THE ROLE OF ELECTROKINETIC SONIC AMPLITUDE ON GRAVURE CYLINDER BANDING

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Abstract In Gravure printing, the destruction of chrome plating in the form of banding is sporadic and destructive. While several factors are involved in this phenomenon, physico-chemical properties of the ink such as particle size, the electrokinetic sonic amplitude (ESA) and conductivity seem to play a major role. Maximizing ESA offers a solution to this problem. While smaller particles are less abrasive, maximizing ESA corresponds to smaller particles with low conductivities in solvent based gravure inks.

Introduction

Of the three dominant printing processes: lithographic, gravure and letterpress, the gravure printing is the preferred type for long run publications because of its high quality reproduction at high speeds. Gravure printing is also used in packaging materials such as paper and board since line cutting and creasing operations are easier because of the drying characteristics of inks. In addition, for printing on non-porous substrates such as aluminum foils it is ideal since lithography is easier on absorbent substrates. The printing image is engraved into the gravure cylinder in the form of cells which are filled with ink. The cylinder is made of a copper plated steel tube using a diamond stylus to engrave cells shaped like inverted pyramids. The end result is a cylinder of varying depths of cells. Deeper cells carry more ink and generate darker tone. Finally, the finished cylinder is chrome coated[1].

Schematically, the gravure process is shown in Figure 1. The printing unit is composed of an ink duct in which the etched cylinder rotates in a low viscosity ink. Excess ink is scraped with a doctor blade and printing occurs at the nip between the etched cylinder and a rubber covered impression roller. The printed web is then heated in a dryer and succeeding colors are printed.

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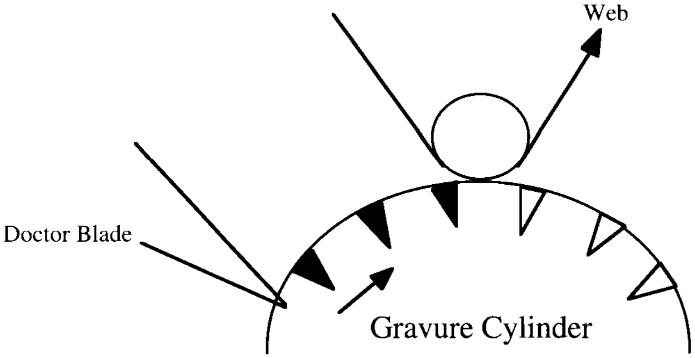

Figure 1. A schematic of gravure printing showing wiper, cylinder and web.

Most publication gravure inks are toluene based in which the polymeric binder is usually a calcium or zinc resinate. In process printing, carbon black, phtalo cyanine blue, diarylide yellow and lithol rubine pigments are used. A frequent complex problem in gravure printing is called banding. Banding is the scoring of the gravure cylinders, beginning at the edges and progressing into printing areas. It occurs erratically and predominantly on the cylinders running black ink. Although some cases of blue ink banding have been reported, very few of the other colors are involved. As the length of run increases, banding causes spoilage of the prints. De-chroming and re-chroming of the banded cylinder help prolong the life of the cylinder, but it usually recurs. The erratic nature of the occurrence of banding and the potential involvement of over twenty operating parameters make the analysis extremely complex.

Major factors which can lead to the destruction of the chrome plating in the form of scaling include the source of chrome electrolytes which have different wear behavior due to different chromium structure, the speed and pressure of the wipe and the physico-chemical properties of the printing ink. This paper will address the properties of the ink, specifically the colloidal aspects which include the influence of electrokinetic sonic amplitude, particle size and conductivity and how these factors come to bear on the double layer and abrasiveness of carbon black pigments in solvent gravure inks. ESA involves the application of an oscillating electrical potential to the sample.

Interaction of the sinusoidal electric field with the charged particles generates an ultrasonic wave.

Experimental

Electrokinetic Sonic Amplitude - The electroacoustic measurements were performed with the Matec ESA 8000 system[2]. The system was calibrated in the aqueous mode with a 10% (v/v) suspension of Ludox-TM. The system was then placed in the non-aqueous mode. 200 to 250 ml of ink was stirred with a magnetic stirrer throughout testing. The sample was referenced against itself to a phase angle of zero. The electrokinetic sonic amplitude (ESA) is the average of five readings and has units of μPa*(M/V). All inks were tested at the press viscosity unless otherwise stated.

Particle Size - Particle size analysis was carried out using the Microtrac Ultrafine Particle Size Analyzer (UPA). Samples were diluted 0.05% (wt/wt) with toluene and then sonicated. The stated particle sizes are the average of two runs, each acquired over 300 seconds. The resulting histograms exhibited mono-modal distributions.

Conductivity - The conductivity of the inks, as tested for use in ESA measurements, were determined with a Scientifica 627 Conductivity meter which is capable of measuring highly resistive systems.

Results & Discussion

Microscopy of Banded Cylinder and Doctor Blade

In Figures 2 and 3 are shown the optical photomicrographs of representative areas of banded cylinder shells. A network of surface cracking or reticulation of the chrome plated surface of the banded areas are visible in both specimens. The network of defects extends beyond the actual banded area and appears to be the initiating stage of the failure of the chrome plating. A possible mechanism for the destruction, which is most prominent in the center of each band, might be the flaking off of small chips of chrome loosened by this cracking or crazing phenomenon which later become trapped under the doctor blade. The hardness of the chrome flakes would then cause a rapid erosion and scoring of the cylinder's surface.

Also visible in the photomicrographs of the cylinder shell is the leading edge of the band which reveals an area extending beyond the heart of the band exposing the copper underlayer. Here, the surface is covered with the crazed or cracked chromium surface which has not yet deteriorated to the point of flaking off to expose the copper sub-surface. Moreover, there is also evidence of the beginning of a non-banded area which is essentially free of these hairline surface defects in the chromed surface.

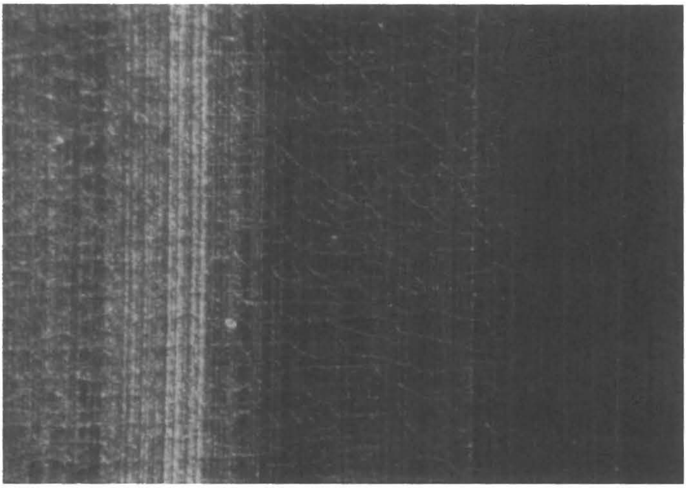

Figure 2. Optical photomicrographs of banded cylinder shells showing exposed copper in light areas. 46X

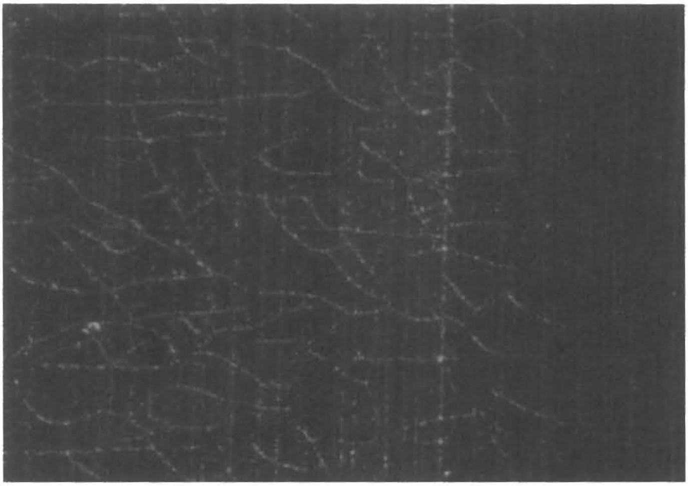

Figure 3. Optical photomicrographs of banded cylinder shells showing progression of surface crack from edge of band. 115X

A doctor blade section taken from the press was also examined and the corresponding optical photomicrographs are given in Figures 4 and 5 for the upper edge. Visible is the wear of the blade which occurs in the vicinity of the band and its identified as a low spot in the blade edge. Additionally, a number of areas of metal wear as well as a leaf blade metal are visible. The latter defect

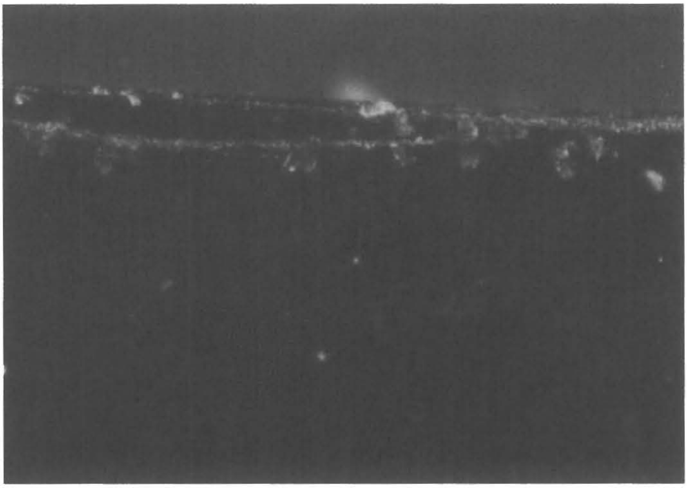

Figure 4. Optical photomicrographs of a doctor blade showing formation of loose wire edge on top of blade. 115X

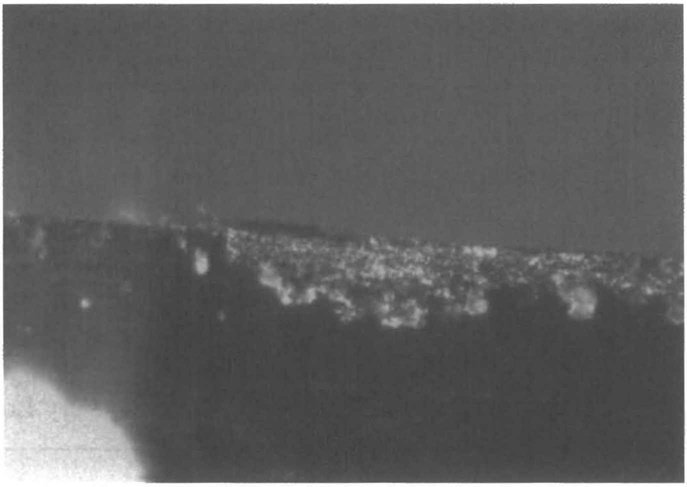

Figure 5. Optical photomicrographs of doctor blade showing peel-back of metal edge. 115X

is peeled backward and is about to break off. This excessive amount of wear would be expected if an unusual concentration of hard and/or abrasive materials, such as chrome flakes, collected under the blade while running.

Particle Size and ESA of Solvent Based Gravure Inks

Four inks of similar formulation were studied and differed only in the small amount of surfactant used. All were solvent based black gravure inks. The pigment to resin ratio was kept constant. The particle size distribution of Ink C is given in Figure 6 and is typical of all samples: broad particle size range with a monomodal distribution. The mean average particle size was determined to be 0.41μm calculated assuming a normal distribution.

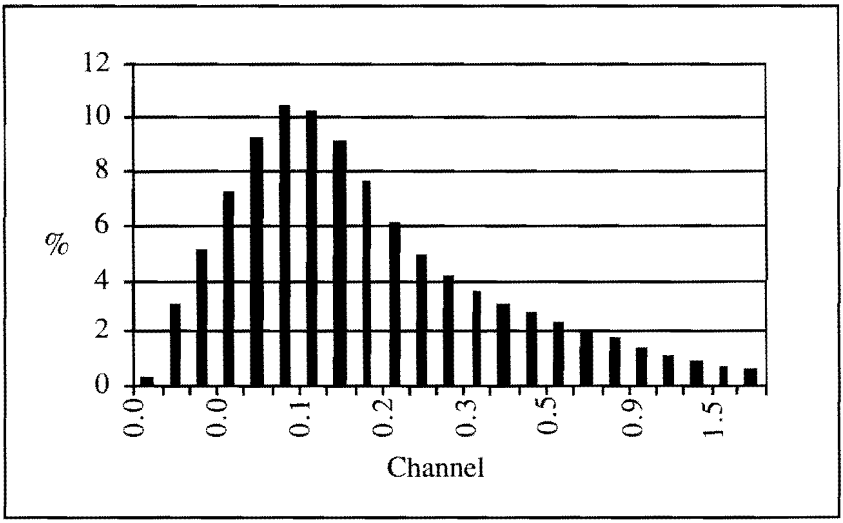

Figure 6. Particle size distribution of Ink C.

Table I ESA and Particle Size

Ink	Particle Size (μm)	ESA μPa*(M/V)	Banding Tendency
A	0.65	0.27	High
B	0.50	0.62	Medium
C	0.41	1.24	None
Mod A	0.46	0.75	Very Low

As shown in Table, whenever the ESA is less than 0.5μPa*(m/V) the incidence of banding was high. Correspondingly, the particle size is high. A hypothesis for the problem of cylinder wear can be proposed. While solvent based inks are stabilized sterically, charge appears to play a major role in obtaining smaller particles. As shown above, particle size and ESA are inversely related. Under high shear conditions, such as those generated between the doctor blade and the gravure cylinder, inks having a lower ESA would tend to flocculate thereby causing the particle to become abrasive and induce plate wear. Addition of small amounts of surfactant to sample A increased the charge from 0.27 to 0.75 μPa*(m/V). Use of ESA allowed the efficient use of chemical additives which would maximize charge.

Conductivity and ESA of Solvent Based Gravure Inks

While the relationship between particle size and ESA has been shown, there were many instances where the differences in particle size and ESA were not sufficient to predict banding Oftentimes, the mean average size of the particle were indistinguishable, particularly when taking into consideration the breadth of the histogram. Twenty black solvent based inks of known tendency to band were tested for conductivity and ESA. The data for the first ten samples are given in Table II. It would appear that low conductivity inks tended to band more than high conductivity inks. Low values of ESA also tended to band. The product of both conductivity and ESA measurements are plotted in Figure 7. While the theoretical basis for the product of ESA and conductivity correlation is not fully understood, there appears to be a strong empirical relationship, particularly when the values are greater than 40 or less than 30.

Table II Conductivity, ESA and Banding Tendency

Ink	Conductivity nanomho/cm	ESA µPa*(m/V)	Banding Tendency
1	1.98	10.9	Yes
2	4.26	10.8	No
3	2.36	10.3	Yes
4	4.06	10.5	No
5	3.68	7.4	Yes
6	4.57	8.4	No
7	3.60	11.9	No
8	3.53	10.1	Yes
9	3.18	6.8	Yes
10	3.81	10.9	No

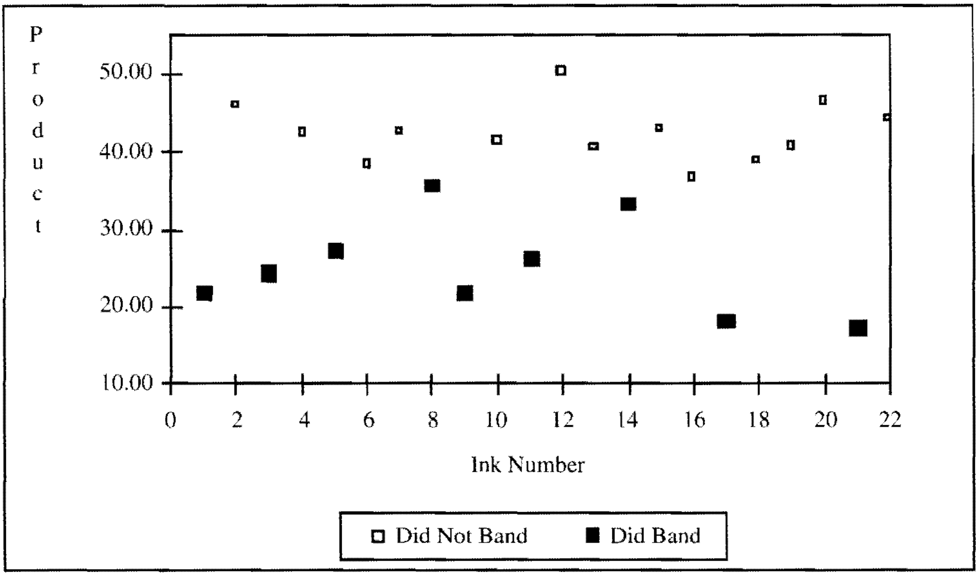

Figure 7. Product of Conductivity and ESA versus Ink Sample. Open symbols banded, closed symbols do not band.

The origin of conductivity in solvent based inks is probably from the presence of trace amounts of water[3]. Small amounts of adsorbed water may prevent flocculation and result in larger ESA's. However, when the levels of water are increased, more water is distributed on the carbon black particle surface. This water then is able to dissolve counter ions which reduce the net charge. Studies have shown that the optimal water level that corresponds to a maximum charge occurs at trace amounts, the level dependent on surfactant concentrations. At low conductivities, a small surface charge yields a large surface potential since the double layer is diffuse[4].

Evidence of this is supported in a separate case of banding involving solvent based cyan gravure inks, both which banded severely. The conductivity was found to exceed 200 nanomho/cm for both inks while the ESA was less than 1.0 µPa*(m/V). In carbon black inks the conductivity never exceeded 20 nanomho/cm. Determination of water content found between up to 5% water in the inks. At these levels, the dissolution of counter ions into the increased water adsorption layer around the particles has effectively reduced the charge. In an ongoing evaluation of more than 40 black gravure inks, the relationship between ESA, conductivity and banding has been maintained.

Conclusion

The phenomenon of gravure cylinder banding has at its origin the electrical process at the interface. From the inks perspective, both ESA of carbon black particles and conductivity of solvent gravure inks show good correlation for predicting the occurrence of banding. Low ESA generally leads to larger particle size via flocculation of the particles which are in turn more abrasive. The stability of the dispersion is evidently governed by the double-layer electrostatic repulsion as demonstrated by the close relation between ESA and stability. The conductivity plays an important role in charge dissipation at the particle surface, with large amounts water shifting the balance of charge to smaller values due to dissolution of counter ions.

Acknowledgments

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