A novel solution to the evaluation of flexographic print quality

David Galton* MSc Roy Rosenberger

Keywords: Circularity, Flexo, Dot perimeter, Image analysis, Standardisation.

Abstract

Abstract: This paper presents results of a research project that was designed to be able to eliminate the subjectivity from assessing flexographic print production. The printer often finds it difficult to find the optimum setting for the printing press thus creating levels of waste. An optical device has been invented that is capable of digitally capturing a highly magnified image of the print sample. The associated print quality analysis software produces individual dot measurements of area, shape (expressed as circularity) and the ink distribution. The measure is able to discriminate between the intensity of the ink within the dot and the background. The variations reported are numerically quantified and are enumerated for each dot included within the area of interest. The reported physical dot characteristics can be related directly to press controls, substrate quality and ink performance.

The results of a small two level factorial experiment conducted to calibrate the device form the basis of the paper. The results and conclusions from the experiment are reported and highlight how the instrument can be used in normal print production to deliver improved printing performance and consistency.

The device is used with a small pattern or image that remains a constant indicator of image quality through the many production stages of the process. The devise, the small patterned image and supporting software that are described in the paper are protected by US patent application number 60/681,700 accepted August 11th 2005.

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*Asahi Photoproducts (UK) Ltd, 1 Prospect Way, Hutton Industrial Estate, Shenfield, Essex, CM13 1XA, England.

Introduction

This paper presents results of a research project that was designed to help the printer achieve optimum flexographic press settings efficiently. Two versions of the invention are ultimately envisaged. The first stage has been completed. A manual system has been developed and tested. The system comprises of four separate elements, an optical imaging device, computer, software and engineered print quality inspection image.

Stage two uses the same image analysis software computer and print quality inspection image but the print sample is digitally captured whilst the press is running (on line press system). This system is still in the evaluation and development stage.

Modern flexographic printing wide web printing presses are designed to run at speeds of up-to 600 linear metres per minute. The fast printing speed reduces the thinking/adjustment time for the operator to achieve optimum press settings. Substantial cost savings can be made by reducing the subjective analysis of the print sample by using a device to capture a digital image and use image analysis software to assess the print quality. The values are ascribed by the system to a particular area of interest within the print sample. A special print quality assessment wedge helps indicate to the printer which of the parameters needs to be adjusted and in which direction to be able to optimise the print quality.

The paper reports the results of a two level factorial experiment that was designed to identify which parameters significantly affect the print quality of the flexographic print. The printer often adjusts the printing press based on empirically gained experience and logic. The press settings required to optimise the print quality can be subtle and are often discreet (not obvious). The experiment consisted of sixteen separate tests with a combination of high and low level settings for each of the four factors that were included. A small pre-experiment was conducted on the press to calibrate the machine settings. The purpose was to ensure that meaningful and consistent data was gathered during the experiment. The press was operated under tightly controlled conditions throughout the duration of the experiment. There were several interactions occurring between the different parameters investigated. The values attributed by the image analysis software to the print results are discussed in detail in the paper.

To be able to accurately interpret the information that is ascribed to individual print samples the Vari-Print ™ system has to be calibrated to a particular printing press. The most efficient method of accomplishing this task is to conduct a four factor sixteen test factorial designed experiment.

Whilst it is appreciated that many variables in the flexographic printing process affect print quality four factors have been found to be the most significant. The four key factors have been found to be the Printing Speed ~ Plate to Substrate printing pressure ~ Plate to Anilox pressure ~ Ink Viscosity.

The advantages of the experimental design and statistical data analysis have been demonstrated by Lin through his extensive studies in this area of research (Lin and Guthrie, 1993, 1998; Lin et al., 1992, 2000, 2001, 2003).

The printing plate, as the image carrier plays an important role in defining the quality of the printed image (Gross 2003). Various technologies exist for the manufacture of flexographic printing plates. To be able to maintain a tight control of the physical characteristics of the images that were transferred at each stage of the production process conventional analogue plate technology was used for this experiment. It was perceived that in order to make a significant improvement to the flexographic print quality the understanding of the underlying causes for print inconsistency on the press needed to be defined. The research project was designed in three separate phases. The first phase was to design the image analysis software and the associated imaging technology. The second phase was to design a factorial designed experiment using conventional analogue plates, paper substrate and water-based ink on a small label press and analysing the results to understand the parameters that were significantly affecting the print quality. The third phase of the evaluation was to verify if the image analysis algorithms could define which of the varying factors on the press was causing the variation in the print quality.

The aim of the experiment reported here was not to define the optimum printing condition, but to improve the understanding of the characteristics and properties of the interaction of several of the key components used during the printing process (Kanda *et al.*, 1993; Kidokoro and Usui, 1991; Kraft *et al.*, 1999;Martin, 2002; Maruno *et al.*, 1996 2000; Moyson 1999; Nagahara and Imahashi, 1999; Nakano *et al.,* 1993; Sanome, 1978; Suzuki *et al.,* 1994, 2004; Takagi and Komano, 1995; Taniguchi *et al.*, 1990,1993; Yatsuyanagi, 1993).

Measurement defined

The area of interest can be adjusted within the software according to the size of the control image that is being used to define the print quality. Two types of measurement can be made with this system, one is the analysis of dots and the other is the analysis of solids. The patent incorporates a specially engineered halftone image. Using the specifically designed image analysis software the dots are measured to determine their optical and physical properties to give a dot characterisation. When the image does not contain printed dots the software automatically switches to solid image analysis (IROC). The image analysis is accomplished automatically in the software by interrogating a 100x magnified digital image of the print sample. The acquired digital image is 24 bit, composed of three separate bands, or images, (red, green, and blue). The colour bands can be combined to generate cyan, magenta and yellow. Ink luminance within the dots is calculated by averaging the three primary bands (RGB) together at each pixel location to create a new grey image. All pixels that are not part of a dot are converted to white. The cleaned and average image is then used to compute the ink coverage within the dots as statistics: Mean Luminance, the Skew of the distribution (the evenness of the ink coverage on individual dots) and the Standard Deviation. The report produced by the software is shown in Figure 1.

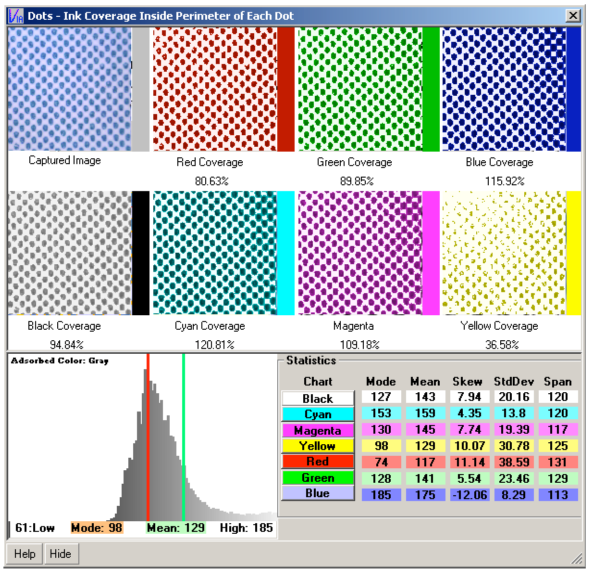

Figure 1 Ink coverage inside each dot

The final indices ascribed to the print sample are derived from the cumulative dot measurement statistics listed below:

- Dot area ~ The actual calibrated area is measured in square millimetres
- Circularity ~ The ratio of the perimeter squared to the area subtended by the perimeter.
- Luminance ~ The average luminance of the pixels subtended by the perimeter

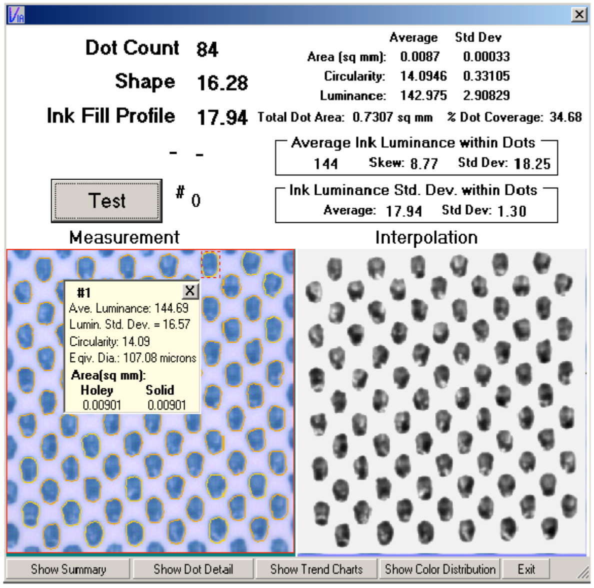

Figure 2 A dot analysis on-screen report

Solid image analysis is calculated by characterising the internal rate of change or (IROC) within the digitally captured image. The IROC is a measure of the inverse ink deposition uniformity. It measures the image roughness in three dimensions; luminance variations in the X and Y axis.

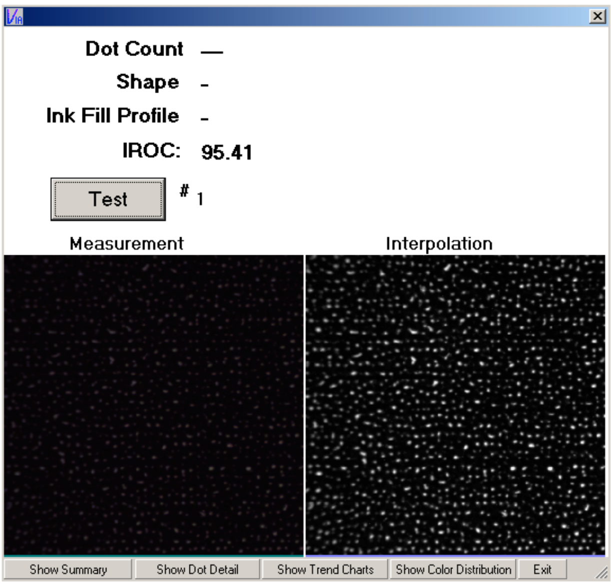

Figure 3 IROC analysis on-screen report

Closer inspection of the images used for the on screen reports shown in Figure 1, 2 and 3 reveals that a lot of sub-visible information is analysed by the software. The various indices produced are used by the printer to be able to optimise the printing condition. To improve the operators understanding of the nature (and the causes) of the effects recorded on the digital image, they are enhanced using an image interpolation process.

Evaluation techniques

As can be deduced from the introduction, it is the consistency of the dot reproduction that has been shown to have a significant impact on the reproduction qualities of the image being printed. The basic hypothesis of this research project is based on the principle of circularity; (Archimedes BC287)

$$\text{Circle} = 4\pi\ (\text{area}/\text{perimeter}^2)$$

As previously stated the size and shape of halftone dots and levels of luminance of individual or small groups of dots was the chosen method of evaluating the finished print quality. It is recognised that the substrate makes a significant contribution to the quality of the print. On paper and board substrates the surface roughness, absorbency and surface reflectance make a significant contribution. On filmic substrates it is the surface energy of the substrate that is arguably as significant as the surface reflectance.

With the properties of the substrate stated it is logical to assume that a combination of properties can have an influence on the uniformity of the ink lay-down across the entire printed surface. As a result of the inconsistency of the substrate surface print quality can show a discrepancy in any spatially diverse area. It is for this reason that the IROC (internal rate of change) analysis is also made from the solid areas of the print.

A two level design was selected to quickly analyse the interactions of the various components used in the normal production process. Whilst the two level design was not able to be used to explore the full extent of the factorial space, the experiment was able to provide useful information from the sixteen tests. The factorial technique allowed several factors to be varied on the press simultaneously thus replicating typical printing conditions whilst maintaining strict scientific control. This allowed sixteen different print samples to be produced with known print characteristics. These were then interrogated using the digital microscope device. The image analysis algorithm was used in the analysis of the digitally captured image. The algorithm reports the spatial distribution and the relative size of un-printed and lightly printed (sub-visible) areas of the print sample. The data generated relates to the dot definition, size, circularity average luminance and spatial distribution of half tone areas of the print sample. The indices reported in the results have a direct co-relation to the surface uniformity of the substrate and the ink receptivity. The values ascribed by the software can then be related to the specific printing condition in which they were produced. This allows correct interpretation of the announced values into corrective action by the printer on the press to achieve optimum setting of the press.

Experimental

Apparatus equipment and instruments

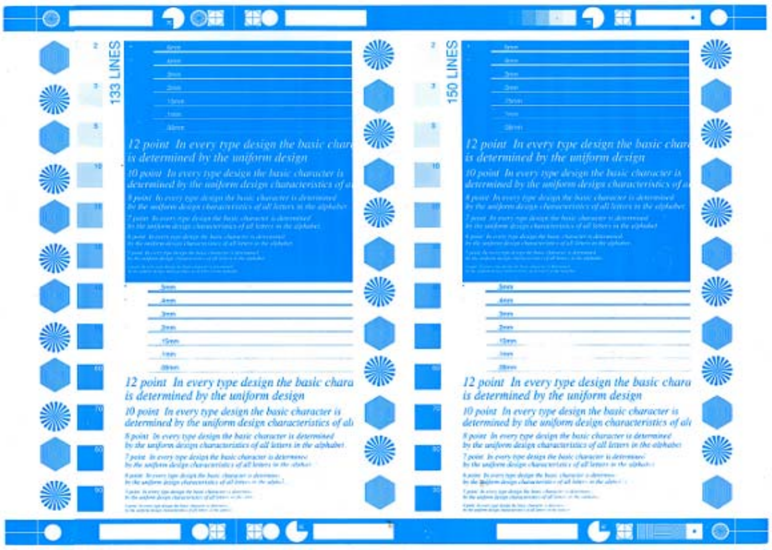

Figure 4 test image

The digital test image
The test image was constructed to reflect the type of design that would be required for normal print production. Three panels of flat tint were imaged in the following tint values 2% 3% 5% 10% 20% 30% 40% 50% 60%70% 80%90%, in 120 lpi 133 lpi 150 lpi, the design also included a solid block positive and negative fine line and text images. The 170mm x 310mm test image shown in Figure 4 was created on an Apple Macintosh iMac using freehand software. The design was influenced by the need to guarantee that the image was representative of normal flexographic print reproduction requirements. The 60^0Anilox roller dictated that 150 lines per inch for the test image would generate the best quality print characteristic data. Screen ruling for the tone wedges using circular dot screen technology was set at a 7.5° angle. 8mm bearer bars were included in the design to ensure that the whole image had even printing pressure applied to the surface of the plate. Six large impression targets were included across the web for each different screen ruling to give a visual check of the correct printing pressure on the plate during the printing test.

Conventional negative
The negative was output onto Agfa 0·007” red laser sensitive matt Rapid Access film. The AGFA HNM7 Rapid Access hard dot film was processed in Agfa ACD Rapid Access chemistry. Agfa G333c RA Fixer was used to ensure that all of the clear areas of the film did not exceed the D min 0·05. The film density was D max 4·72 and D min 0·03. The quality of the negative was controlled to ensure that optimum edge-line sharpness was achieved as the regularity and definition of individual dots was particularly important for this experiment.

Equipment for the conventional negative output

The image shown in Figure 4 is the image which was output onto film at 2400 dots per inch via an Agfa SelectSet Avanttra 25S laser image setter. The image was formed by a red diode laser 650 nanometers wavelength. Resolution was set at 2400 dots per inch. A compromise was made in the output resolution to see if the speed advantage gained by outputting the films at the lower resolution could deliver reliable data that would allow the printer to find the optimum press setting.

Equipment for platemaking

The platemaking process was split into five stages namely exposure, washout, drying, stabilisation, post exposure/de-tack.
Each stage was completed in its own independent unit.
Relevant information of each of these units is given as follows:

1) AFP 912 Fast Frame.

Fast Frame single sided exposure technology was used for the experiment. The unit was fitted with Phillips 140 Watts UV A Lamps. The back exposure was controlled by a light integrator via an exposure computer. A timer controlled the main exposure. The plate exposure was quantified by measuring in milli-Joules of UV-A energy (365nm) using the following equation:

$$\text{mJ quantity} = \text{UV quantity } (\text{mW/cm}^2) \times \text{exposure time (seconds)}.$$

The heat of the exposure bed was controlled at 25°C during plates being made for the experiment.

2) AFP 912W.

The washout unit was fitted with a programmable logic controller (PLC) computer, which controlled all machine functions to ensure repeatability. Solvent replenishment was automatic for the duration of the experiment. The computer controlled washout speed and brush pressure settings.

3) AFP 912D.

The drying unit had controlled temperature and forced air regime.

4) AFP 912S.

The plates rested in the stabilisation unit for approximately eight hours in ambient airflow, in an attempt to achieve original plate tolerance.

5) AFP 912F.

The finishing unit was fitted with two banks of lamps set at 90°. One bank used the same lamps as fitted to the main exposure unit (UV A). The other bank of lamps was of a shorter wavelength at 250nm (UV C) and was used to de-tack the plate. Independent timers control both sets of lamps.

Solvent

Gravosolv solvent was used to process the conventional analogue plates.

Photopolymer printing plates selected for the experiment
The conventional analogue printing plate selected was 65 Shore hardness

Mounting tape selected for the experiment
The mounting tape that was selected for this test was medium hard and was selected on the basis of compressibility and consistency.

Waterbased Ink selected for the experiment
One batch of standard ink was modified for the test. The only difference between the two batches of ink was the level of water that was added to give two different viscosities of ink. The lower viscosity was (-1) and the higher viscosity (1). The viscosities of both samples of ink were adjusted using a Zhan cup $N^{\underline{0}}$ 2.

Anilox rollers selected for the experiment
The Anilox screen count was set at 800 lpi. The experiment was carried out in one unit of the printing press.

Doctor Blade selected for the experiment
A standard mild steel square edged blade was used for the experiment.

Printing press used for the experiment
A small Comco label press.

Substrate used for the printing test
The substrates that was used for the experiment was a filmic/paper laminate that was pre-selected from stock.

Instruments used for the Characterisation of the Printed Images
Densitometer
The film was measured using a Gretag Macbeth D200-11 transmission Densitometer. A Gretag D 19c reflection Densitometer was used to measure the ink density of the printed images. Using the Murrey-Davies equation, dot percentage was calculated and displayed by both instruments.

Digital Microscope
Verity IA™ (optical light microscope) was used for the capture of the print sample image and evaluation of the negative and plates.

Software used for the sample analysis
The data values used for the statistical analysis of the print sample was assessed using the Vari-print™ software package from Varity IA™ .

Software used for the Experimental Design and Data Analysis
A MINITAB software program was employed for the design of experiments and for analysis of the data collected. The MINITAB version 14 software programme is a powerful statistical package that provides a wide range of data analysis and graphic capabilities. The exploratory data analysis functions were used in the compilation of this paper.

Sample data gathering

A combination of sampling theory, probability theory and statistical inference were used for the analysis of the data. The experiment was designed to determine if the observed differences in the data relating to the variable factors included in the experiment were due to chance process variation.

A small pilot test was conducted to establish the range that would be used for the upper and lower levels for each factor used in the experiment. The small test established the levels that would provide the useful data for materials under investigation. Data was subjected to two proving tests, to ensure that it was reliable.

The initial test was used to indicate how many readings were required to be taken from each sample. A standard margin of error equation was adopted to ensure an appropriate sample size was obtained for each of the properties being investigated. An error level was set of 1%-2% for the raw data gathered, that was included in the result field in the Minitab software.

Due to the small number of tests (16 x 2) involved in the experiment it was not always possible for the Minitab software to display a clear histogram of normal distribution. Prior to the data being entered into the Minitab software a standard equation was used and referenced against a published confidence of normal distribution table. During the data gathering, each of the measurement points were selected randomly for the required number of measurements to satisfy the error criteria of the initial test to ensure that the true underlying value was recorded.

Experimental design

Table 1 The basic factorial designed experiment

	C1	C2	C3	C4	C5	C6	C7	C8
	StdOrder	RunOrder	CenterPt	Blocks	Speed	Anilox/plate	Plate/substrate	Ink viscosity
1	2	1	1	1	1	-1	-1	-1
2	13	2	1	1	-1	-1	1	1
3	6	3	1	1	1	-1	1	-1
4	16	4	1	1	1	1	1	1
5	7	5	1	1	-1	1	1	-1
6	5	6	1	1	-1	-1	1	-1
7	9	7	1	1	-1	-1	-1	1
8	8	8	1	1	1	1	1	-1
9	15	9	1	1	-1	1	1	1
10	10	10	1	1	1	-1	-1	1
11	14	11	1	1	1	-1	1	1
12	4	12	1	1	1	1	-1	-1
13	3	13	1	1	-1	1	-1	-1
14	1	14	1	1	-1	-1	-1	-1
15	11	15	1	1	-1	1	-1	1
16	12	16	1	1	1	1	-1	1

Using Minitab, a factorial experiment was designed as shown in Table 1. The factorial experiment shown in Table 1 displays the four press setting factors which are labelled under the column heading C5 ~ C8. The design is a two level experiment represented by the (-1) ~ (1) symbols. Test 8, 9, 11 and 16 are designed to allow the identification of the effect of changing one press setting factor independently and the effect that it has on the print quality.

The standard flexographic printing technique was adopted for the experiment. The press used for this experiment was a standard production machine with a web width of 230mm. The machine was manually controlled. This meant that special calibration marks had to be devised to enable accurate press settings to be recorded throughout the duration of the experiment. The chamber doctor blade angle was pre-set for the duration of the experiment.

Methods for data analysis

The experimental data provided by the software was analysed using ANOVA techniques. Units of standard deviation (any value in a distribution can be converted into z-values by subtracting the mean of the distribution and dividing the difference by standard deviation) were converted to z-values to be able to rate the samples. The results were analysed using a level of confidence of 0.10 (meaning that there was a 10% risk of the null hypothesis being rejected when it was true). The various combinations of materials responded differently during the sixteen tests and it is these differences that have been used to characterise the printed results. The tests were designed to observe the changes in the (output) response to test factor level changes (input) and to draw conclusions from the responses. The first stage in the design of the experiment was to identify all of the interacting factors that were considered to have an impact on print quality as follows:

- Repro screen ruling
- Plate type
- Ink viscosity
- Mounting tape compressibility
- Printing plate to substrate pressure
- Anilox to plate pressure
- Printing substrate
- Printing speed

Four of the factors monitored in the printing experiment were assigned high and low values. The Printing Speed ~ The Plate to Anilox Pressure ~The Plate to Substrate pressure ~ The Ink Viscosity.

The sixteen tests used in the experiment were designed to investigate which interactions between various production factors influence the print quality. The experiment was designed to confirm if the image analysis data could detect which factors were the most significant influence on the print quality. Statistical analysis was used to explain the relationship between the various interactions that take place between the materials used in the experiment. Each separate test of the experiment consisted of a combination of factors at the high and low settings set as far apart as possible. The various tests of the experiment were designed to indicate possible improvements to allow the printer to easily find the optimum press setting. The ease of transferring information generated by the experiment to the operators (in an easy to understand practical way) was of paramount importance.

Evaluation of Results and Discussion

Due to the space restriction for the paper two systems of measurement are shown in the results graphs. To prove that the image analysis technique of characterising a print sample is valid a benchmark was made using the same print samples but the measurements were made using Gretag D19c densitometer.

The experiment was conducted as an integral part of an R&D project to develop a new print characterisation protocol using a synthesis of statistical and image analysis techniques. The factorial designed experimental process is a proven method of optimising production processes. The image analysis techniques are a proven technology for accurate integration of digital images. This project was designed to bring the two technologies together to make a new user friendly "press side" tool to help the printer find optimum press settings for normal daily production. The aim of the project was make a simple to use device that would take the subjectivity out of the decision making process when running a printing press at fast printing speeds. For the device to produce meaningful results for the daily production a series of calibration tests have to be run on the press to make a calibration which indicates the median for the four press controls that are used to optimise the print quality.

The sixteen tests that comprised the complete experiment were run over a three hour period. The tests were run randomly in order to eliminate such variables as press-hall temperature, humidity and press temperatures from influencing the data. The factors influencing print quality properties have been the focus of the characterisation work carried out and reported here. Other useful conclusions were drawn from the experiment by filtering the data and measuring other elements on the test image. Graphs of the various combinations are provided in the report to illustrate the findings.

This section of the paper includes a representative selection of some of the graphs that were produced from the statistical analysis of the raw data gathered during the experiment. Such results, (i.e. experimental data) were subjected to both statistical analysis and logical reasoning in order to reach some conclusions that would be of benefit to the understanding of how the variation of the four press setting factors affects the print quality.

Table 2 The results of the factorial designed experiment

	C1	C2	C3	C4	C5	C6	C7	C8	C19	C20
	StdOrder	RunOrder	CenterPt	Blocks	Speed	Anilox/plate	Plate/substrate	Ink viscosity	Ave Lum 3%	Circularity 3%
1	2	1	1	1	1	-1	-1	-1	116	14.59
2	13	2	1	1	-1	-1	1	1	129	25.94
3	6	3	1	1	1	-1	1	-1	156	13.70
4	16	4	1	1	1	1	1	1	130	40.24
5	7	5	1	1	-1	1	1	-1	135	67.50
6	5	6	1	1	-1	-1	1	-1	130	13.33
7	9	7	1	1	-1	-1	-1	1	173	20.19
8	8	8	1	1	1	1	1	-1	127	63.25
9	15	9	1	1	-1	1	1	1	122	13.61
10	10	10	1	1	1	-1	-1	1	174	35.11
11	14	11	1	1	1	-1	1	1	170	34.48
12	4	12	1	1	1	1	-1	-1	0	0.00
13	3	13	1	1	-1	1	-1	-1	184	66.03
14	1	14	1	1	-1	-1	-1	-1	164	30.99
15	11	15	1	1	-1	1	-1	1	174	23.77
16	12	16	1	1	1	1	-1	1	188	19.91

Assessment of the print quality samples

The first test applied to the raw data was to see if the data gathered from the sixteen tests was statistically valid. The histogram plot of frequency was produced and is shown in Figure 5. The plot follows the classical distribution curve expected. The relatively small number of tests used in the experiment often makes it very difficult to produce a classical bell shape to confirm that the data gathered is statistically valid. The graph displays the results for dot gain data gathered from the analogue plates used during the experiment. A second test that was applied to the data was to identify the effect of varying one of the press setting factors singularly, whilst all others remain constant and identifying the effect on the print quality.

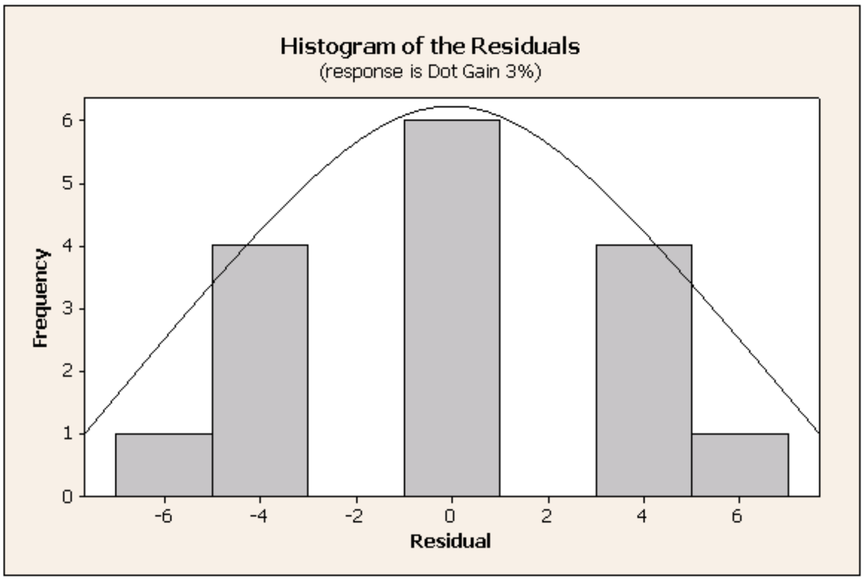

Figure 5 Histogram of frequency results from the analogue plates

The most significant effects for the four factors included in the analysis of the print samples are illustrated in the main effects plot shown in Figure 6. The plot clearly indicates that when dot gain is being assessed the plate to substrate factor is the most significant. The main effects plot also graphically displays the other factors such as the amount of ink that is being released from the anilox roller through the manipulation of the pressure on the plate which also makes some contribution to the dot gain. The speed of the press changes the printing characteristic. The hydraulic and shear forces on the liquid ink in the nips (Bohan et al 2003) means that press speed has an influence on the final printed result. The result shown on Figure 6 shows that ink viscosity also has an effect on the dot gain characteristic but to a less extent than the plate to substrate pressure. The result for the ink viscosity change is amplified as the experiment used viscosity levels at the two extremes that would be encountered in normal print production. This fact is also having a similar effect on the anilox to plate results. The graph displays the results produced by a densitometer. A cross reference was made using the dot diameter and luminosity results produced by the image analysis software. When these are compared with graphs of the results from the densitometer, very similar trends are displayed. The big difference is that the Vari –Print™ gives printers some suggestions on the press setting to adjust and in which direction (positive or negative).

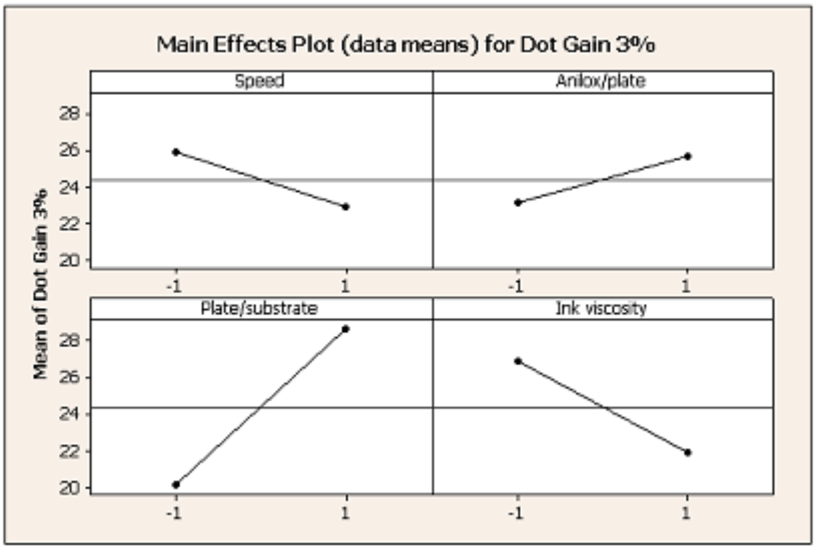

Figure 6 The main effects plot for dot gain from the analogue plate

The results recorded from the analogue plate shown in Figure 7 clearly shows the inter-dependence of the ink viscosity and anilox to plate pressure on the dot gain print characteristic.

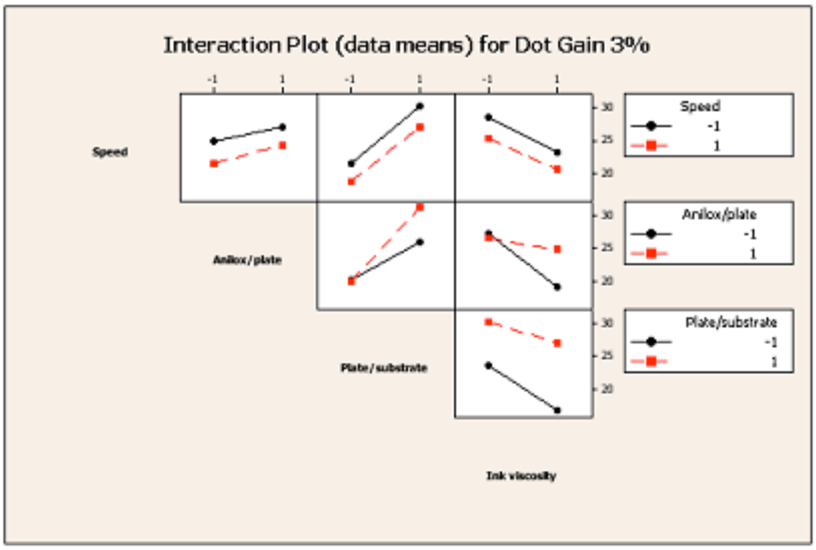

Figure 7 The interaction plot for dot gain from the analogue plates

The cube plot of the data from the analogue plates shown in Figure 8 indicates the conditions which provokes the least amount of dot gain. The optimum combination is reduced anilox to plate pressure combined with increased ink viscosity and reduced plate to substrate pressure.

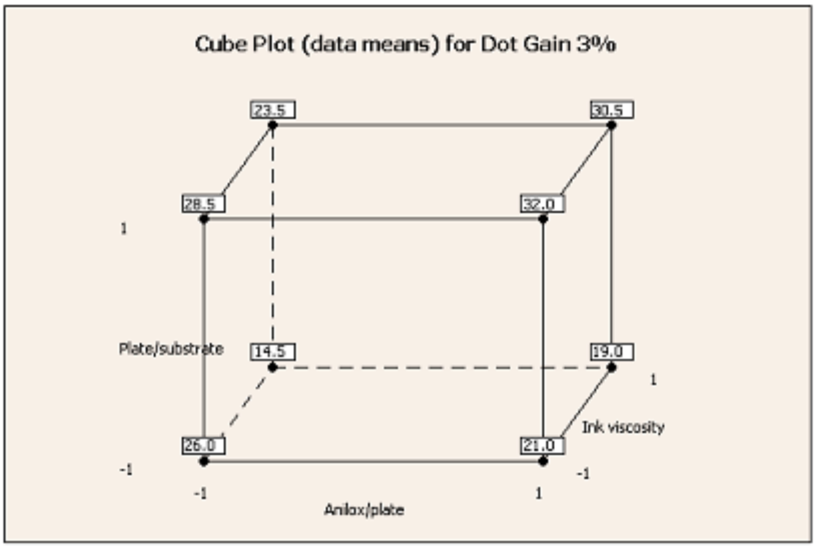

Figure 8 Cube plot used for process optimisation dot gain for the analogue plate

The main effects plot shown in Figure 9 shows that when density is being evaluated the anilox to plate pressure is the most significant factor. As can clearly be seen the other factors being evaluated are interacting but have much less significant effect on the print density.

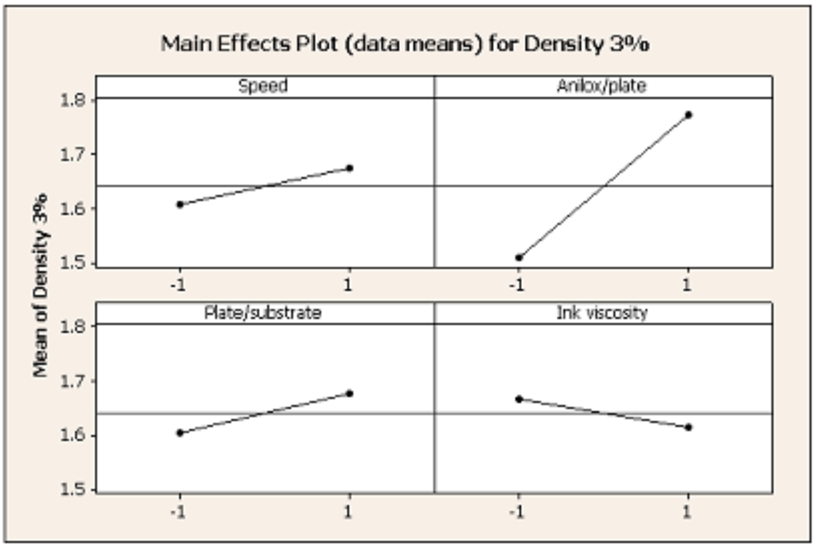

Figure 9 Interaction plot for the print density for analogue plate results

The results shown in Figure 10 indicate that an inter-dependence exists between the ink viscosity and the plate to substrate pressure when print density is being evaluated.

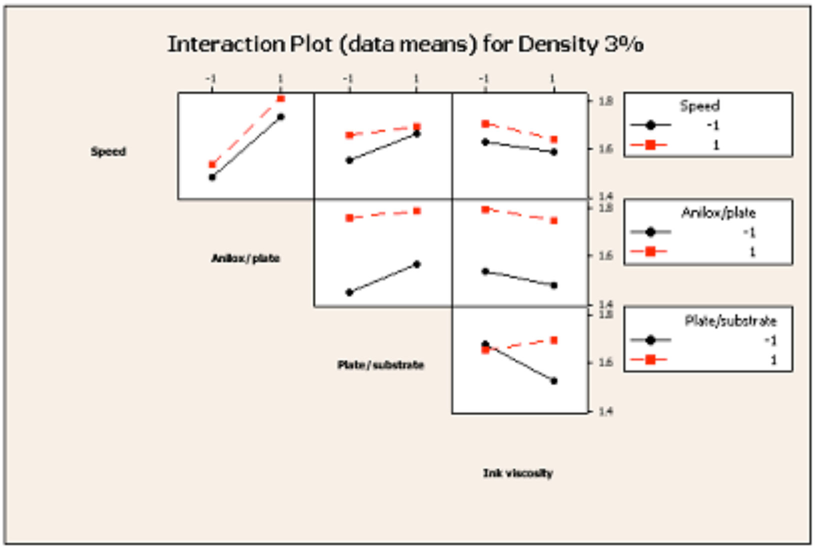

Figure 10 The interaction plot for print density for the analogue plate results

The cube plot shown in Figure 11 indicates that the best combination for print density will be achieved by increasing the plate to substrate pressure in combination with increased ink viscosity and increased plate to anilox pressure.

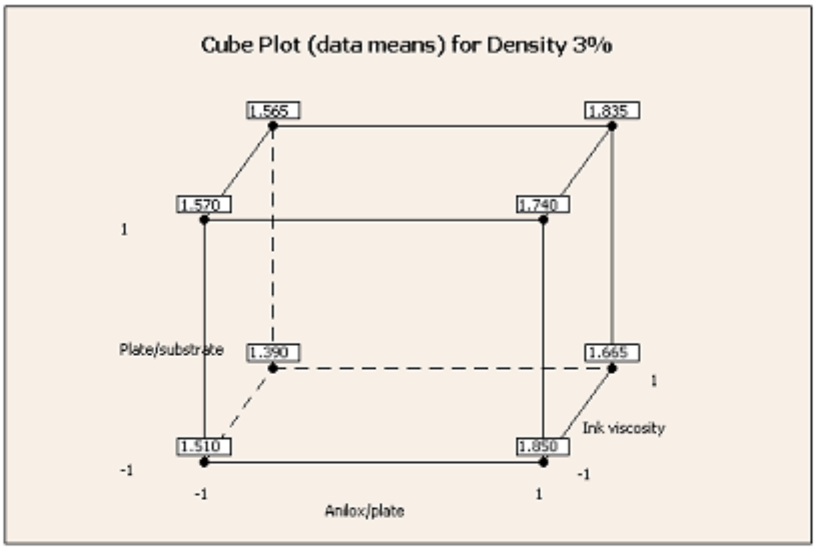

Figure 11 The cube plot for print density for digital plates

Conclusion

One of the most significant aspects of this type of project is that it requires a holistic approach to the production process to be taken. The most significant conclusion that can be drawn from the data presented is that it is possible to identify the complex interactions that are contributing to the quality of the print bring produced. The Verity IA multi-functional image analysis software gave accurate values for the effects caused by the changing print machine settings (factors). The accuracy of the image analysis system made it possible to predict the interaction effects of the combination of factors used in the experiment. Subsequent print trials using the findings of this report have resulted in a significant improvement in the consistency of printing results. Analogue plates were selected for these trials as they are more robust and tolerant of the changing press conditions during the experiment.

The first hypothesis that the print quality could not be accurately predicted was rejected. This conclusion was reached on the basis that it was possible to statistically identify and characterise the print quality by using a variety of different criteria i.e. luminosity, circularity, dot diameter etc.

The second hypothesis that it would not be possible to find the optimum press setting for each job ("sweet spot") by the data provided using the image analysis technique was also rejected.

Much of the data produced by the experiment has been filtered. Only the relevant statistical data is reported here. Graphs generated from the results have been used to graphically describe how the factors selected for the experiment interact to produce the quality of the final print result.

The use of the statistical approach dramatically reduced the number of tests required for the experiment. The results allow an informed judgment to be made about the quality of the printed samples. The scientific process described in this paper can easily be adapted for daily production use. The images captured by the Vari-Print device can simply be analysed by the image analysis software at press side to give a very clear indication to the printer on how best to set the press to achieve optimisation of the print quality.

Optimisation of the flexographic printing allows consistent quality to be produced. Accurate press control will make the possibility of producing the same complex graphic image to a similar standard as other established printing processes such as gravure and offset litho a reality.

Optimisation of the print process facilitates the improvement of the press OEE (overall equipment efficiency) thus the improvement in efficiency translates into means of driving costs out of the production process.

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