Effect of Viscosity on Halftone Reproduction in Rotogravure Printing

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Abstract

Rotogravure printing is still arguably the best reproductive method for high speed printing of quality publications, with the ability to print discrete dots of ink varying in size and volume creating the illusion of constant tone. The size and shape of the printed dots is dependant on a number of factors such as substrate, cylinder manufacture, cell shape and size and ink viscosity. Some print plants see viscosity as a suitable and applicable method for control of colour on the print by adding solvent to reduce the pigment concentration per unit volume; hence reducing the saturation. In addition some companies use higher solvent concentrations to increase the drying speed of certain types of solvent-based inks by speeding up the rate of evaporation.

As part of a series of investigations into the consequence of changing process parameters the effects of viscosity changes in a solvent based ink printed on to a porous paper substrate were investigated. The result of viscosity reductions on the halftone dot reproduction was established by the use of spectrophotometric and image processing methods. As the viscosity was lowered the pigment concentration fell resulting in a reduction in the print density of the solid. However for the halftones reductions in ink density were to some extent offset by an increased flow of ink across the substrate, the result of which would be to lower the print contrast and image sharpness on the final print.

Introduction

Rotogravure printing is used primarily for packaging and publication where high quality or longer print runs are required. The process has the least number of components of all the major print processes; a schematic of the process is shown in Figure 1. The printing cylinder rotates in a bath of low viscosity ink and as the cylinder rotates the ink is transferred to the cylinder, coating its surface and entering the cells. The excess ink is then removed from the cylinder surface by a

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doctor blade, leaving only the ink in the cells available for transfer to the surface of the substrate.

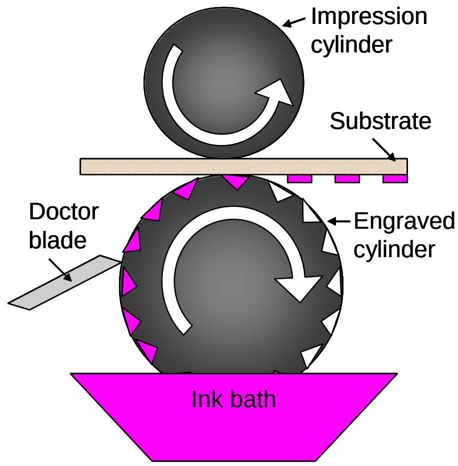

Figure 1: Schematic of rotogravure print process

Contact between the engraved cylinder and the substrate, which is backed by an electrometric coated steel roller (impression cylinder), transfers the ink from the cells to the substrate printing one colour per cylinder. The size and distribution of the cells on the print cylinder are the primary control mechanism for determining the contribution of the individual colour within an image; however the properties of the liquid ink used will influence how the ink transfers to the substrate.

In a large number of print plants setting the ink viscosity is the prerogative of the press operator, where the viscosity is sometimes reduced as speed is increased or to induce faster drying. It is also sometimes used to control the print density. Lowering the viscosity of the ink on the press by increasing the amount of solvent within the ink changes the pigment to solvent ratio, hence reducing the ink density.

Little research has been previously conducted into the rotogravure process, the majority of the studies have utilised laboratory equipment to replicate the process. Kunz [1] found that the impression roller, press speed, doctor blade, cell geometry, ink viscosity, and substrate all have significant roles on the ink transfer in the gravure process. Changing the ink viscosity had a significant effect on the flow of ink in and out of the cylinder cells and the way in which the ink flowed across the substrate surface. In addition, viscosity had an effect on the speed of relaxation of the ink in the cell after the dragging action of the doctor blade. This relaxation also changed the way in which the ink was transferred at the nip.

Jeske [2] conducted an investigation into the use of an impulse press simulation of the gravure printing nip. The ink transfer to the substrate increased with increased nip pressure, contact time and cell size. A reduction in ink viscosity also increased the ink transfer as did a change in substrate from a coated paper to a more absorbent news paper. The smoothness and compressibility of the substrate influenced its ability to conform to the cells under the pressure of the nip. At high speed neither capillary nor hydraulic forces were thought to have played a significant role in the transfer at the nip.

Sprycha and Hruzewicz [3] showed that the most important wetting occurred within the first 50 to 100 milliseconds of ink transfer on to the substrate surface. The wetting out of the ink on a substrate was a complex function of interfacial energies, surfactant migration to the substrate-ink interface, and penetration of solvent into the substrate and viscosity changes at the interface.

In order to understand effect of viscosity on the rotogravure print process an investigation was conducted under controlled conditions on a production press. Following a description of the experimental procedure the effect of viscosity on tone gain are presented and discussed.

Experimental Programme

A set of four process colour test cylinders were manufactured for use in the print trial. The test image Figure 2, contained areas used to assess the effects of viscosity variation on the quality characteristics of colour gamut, density, tone gain and trap. The tone gain was assessed both parallel and orthogonal to the print direction.

Figure 2: Representation of the test image printed during the trial

The test image was printed using inks at three viscosities onto an 80gsm one side coated paper. The inks used were nitrocellulose resin based and near Newtonian in nature. The viscosity was adjusted by the addition of a blend of solvents, each addition was allowed to distribute evenly through the ink mass. The viscosity was then measured using a Zahn cup, and additional solvent additions were made until the desired viscosity was reached. The viscosity and temperature of the ink was checked prior to and post print sample runs. The viscosities of the inks used in the print investigation were 0.038 Pas (22 sec Zahn 2), 0.0255 Pas (19 sec Zahn 2) and 0.006 Pas (16 sec Zahn 2); the temperature of the inks remained unchanged at 22° C.

The printed web was cut into sheets and labelled, 32 sequential sheets were then measured using a spectrophotometer and the results checked and an average value taken. This number of sheets allowed for the frequency variation during the run to be investigated, in addition to improving the accuracy and error elimination due to copy-to-copy variation [4]. The results of the investigation were then analysed using an L9 orthogonal array techniques.

Results

The effect of viscosity reduction on the solid printed ink density is shown in Figure 3.

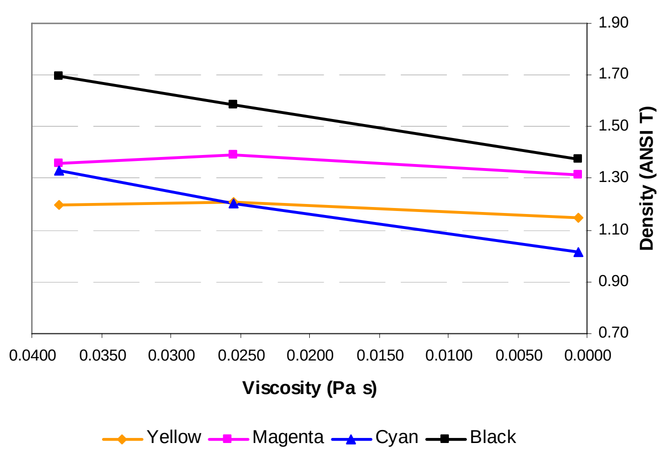

Figure 3: Solid density of the four process colours plotted against viscosity reduction

The cyan and the black showed similar trends, to each other with a linear reduction in solid density as the viscosity was reduced. The black solid density fell from 1.69 to 1.38 and the cyan solid density fell from 1.33 to 1.01. Both reductions in density were significant and were consistent with the reduction in the ink strength due to the addition of solvent

The magenta and the yellow also shared similar trends to each other. The initial viscosity reduction from 0.0380 Pas to 0.0255 Pas showed a small rise in solid density of the yellow of 0.01 and the magenta of 0.03. However a further reduction to 0.006 Pas showed a solid density reduction for the yellow of 0.06 and the magenta of 0.08. The trends for the yellow and magenta were not consistent with the change in ink strength and therefore suggest the ink transfer to the substrate was also affected by the reduction in viscosity.

Figure 4 shows the effect of ink viscosity reduction on tone gain for the yellow and magenta inks, while the tone gain for cyan and black is shown in Figure 5. The high values of tone gain were the result of using of test cylinders, with no gamma correction applied, this is also the reason why there appeared to be a loss of tone between 0 and 10%. The cells being to small to transfer the correct ink volume. The tone gain for all the colours printed show the largest gains between 20% and 60% nominal values.

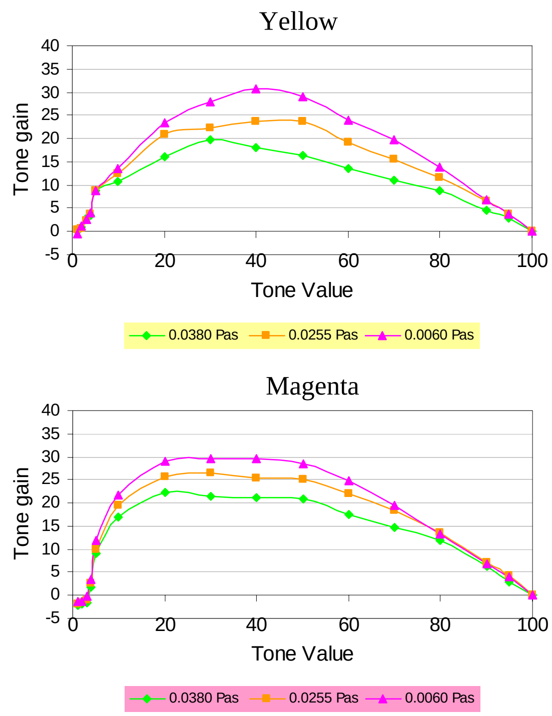

Figure 4 :Tone gain for yellow and magenta plotted against expected tone value

The effect of viscosity reduction on tone gain was similar for the yellow and magenta test patches. As the viscosity was reduced there was little change in tone gain for the nominal tone values up to approximately 15% or after approximately 90%. Between 15% and 90% the tone gain increased as the viscosity was reduced. Both the yellow and the magenta inks showed discrete changes in tone gain as the viscosity was reduced, with the tone gain increasing by similar amounts for each viscosity reduction. The yellow showed the largest response to change in viscosity, with approximately 15% increase for the 50% nominal tone value.

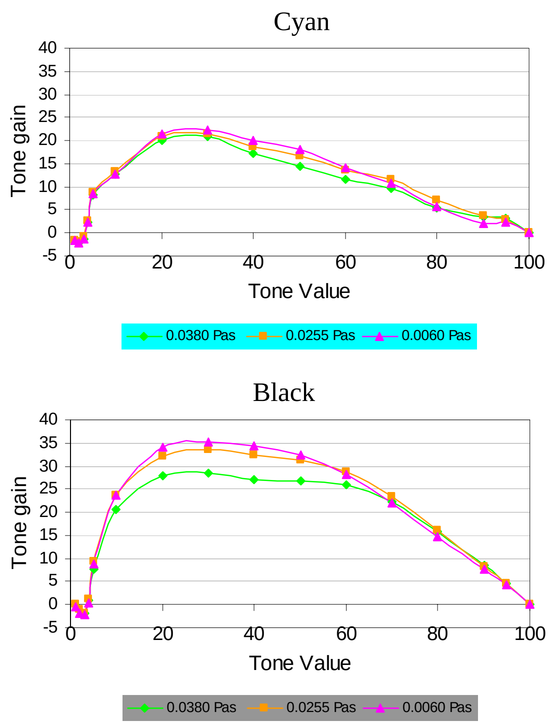

Figure 5 - Tone gain for cyan and black plotted against expected tone value

The black tone gain curve (Figure 5) showed little change in the tone gain with the viscosity reduction for the nominal tonal values up to 15% or those after 60%. Between the nominal tone values of 15% and 60%, the first viscosity reduction to 0.0255 Pas produced a relatively large increase in tone gain. However for the second viscosity reduction to 0.006 Pas the affect on tone gain was much smaller. Overall the cyan produced the least amount of tone gain of all the colours and it was also the least affected by changes in the viscosity. Like the majority of the other colours the tonal values up to 15% were unaffected by the change in viscosity. Small changes in the tone gain were observed in the mid tones as the viscosity was reduced; however these changes were insignificant when compared to those observed in the other colours.

Discussion

A significant reason for the different responses of the four process colours is the shape of the engraved cells. In rotogravure printing moiré patterns are avoided by changing the configuration of the engraved cells for each of the process colours. Figure 6, shows the different cell configurations used for each of the process colours.

Colour	Cell Orientation	Comments
Yellow		*Normal course cut cell* *45 degree cell*
Magenta		*Elongated cell* *60 degree cell*
Cyan		*Compressed cell* *30 degree cell*
Black		*Normal fine cut cell* *45 degree cut*

Figure 6: The orientation of the cells engraved on each of the four colour process cylinders

In addition to the variation in cell shape, the distribution and size of the cells alter as the percentage of the tone decreases; all of which impact on the amount of ink that can be transferred [1]. The ink in the cell, as it passes under the doctor blade, is dragged back by the blade toward the trailing edge of the cell. The ink left in the cell then relaxes back into the centre of the cell forming a concave meniscus. The faster the relaxation, the more uniform the ink is within the cell before it reaches the printing nip and hence leads to a more effective ink transfer. The speed of ink relaxation is dependant on the ink viscosity, the shape, size and type of the engraved cell. A lower ink viscosity and smaller and less elongated engraved cells, also lead to faster ink relaxation. This would explain why the coarse square cells of the yellow and the elongated cells of the magenta have similar trends, while the fine square cells of the black and the compressed cells of the cyan have similar trends.

The physical effect of changing viscosity on the magenta and cyan printed dots is shown in Figure 7. These images were captured on the 50% nominal halftones using a stereomicroscope. At the highest viscosity (0.0038 Pas) the differences in dot shape between the two colours resulting from the different cell configurations can be observed. The magenta dots showed the classic ‘doughnut’ effect; the hole in the centre of the printed dot caused by the dragging action of the doctor blade and the speed of relaxation of the ink in the cell prior to the contact with the substrate. As the ink viscosity is reduced the speed of relaxation of the ink in the cell increases and less ink is scooped from the cell as the ink flows more easily beneath the blade. Although this results in more ink being available for transfer and the smaller the doughnut effect, the ink in the cell now has a lower pigment concentration. Due to the different cell shape used for the cyan, the speed of relaxation and scooping action of the ink from the cell is was enough to result in a hole in the printed dot.

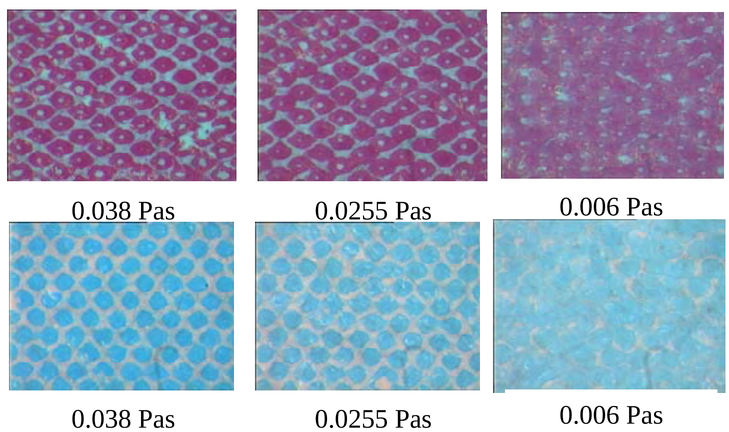

Figure 7: Images of 50% dots printed at viscosities of 0.038, 0.0255 & 0.006 Pas

Viscosity also had a significant effect on the size of the printed dot, however to some extent this could also be dependant on the absorbent nature of the substrate. As the viscosity was reduced from 0.038 Pas to 0.0255 Pas the magenta dots increased in size, but the ink film did not appear to loose saturation. A further reduction to a viscosity of 0.006 Pas resulted in no structure to the printed dot pattern; the dots had joined together. At this ink strength there was a reduction in the saturation of the printed ink film. The solid density of the magenta changed very little as the viscosity was reduced, this was also observed in the images captured by the stereomicroscope. This suggests that the reduction in ink strength as the viscosity was reduced was compensated by an increase in the amount of ink released from the cells. The decrease in viscosity also increased the flow of ink across the substrate surface. When combined with the negligible change in solid density this led to the increases observed in the tone gain.

For the cyan, when the ink viscosity was reduced from 0.038 Pas to 0.0255 Pas, there was a small increase in dot size, combined with a slight fall in saturation of the ink film. A further reduction to a viscosity of 0.006 Pas showed that there was no structure to the dot pattern and that there was a significant reduction in saturation of the ink film compared to the prints made at the highest viscosity. The reduction observed in the saturation of the cyan as the viscosity was reduced was consistent with the trends observed in the solid density. This suggests the quantity of ink transferred to the substrate was largely unaffected by the changes in viscosity. The majority of the changes observed in the density were therefore due to the reduction in the ink strength. Although for the mid tone and shadow regions the reduction in viscosity increased the flow of ink across the substrate. Unlike the magenta, the solid density of the cyan reduced significantly as the viscosity was reduced, therefore resulting in little change in tone gain.

Conclusions

This investigation has shown that failure to specify and control the viscosity in the rotogravure print process will result in changes in the reproduction of a printed image. The changes in overall density and dot size will result in unpredictable colour changes in the printed image. The loss of dot structure will also result in a loss of clarity of the image the image will appear soft or out of focus. The main conclusions of this investigation are as follows: -

- Changing ink viscosity affected the quality characteristics of print in different ways.
- Reduction in viscosity produced an increase in tone gain, which was more significant for the half tones than the shadows and the highlights. The process inks appeared to behave as pairs, yellow with magenta and cyan with black, which was due to cell geometry rather than the pigment to solvent ratio.
- The different cell shapes appeared to have different fill and release characteristics.
- Dot structure is lost at very low viscosities.

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