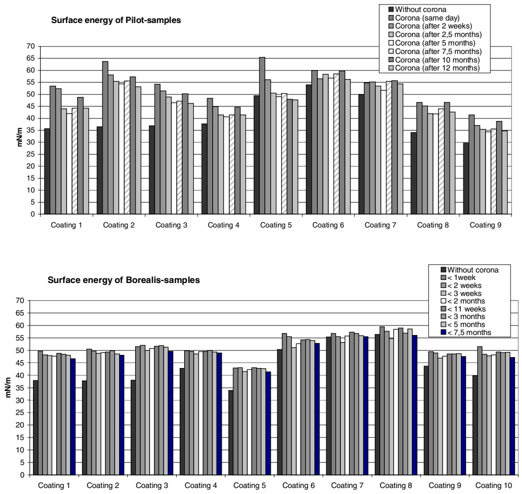

Figure 6. Decrease of surface energy as function of time. The top graph illustrates TUT pilot samples and the bottom graph Borealis pilot samples.

The contact angle measurements show that corona treatment clearly increases the surface energy of the plastic coatings. Surface energy has, however, the habit of decreasing with time. This phenomenon has been studied earlier by several researchers and the same result was observed in this study also. As Fig. 6 shows, the decrease is more rapid just after treatment and after that the surface energy settles to a certain level. In Fig. 6, the first bar indicates surface energy of the sample without corona treatment and the following bars indicate surface energy after the treatment.

Despite the decrease, the surface energy level of corona treated samples stays higher than that of samples without treatment.

Electret Phenomenon

As mentioned above, corona treatment can cause a permanent electrical charge on a plastic surface. This electret effect can be investigated with polar powder. The powder is poured on an extrusion coated board sample. The sample is carefully swung back and forth and the excess powder is poured away from the surface. The electrical charges induced by corona treatment cause the powder to spread out unevenly on the surface. The powder forms figures on the plastic surface.

When samples without corona treatment were studied, it was discovered that the powder did not attach to these surfaces at all. When poured on samples which were corona treated, the powder attached more or less with every sample. Figures 7 and 8 are images of two separate plastic coated boards. Distinctive differences in powder spreading can be observed between samples A and B.

The same pattern was observed when toner was spread out, by hand, on the plastic coatings. With some plastic surfaces toner particles spread out evenly and with some surfaces toner particles attached unevenly and formed figures. These results indicate that corona treatment affects differently on separate plastic coatings, and that the charge uniformity varies depending on the plastic type. Also contact angle measurements support these conclusions.

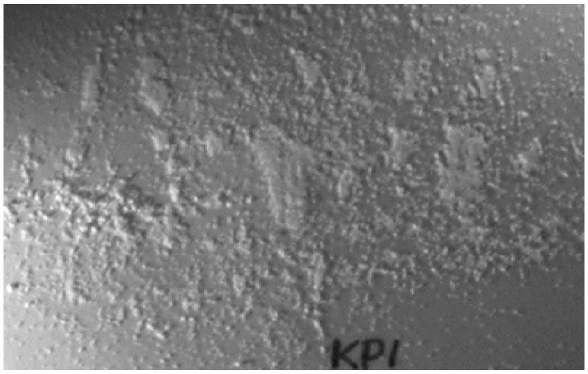

Figure 7. Polar powder has formed figures on the plastic coating A.

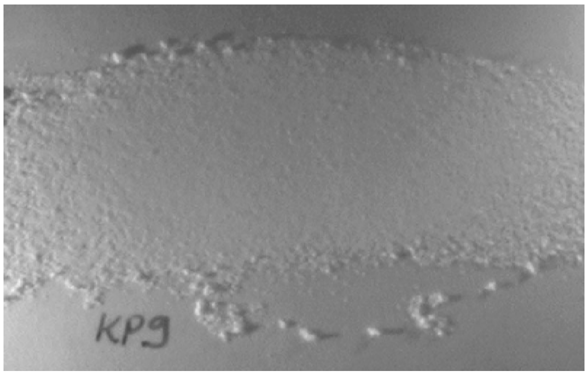

Figure 8. Polar powder has spread out evenly throughout the surface of sample B.

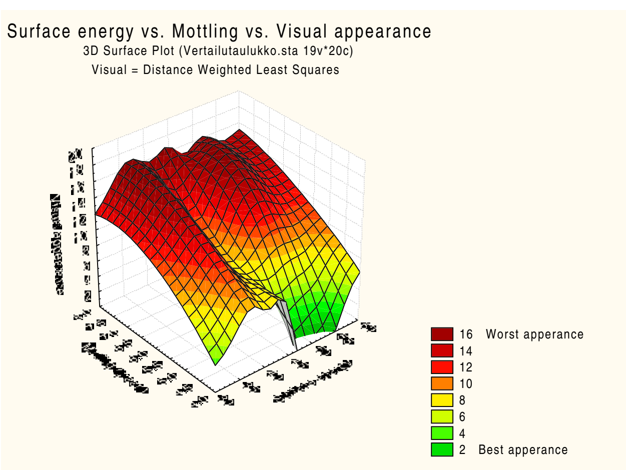

Figure 9. The effect of surface energy level on print mottle and visual quality. (The lower the mottle value, the less mottling.)

Correlation Between Surface Energy, Toner Adhesion and Print Quality

Surface energy of the plastic coating surface seems to play a quite important part in visual quality formation. As Fig. 9 presents there seems to be a certain level for surface energy in order to achieve low mottling and good visual appearance.

Rub-off is one measure of toner adhesion. As Fig. 10 shows high abrasion durability, i.e. toner adhesion, ensures low mottling values and high visual quality.

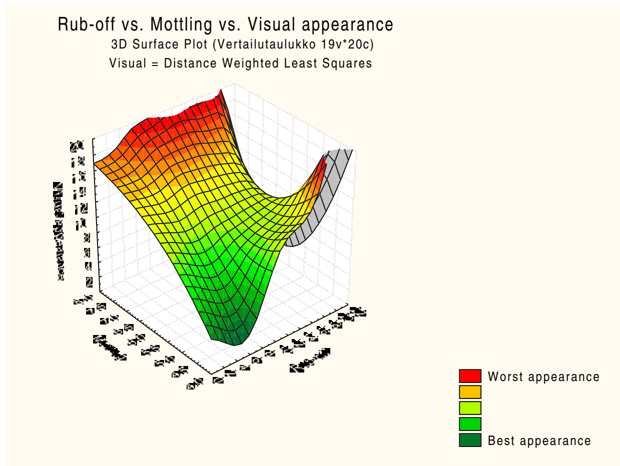

Figure 10. The effect of abrasion durability on print mottle and visual quality.

Conclusion

Adequate toner adhesion is essential when extrusion coated packaging applications are concerned. High enough surface energy and surface charge uniformity are necessary for uniform print quality and toner adhesion. Some plastic coatings have the required surface energy level without corona treatment, but some coatings need surface modification in order to succeed in digital printing process.

Future Work

This research work continues and the purpose is to use also microscopic techniques, e.g. ESCA (XPS), SIMS and AFM, to investigate more detailed the effects of corona treatment on plastic coatings. This includes the amount and nature of chemical groups formed on the surface and the surface charge uniformity. These studies will hopefully help to define the relationships between plastic coating structure, electrical uniformity and print quality.

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Biography

Johanna Lahti received her M.Sc. degree in Mechanical Engineering from the Tampere University of Technology, Finland, in 2000. Her main subject was Paper Converting Technology. After graduation she continued her work at TUT´s Institute of Paper Converting as a research scientist. The same year she was accepted to the International Ph.D. Program in Pulp and Paper Science and Technology (PaPSaT) in Finland. Her Ph.D work involves digital printing of packaging boards and her current interest is the dry toner based electrophotographic printing of plastic coated boards. E-mail: johanna.lahti@tut.fi.

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