Automatic Viscosity Control in Gravure Printing

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Abstract

Ink viscosity has a significant impact on the ink transfer and colour in gravure printing. An evaluation of the use of automation compared with manual viscosity control was undertaken on a 5 colour web gravure press. The press was first operated with manual measurement control of solvent addition. The adjustments and corresponding colour were noted. The installed automatic viscosity control was used for monitoring. The trial was then repeated with the control of solvent addition by the automatic viscosity measurement system and manual monitoring of viscosity by the operators, with corresponding sample colour.

Under manual control the colour varied significantly, whereas a more consistent result was obtained using the automatic system to control solvent addition. This difference can be ascribed to intrinsic measurement errors in the use of the flow cups to measure viscosity, highlighted in both the preliminary evaluation of the operators and the comparison with on the press automatic viscosity control system.

Introduction

The control of the viscosity of ink in gravure printing has a large effect on the quality of the final printed image. During the gravure printing process ink must first fill the engraved cells on the cylinder surface, then after doctoring transfer to a web of substrate. To achieve transfer the ink must be highly mobile and of low viscosity although addition of solvent to neat ink will produce a non-linear reduction in the inks viscosity, (Figure 1). Increasing the solvent ratio however, also has the effect of lowering the pigment concentration thus reducing the

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strength of the colour. Another effect of ink viscosity is the change in the ink transfer rate as the cylinder is doctored changing the amount of ink available for transfer from the cell to the substrate.

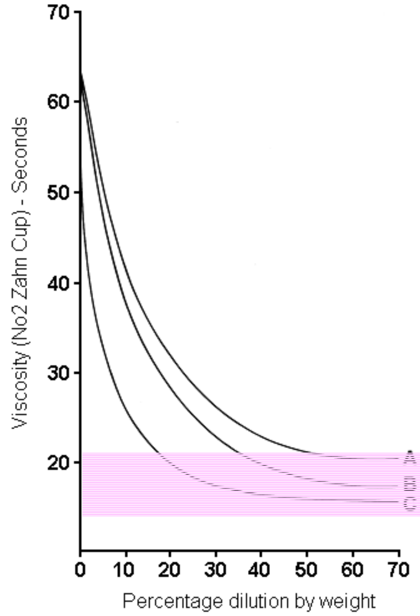

Figure 1: Dilution-viscosity curves for gravure inks [1]

Solvent evaporation through the course of a print run changes the concentration of the pigment in the ink. Addition of solvent during the print run is therefore required to maintain the stable operating conditions. Previous work [2] has demonstrated the significant effect that viscosity has on the quality of gravure printing. Reducing the viscosity of the ink resulted in an increase in tone gain. The magnitude of this variation was found to be colour dependent, due to the different cell configurations for each colour. Changes to the overall colour gamut were also observed as viscosity decreased.

The purpose of this investigation is to evaluate how different methods of viscosity control affect the quality and consistency of the printed product. An automatic viscosity control system was compared with a manual system. An evaluation of the ability of press operators to perform repeat manual measurements of ink viscosity was also performed.

Automatic viscosity control systems are independent of the operator, by constantly sampling and measuring the viscosity of the ink. The ink viscosity is established by measuring the time it takes for a known mass to travel a fixed distance in an ink filled chamber. Correctly calibrating the time of fall (TOF) provides information on the viscosity of the ink. Constant sampling allows for the regular addition of small quantities of solvent thus maintaining the ink viscosity avoiding large fluctuations. The manual viscosity control consisted of the operator filling an efflux cup with ink, then recording, the time that ink takes to evacuate the cup. The system is reliant on the operator making frequent measurements and small additions of solvent. To maintain consistency, measurements should be performed regularly in order to avoid gross changes in the viscosity.

Methodology

To assess the effectiveness of manual viscosity systems, the operator's ability to perform repeated measurements for a range of viscosities was established by experiment. Using the automated viscosity control system, bulk samples of ink were manufactured at viscosities of 2.7s, 2.3s, and 1.8s measured as a time of fall (TOF), using the automatic viscosity system. This represented the viscosity range used by the company. The volume of ink was such that any small solvent loss over the course of the measurements would have a negligible effect on the overall viscosity. Five operators performed a series of blind measurements using a stopwatch and a shell 2-efflux cup. Each operator measured each ink sample six times over a period of 2 hours. The results of the measurements were recorded and plotted graphically.

A five colour, web fed gravure press, fitted with an automatic viscosity control unit was used for the printing trials. To assess the effect of different viscosity control methods on print quality, two trials were performed. Each trial used the same image, which consisted of a large region of solid colour, on which subsequent colour measurements were taken. The first trial utilised the press's automatic control system to measure and control the viscosity of the ink. In order to enable comparison, manual measurements of the ink were also taken at 15 minute intervals and a sample of ink collected. During the second experiment, the viscosity of the ink was measured and controlled by the press operators, again at 15 minute intervals. A sample of ink was also collected for subsequent analysis. The viscosity of the ink was also monitored using the automatic control system, to enable comparison between the manual measurements and the results from the automatic measurement.

For each of the two print trials, print samples were collected at the end of each reel and measured spectrophotometrically, to assess their colour. The L*, a* and b* from all the print samples were then averaged, and the ΔE from the average was calculated.

A draw-down analysis was performed, using the ink samples collected during the print trials, using the same substrate as for the print trial. The prints from the draw-down analysis were then measured spectrophotometrically and compared with the results of the analysis of the printed samples.

Results

Operator consistency

Figure 2 shows the operator measurements for the 2.7s time of fall. All operators obtained results, in a similar range, with an average recorded time of emptying of the efflux cup of 29.2 seconds. However, there is a large spread in the overall result, with a 4.6 second difference between the maximum and minimum difference for all operators, corresponding to a measurement error of 16%. The spread of results for each individual operator was also large, with a maximum difference for a single operator of 2.7 seconds (Operator 3), which corresponded to an error of 9%. Therefore, the results show large inconsistencies in measurements for the highest viscosity ink tested. This was attributed to timing errors or procedural errors by the operators and not due to any effects from the efflux cup, as the same cup was used through out the investigation.

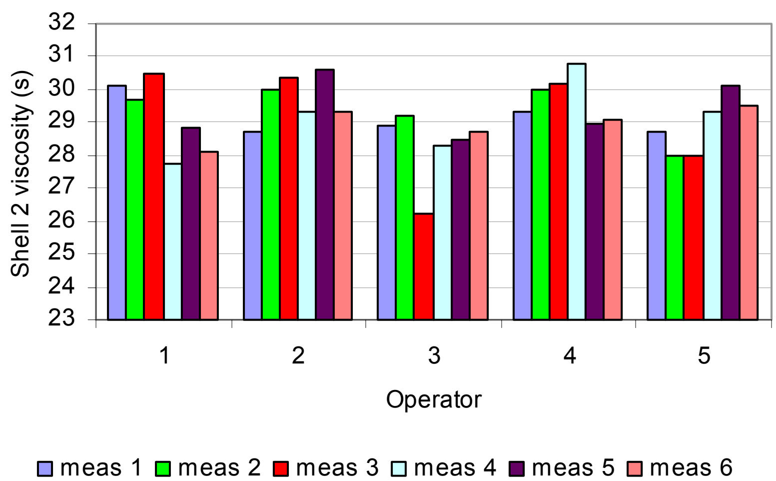

Figure 2: Comparison of results of viscosity measurement for five operators performing six measurements on ink with a time of fall of 2.7

For the viscosity of 2.3s TOF (Figure 3), greater variation between operators was observed. The 6 results for Operator 1 were all higher than the results for all other operators. The range of readings for Operator 1 was also the highest, at 1.9 seconds, although this was lower than the ranges observed for the 2.7 TOF results. The average time of emptying for all operators was 23.2 seconds. However, if the results from Operator 1 were excluded, the average viscosity fell to 22.4 seconds. The reason for the higher readings by Operator 1 is unclear, but is likely to be due to a difference in measurement procedure from all other operators.

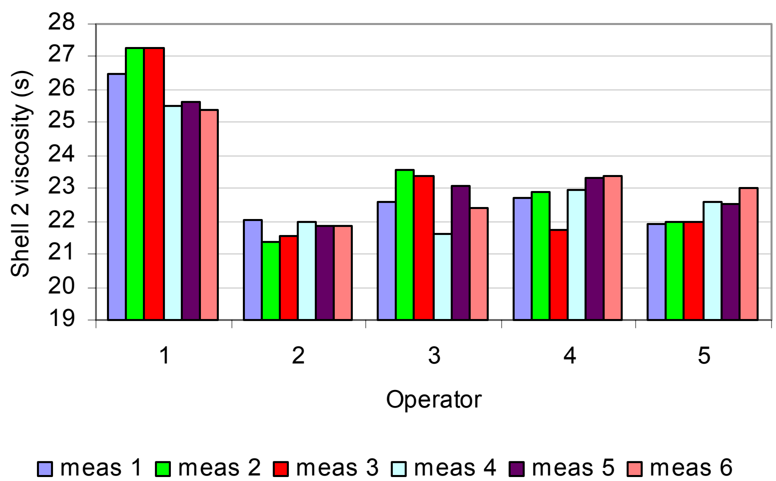

Figure 3: Comparison of results of viscosity measurement for five operators performing six measurements on ink with a time of fall of 2.3

For the viscosity of 1.8 TOF (Figure 4), the average time of emptying of the efflux cup was 20.5 seconds. All operators recorded similar values. The maximum variation between repeat measurements for a single operator was 2.0 seconds, Shell 2, giving an error of 10% and the maximum variation for all the measurements and between operators was 2.2 seconds, which corresponded to an error of 11%.

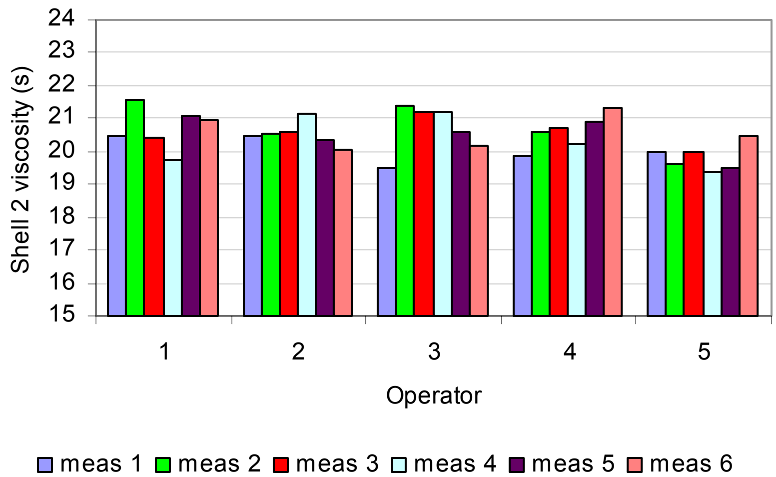

Figure 4: Comparison of results of viscosity measurement for five operators performing six measurements on ink with a time of fall of 2.3

In order to compare how the viscosity range for each operator changed, for the three different inks considered, a graph was plotted, showing the largest difference between the operators' 6 measurement, for each operator, Figure 5. For all operators, the greatest variation in measurements occurred for the highest viscosity ink (2.7s time of fall). The maximum variation for the two remaining inks (2.3s and 1.8s TOF) showed similar trends, with the operators showing very difference in the measurement variation between the two inks. Therefore, as the ink viscosity decreases, the consistency of measurements improves.

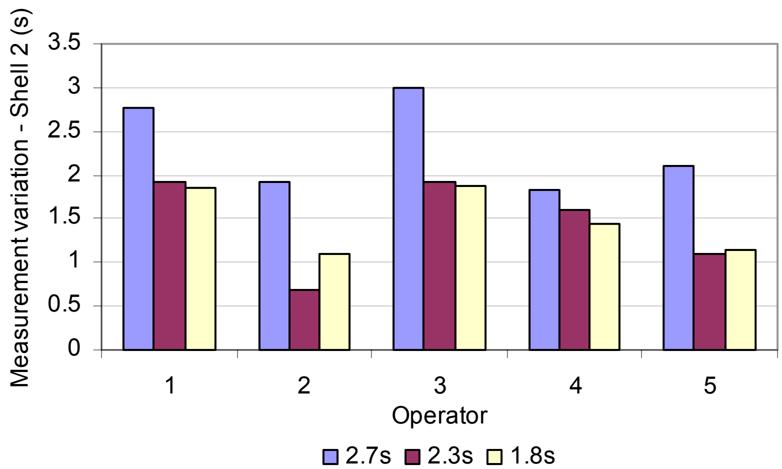

Figure 5: Comparison of maximum variation between measurements for all operators over viscosity range of 2.7 2.3 and 1.8 TOF

Ink Viscosity

The results from the trial with viscosity controlled by the automatic system are shown in Figure 6. The time of fall from the control system is plotted on the primary axis and the data from the manual viscosity measurements (included for comparison) are plotted on the secondary axis. The results for the time of fall show little variation throughout the trial, indicating that a consistent viscosity was maintained by the control system. The manual efflux cup measurements showed greater variation, but followed the same general trends observed for the time of fall analysis.

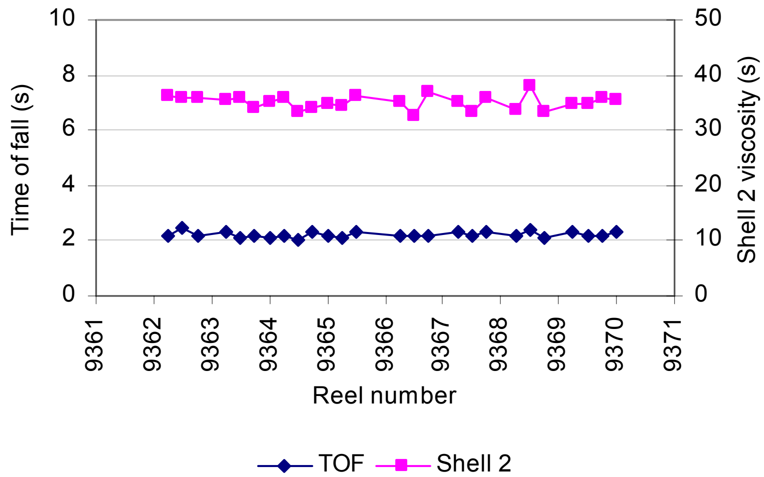

Figure 6: Comparison of automated and manual viscosity measurement methods data recorded near or at the end of each reel

The results from the manual viscosity control trial are shown in Figure 7. Utilising a manual control system and comparing the data shows that both the manual and the automatic measurements (plotted on secondary axis) follow the same trends. However, the variation in viscosity is much greater than was observed for the trial in which the viscosity was controlled by the automatic system (Figure 6), with a maximum variation in results of 25.2 seconds, Shell 2. Therefore the results from the assessment on operator capability, which shown a wide spread of data for measurement of ink viscosity, are also reflected in the results of the print trial, with much greater variation in ink viscosity for the manual control, than for the automatic control.

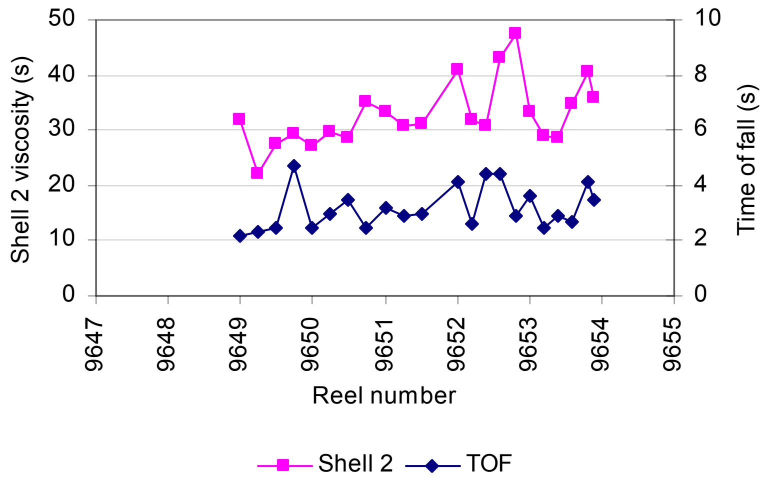

Figure 7: Comparison of manual viscosity and automated measurement methods data recorded near or at the end of each reel

Colorimetric analysis

To evaluate the effect of the viscosity variations observed in the previous section, a colorimetric analysis was performed to quantify the resultant colour differences. Figure 8 shows the colour variation for the samples collected during the print trial and the colour variation of the draw downs using the ink samples collected through the course of the trial. Also plotted on the secondary axis is the viscosity measured using a Shell 2 efflux cup, to enable comparison between the colour variation and viscosity variation. The results show very low ΔE values from the average, for both the samples collected during the print run, and the draw down tests. All of the results for the print samples showed a ΔE of less than 1.0. The draw down samples showed greater variation, with a maximum ΔE of 1.4. However, the majority of data showed a ΔE of less than 1.0.

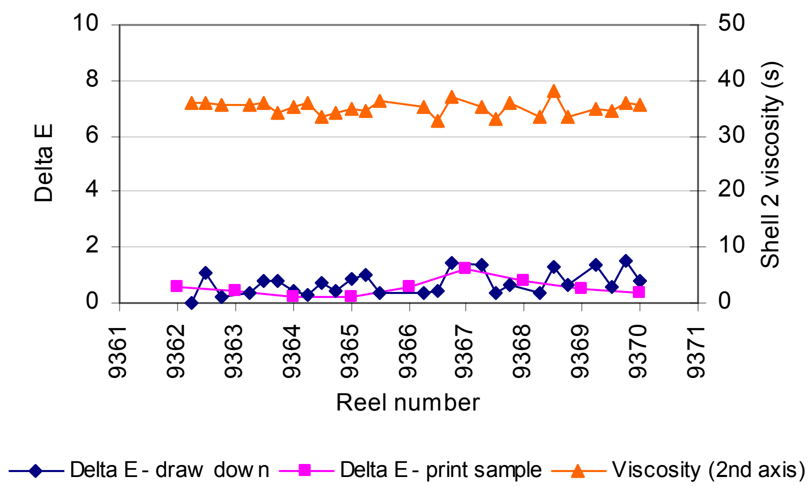

Figure 8 – Delta E variation for automatic viscosity control

A comparison of the curve for the draw down tests with the viscosity curve showed similar trends in the variation, with little variation in the ΔE when the viscosity was consistent and greater variation towards the end of the trial, when greater fluctuation in viscosity was also observed. As the ink samples for the draw down analysis were collected more frequently than the print samples, which were only collected at the end of each reel, it is possible that the ΔE of the samples was varying in a similar manner to that of the draw downs, but the variation has been masked due to the lower sample collection frequency. However, further investigation is not possible, as no further samples from the trial are available.

The results for the colour variation for the manual viscosity control are displayed in Figure 9, with the Shell 2 viscosity plotted on the secondary axis, for comparison. The results show that there was a large initial difference between the draw down ΔE and the print sample ΔE. This could be due in part to the fact that the ink samples for draw down analysis were collected at a greater frequency than the print samples, so it is not possible to state that large colour differences were also not observed in the print samples. The ΔE for the draw down samples settled, after the initial variation, however the colour variation was still greater than for the trial controlled by the automatic viscosity system (Figure 8). The ΔE for the print samples, although generally lower than the ΔE of the draw down samples, was also greater than for the trial controlled by the automatic viscosity system.

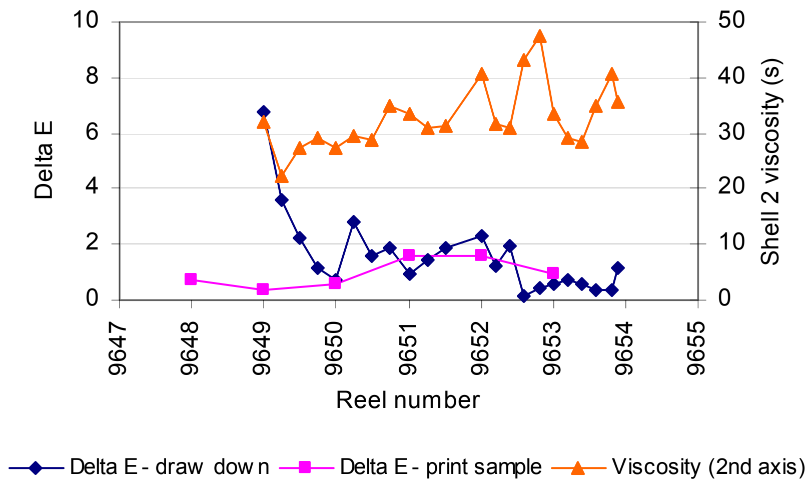

Figure 9 – Delta E variation for manual viscosity control

A comparison of the viscosity curve with the colorimetric results, showed that the fluctuations observed in viscosity were also reflected in the colour variation for the draw down samples, but not in the print samples. The lack of trend between viscosity and ΔE of the print samples was attributed to the lower sampling frequency of the print samples, compared with viscosity measurement.

Discussion

An investigation has been performed to evaluate the effect of using automatic viscosity control systems as a method of closed loop colour control in gravure printing. A preliminary analysis of the capabilities of different operators to perform repeat measurements of ink of known viscosities showed that large differences existed between the measurements of a single operator for ink of the same viscosity. This presents potential problems for presses where no viscosity control system is fitted, as errors due to measurement of the ink viscosity will make it difficult to ensure consistent viscosity on press.

During the experimental trials, the ink viscosity was found to be most consistent, when controlled by the automatic viscosity control system. This was attributed to the continuous sampling of the ink by the automatic system, resulting in many small additions of solvent. The trial controlled by manual viscosity measurement had a lower frequency of measurement and therefore solvent was added to the ink less often than for the automatic viscosity control trial. Therefore, not only was the volume of solvent added left to at the operator's discretion, but larger volumes needed to be added, due to the greater time duration between additions of solvent. This was also reflected in the colorimetric analysis, which showed greater variation in colour for the trial where ink viscosity was controlled manually, than for the automatic viscosity control trial.

Conclusions

As a result of this investigation, the following conclusions have been drawn.

- Viscosity control has a large effect on print quality in gravure printing
- Automatic systems give improved performance over manual systems, giving less colour variation through the print run.
- Large operator errors can occur when performing manual measurements of ink viscosity, which may result in greater variation in ink viscosity due to incorrect solvent addition

References

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