Scumming: The influence of the cylinder

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Abstract

Scumming produces major quality problems in rotogravure printing. It causes a discolouration of the non-image area and is particularly noticeable when printing on clear film. This can cause entire print runs to be rejected. There is currently little knowledge and understanding of causes for scumming.

This paper discusses the results obtained from an extensive industrial trial to evaluate the effect of the cylinder surface on the level of scumming. A rotogravure cylinder was used, with the bands of different surface characteristics. The press was monitored for temperature using thermocouples and doctor blade load with strain gauges attached to the blades. The prints were then produced at a number of controlled conditions.

The prints produced have been measured using densitometry and spectrophotometry. The results have shown it is necessary to measure using the colour space data, even with process colours. The different surfaces showed a significant difference in the level of scumming on the substrates used. A relationship has been identified between the surface and level of scumming.

Introduction

Rotogravure printing is a high speed, high quality manufacturing process where there is little fundamental understanding of the ink mechanisms occurring. The purpose of this paper is to examine these in greater detail. The rotogravure printing system is shown schematically in Figure 1. An engraved cylinder carries the image to be printed. This rotates in an ink bath with the individual cells being filled with ink. This is metered with a doctor blade and the image is transferred to the substrate under impression.

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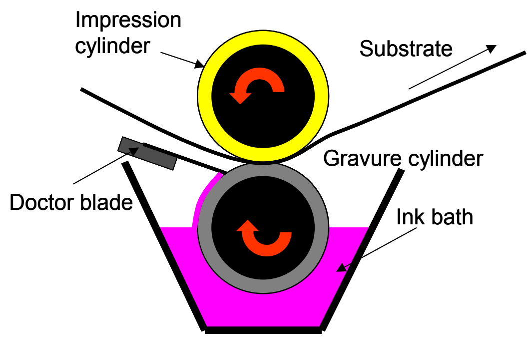


Figure 1 Schematic of the rotogravure process

Though inherently a simple system with a limited amount of components, in comparison to other processes, there are still many factors that can affect the transfer from both the image and non-image areas, Figure 2. Currently, scumming (also referred to as hazing) occurs in a non-predictable manner on the press and has to be addressed when it occurs on the press. This may include altering the ink or doctor blade settings. However, this may not solve the problem and it is then often necessary to produce a new cylinder. This produces problems with productivity as there will be an unnecessary make ready, the job will be delayed and work flows all need to be altered.

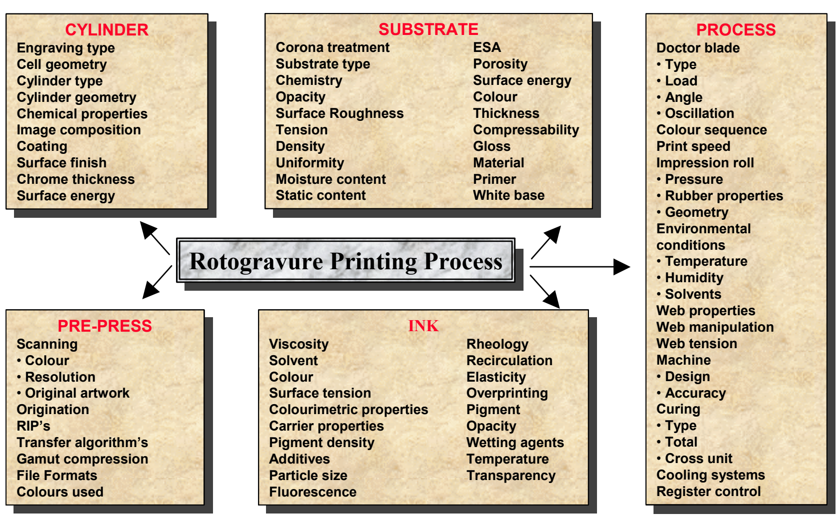


Figure 2 Parameters effecting image quality in rotogravure printing

This paper concentrates on the cylinder effects on the transfer of ink from the non-image areas. This has been achieved using a commercial press trial with a gravure cylinder containing bands of different surface finish.

Experimental design and programme

A full-scale industrial experimental trial was designed to evaluate the influence of the cylinder surface on propensity of scumming to occur. The full-scale trial was required to ensure that the forces and speeds at the transfer were representative, which cannot be achieved on most test facilities. In addition, the use of commercial equipment allowed the findings to be easily and effectively transferred to industry.

In the trial two banded gravure cylinders were used, each with six different, constant width surface finishes. The surface variations were made in both the copper and chrome stages of production. The different surface finishes are shown in Table 1. The cylinder surfaces were measured using a non-contact white light interferometer during the production stages. This included pre-engraving, post engraving, post chroming, post chrome polishing and post printing. This would provide data on the surface topography and how this was altered during production. The post-engraving measurements were required as there is a burr cutter on the engraving head and this can affect the surface dependent on its setting.

Finish	Cylinder	Copper	Chrome
F1	1	Polishmaster, 15 micron paper	15 micron paper
F2	1	Polishmaster	15 micron paper
F3	1	Polishmaster, 2000 grit stone	15 micron paper
F4	1	Polishmaster, 2000 grit stone	800 stone grit stone
F5	1	Polishmaster	800 stone grit stone
F6	1	Polishmaster, 15 micron paper	800 stone grit stone
F7	2	Polishmaster, 9 micron paper	15 micron paper
F8	2	Polishmaster	15 micron paper
F9	2	Polishmaster, 3000 grit stone	15 micron paper
F10	2	Polishmaster, 3000 grit stone	800 stone grit stone
F11	2	Polishmaster	800 stone grit stone
F12	2	Polishmaster, 9 micron paper	800 stone grit stone

Table 1 Surface finishes on cylinders one and two

Each band was engraved with a low coverage image in the centre of each band. This covered approximately 24% of the width of the band and 10% of the total area within the band.

The press trial was carried out on a commercial press running at a speed of 250 m/min on a white OPP film substrate. The impression pressure and blade angle were fixed for the duration of the trial. The ink temperatures and load on the doctor blade were measured to ensure consistency. Each individual trial evaluated the effect of blade load and surface finish on the level of scumming produced. The press was run stabilised at the running speed and prints produced for set intervals at each of the blade loads. The blade load was initially set at a high level and then reduced at 0.25 gauge bar intervals. Tags were inserted at the start and end of each trial to identify the relevant section substrate. This was also timed to allow identification of the prints if one of the tags was missing. The trials were repeated for three substrate types (clear, white OPP and metallised) and two ink types (NC and PVB). This paper will focus on the cylinder analysis and the prints produced with the PVB ink on the white OPP substrate. The ink was run at a slightly elevated viscosity, as it is conventionally believed that higher viscosities lead to higher levels of scumming.

The prints were collected on the reel and unwound after the trial. Sixteen consecutive prints from the end of each print run were collected and used for the measurements into the effect of scumming. Analysis had shown that this many were required for a statistically valid result, due to the natural variability of the process. For each band (different surface finish) seven measurements were made per cylinder revolution. These were alongside and between the images, as indicated in Figure 3. Measurements were made outside the image wipe direction (positions 1 and 3) this area is referred to as open, in line with the image (position 5) and in line with the surface identification label (position 2 and 5). The data obtained from each area were averaged, over sixteen consecutive prints. All measurements were made using a 0/45 spectrodensitometer on a black background. The densitometric and spectrophotometric data were recorded for subsequent analysis. The ΔE values were calculated from the unprinted material.

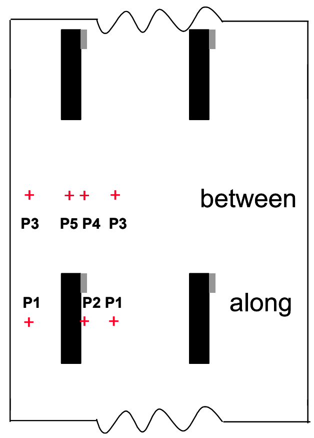
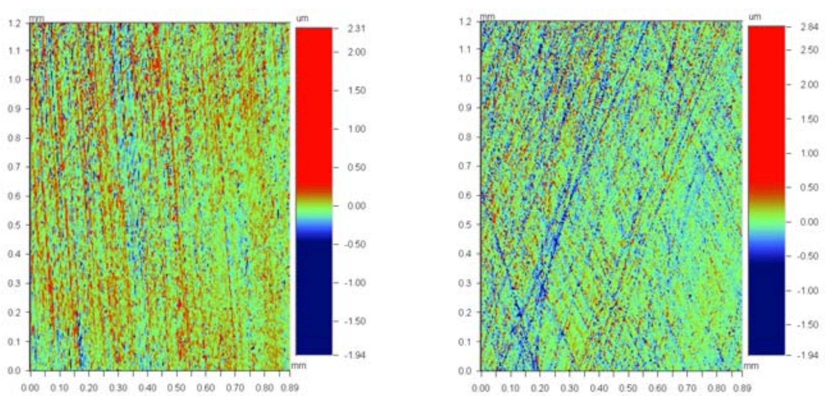


Figure 3 Image and measurement locations

Evaluation of cylinder surfaces

The surfaces of the cylinders were measured using the white light interferometer. Five measurements were carried out at each measurement position and the results averaged. Typical surface profiles are shown in Figure 4 for a stone and paper finish. The roughness and structure formed by the polishing can be seen. The analysis was carried out by removing the cylinder profile and tilt from the measurement using software. Analysis of these images can then obtain traditional metrology measurements, such as r_a and r_z. They can also be used to assess the structure of the surface.



Stone finish　　　　Paper finish

Figure 4 Typical surfaces from gravure cylinder

The surface roughness, defined by r_a, is used industrially as the main control in defining the cylinder surface and is *'optimised'* to minimise the influence of scumming. However, this will change between jobs and the *'optimised'* roughness can give rise to scumming. This was measured for each of the surfaces and the results are shown in Figure 5. These show three distinct surface roughness values on cylinder one, whereas for cylinder two the surface finishes are much closer. The cylinder surface roughness, structure and form are primarily determined in the copper. The surface produced by the Polishmaster is relatively smooth, as indicated by finishes two and five, with the roughness and structure being introduced by the use of either a polishing stone or paper. The engraving is shown to have an effect on the surface as a result of the head passing over the surface. There is a burr cutter diamond on this head and in this case can be seen to affect the surface. This is most noticeable for the rough surfaces. The results are presented separately for the image and non-image areas as the engraving head will be operational over the two areas a differently. While engraving it will traverse the cylinder slowly, while generally a faster transition will occur for the non-image areas. This can be seen by the deviation of the surface roughness for each of the bands. The electroplating of chrome further reduces the roughness, a function seen also in the chrome polishing. During printing with the cylinders there is a wear contact between the doctor blade and cylinder, leading to the final reduction in the surface roughness. The increase shown in surface finish 5 was due to damage to the cylinder surface from the ink, which resulted in a large number of blade lines. This occurred after these trials (after this section of the experimental programme) and therefore do not affect the results obtained.

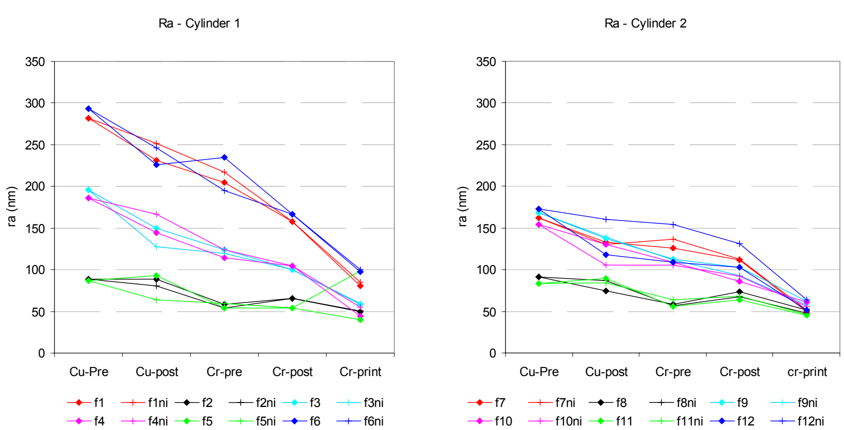


Figure 5 Cylinder surface evolution through production and printing

Experimental results

The density and ΔE colour difference results for the open area alongside the image from cylinder one are shown in Figure 6. These were calculated from unprinted material that had not passed through the press. The results compare the density / ΔE against blade load, in this trial it was reduced from 2.5 bar (gauge reading) until scumming was visually evident on all surfaces. The ink used during the trial was black; the densities are for the black component of the ink. The order of the surfaces was similar for each of the analysis methods. However, the form of the change with respect to alterations in the blade load is different, from which different conclusions can be drawn. These differences were apparent for many of the results. Visual analysis of the prints indicated that there were hue changes occurring at the low levels of ink transfer and that it was this that was giving rise to some of the differences observed. It was determined that for all the analysis the spectrophotometric data was required to be used.

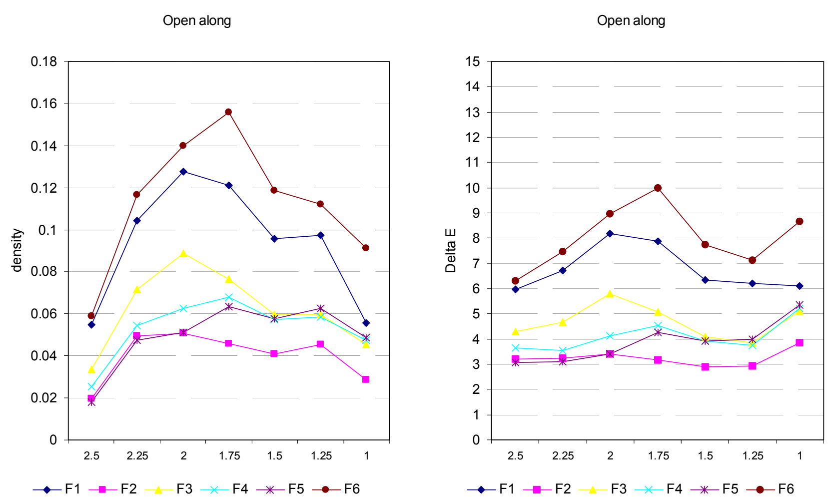


Figure 6 Scumming levels for cylinder one, density and colour space measurements

The scumming levels from the base substrate, for the open area of cylinder one, are shown in Figure 7. The six surfaces act differently, some having a greater susceptibility to scumming than others; with surfaces one and two having the highest scumming level. These were the roughest two surfaces produced, at approximately 100 nm $r_{a,}$ Figure 5. The results also show that there is a general increase in the scumming as the blade load decreases. However, this is non linear with the possibility of increased scumming with increased blade load. The results for the rougher surfaces show a 'bell curve response'. The explanation for this response is covered in [1]. The non-linear changes in ΔE shows the necessity to evaluate the influence of the blade load over a wide range.

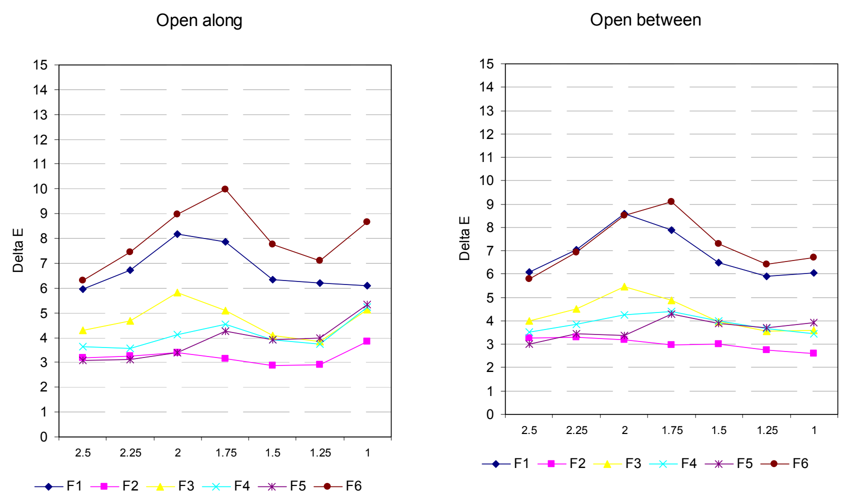


Figure 7 Scumming levels for cylinder one, open area

Differences occur when the analysis is carried out either alongside or in between the images, the measurement positions shown in Figure 3. However, these changes are minimal with the largest differences occurring at the high scumming levels. Similar trends were observed for cylinder two with good agreement between the two sets of results. This would indicate that it is appropriate to average these results. In addition, for subsequent investigations the measurement routine could be simplified with all the measurements being taken between the images.

Analysis of the areas in line with the image (position 5, Figure 3), Figure 8, showed larger differences when the results are compared with measurements taken outside the line of the image, Figure 7. Surfaces one and six again show the highest level of scumming. The four other surfaces can now be separated and the order of the surfaces is altered. Most notable difference is for surface two, the best-performing surface in the open area (lowest level of scumming), for which in line with the image both surfaces four and five perform better. This may be in part due to the change in surface profile caused by the engraving head traversing slower over the image area, Figure 5. However, the surface changes are small in comparison to the differences between the different bands. It is more probable that this due to the influence of having an image in line with the measurement position. These trends were repeated in the second cylinder with the order of the surfaces altering, particularly at the low doctor blade loads.

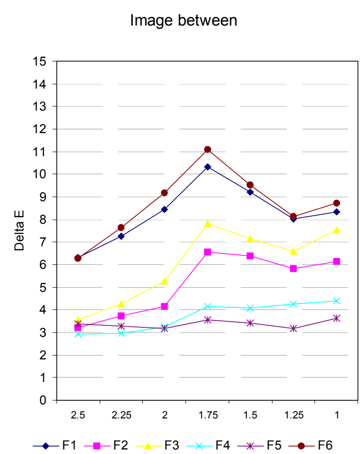


Figure 8 Scumming levels for cylinder one, image area

Measurements were also taken in line with the image identifier, the location being shown in Figure 3. These results showed a difference from either of the previous two in the fine detail, though the general trends remained similar. Differences were detected between the alongside and between measurements. To provide an overall view of the scumming all five sets of data have been averaged at each blade load, Figure 9. These show the two surfaces performing worst were the roughest and that in all cases, as the blade load was reduced, there was a general increase in the level of scumming. This non-linearity of the changes in scumming level showed that it was necessary to evaluate more that two blade load levels, and that in doing so incorrect inferences could be concluded dependent on the blade loads chosen.

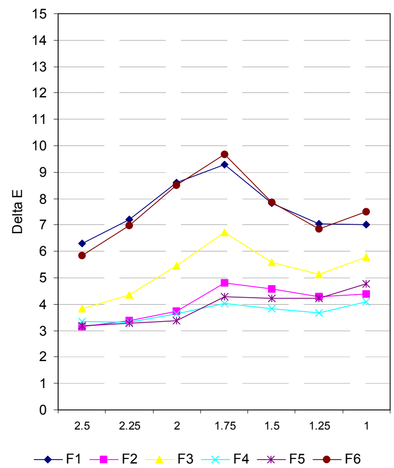


Figure 9 Average scumming levels for cylinder 1, image area

The results, especially from cylinder one, would indicate that the surface roughness was a primary control, function in the level of scumming. To evaluate this the data in line (positions 2, 4 and 5) and in the open area (positions 1 and 3) were averaged. Linear regression was carried out between this data and the surface roughness, r_a, measured prior to printing. This is shown graphically in Figure 10. The relatively high R^2 supports the hypothesis that the surface roughness has a direct relationship with the level of scumming.

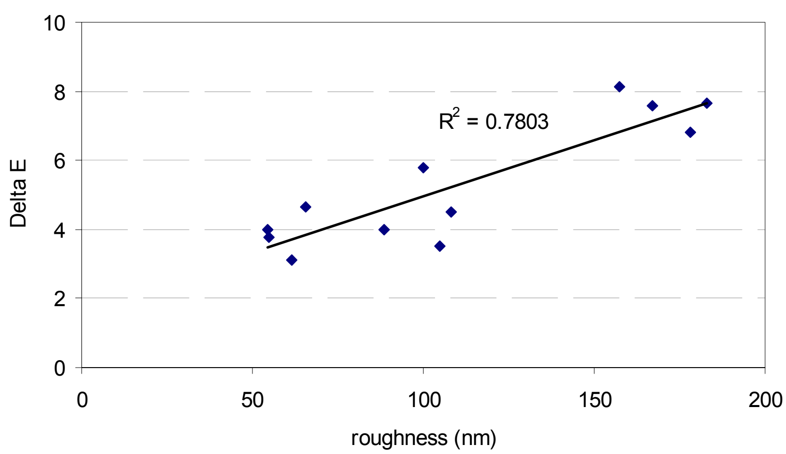


Figure 10 Roughness – ΔE relationship for cylinder one

The cylinders were designed to cover a wide range of surface roughness and the surfaces in cylinder one covered a much wider range than those in cylinder two, Figure 5. The two highest surface roughness values, on surfaces one and six, are at the limit of those used commercially. If these are removed from the analysis the R^2 value reduces to 0.14. This is mirrored in the analysis of cylinder two, with a R^2 value of 0.28, indicating that there is little, of any correlation between the surface roughness measured using r_a and the level of scumming, Figure 11.

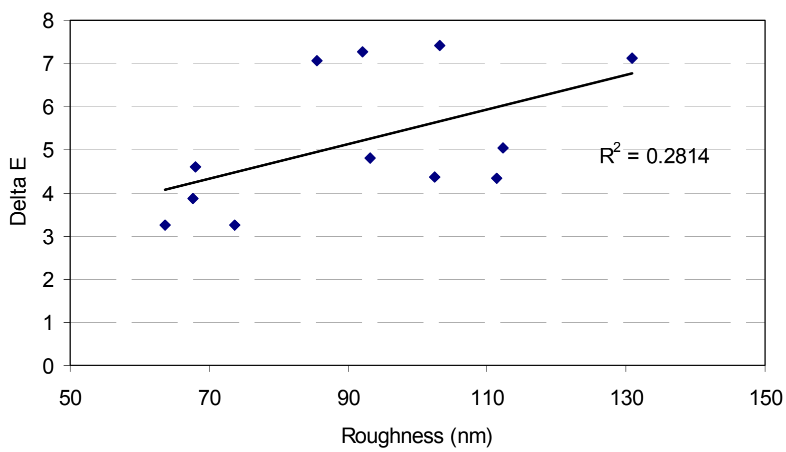


Figure 11 Roughness – ΔE relationship for cylinder two

Conclusions

A trial was carried out successfully on a commercial press to evaluate the effect of scumming in rotogravure printing. The trials were completed under controlled conditions. Prints were produced using two banded cylinders on white OPP substrate at a number of blade load settings. The main findings can be summarised as:

- The surface finish created in the copper dominates that in the finished cylinder
- Chroming the cylinder creates a smoother finish, as does polishing the chrome, though this is a relatively minor effect.
- All prints produced showed some degree of scumming.
- The scumming levels alongside and between the images showed similarity allowing the data to be averaged.

- Differences in scumming level were found between in line with the image and in the open areas of the print.
- The blade load had a non-linear effect on the level of scumming, with in general lower scumming levels at higher blade loads.
- The surface finish, as defined by r_a, only has an effect on the level of scumming at the extremes of surface profiles. Inside this region other mechanisms are occurring.

Acknowledgements

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References

1. Bohan, M.F.J., Clist, A.M., Claypole, T.C. and Gethin, D.T. "The effects of cylinder surface topography on ink transfer from non image areas" to be submitted to Proc. IMechE part B.