A novel solution for the characterisation of corrugated printing quality

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

Abstract: This paper is based on a research project that is designed to be able to eliminate the subjectivity from assessing corrugated 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 an image of the print sample. Interrogation of the captured image using image analysis software produces individual dot measurement 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 the enumerated value relates directly to the quality of the corrugated board. The aim of the project was to make a simple to use device that would take the subjectivity out of the decision making process employed in running a press.

The results of a small experiment conducted to bench mark the printing plate corrugated board combination forms 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 11 2005.

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Introduction

This paper presents results of a research project that was designed to help the corrugated box manufacturer improve the quality of the decoration of the box whilst at the same time driving cost out of the production process.

Two image analysis software programmes have been designed to achieve the required data to be characterised printed corrugated board. The first software is capable of characterising the plain corrugated board before printing takes place. The second software is designed to integrate printed samples to analyse the substrate for washboard effect which describes the pattern of lines that are produced through halftone images which are printed onto corrugated board. The system comprises of four separate elements, an optical imaging device, computer, software and engineered print quality inspection image.

The paper reports the results of an experiment that was designed to identify which parameters significantly affect the print quality of the corrugated 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 ten separate tests with a combination of heavy medium light printing pressure settings for each of the four factors that were included in the experiment. 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. The values attributed by the image analysis software to the print results, are discussed in detail in the paper.

Whilst it is appreciated that many variables in the printing process affect print quality, four factors that have been found to be the most significant in the printing of corrugated board are include in this experiment. The four key factors are; printing plate type ~ plate to substrate printing pressure ~ substrate liner weight ~ type of flute.

The advantages of statistical data analysis have been demonstrated by Lin through his extensive studies in this area of research (Lin and Guthrie, 1998; Lin 1992).

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 liquid plate making 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 experiment using five different conventional liquid plates, two different types of liner for the board and two different flute types. Water-based ink was used on a standard corrugated printing press and the results were analysed to understand the parameters that were significantly affecting the print quality on the corrugated board.

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 Moyson 1999; Sanome, 1978; Suzuki *et al.*, 1994, 2004;

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. Using the specifically designed image analysis software the dots are measured to determine their optical and physical properties to give a dot characterisation. 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.

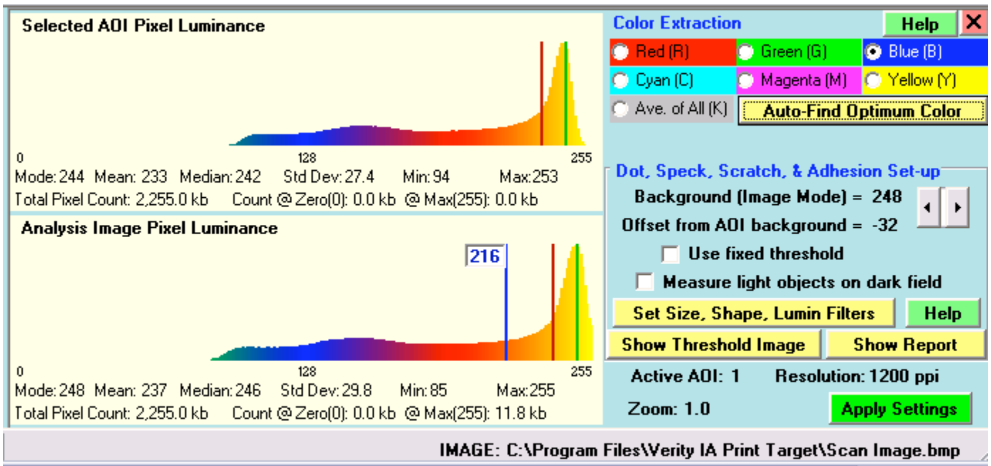

Figure 1 Ink coverage inside each dot

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

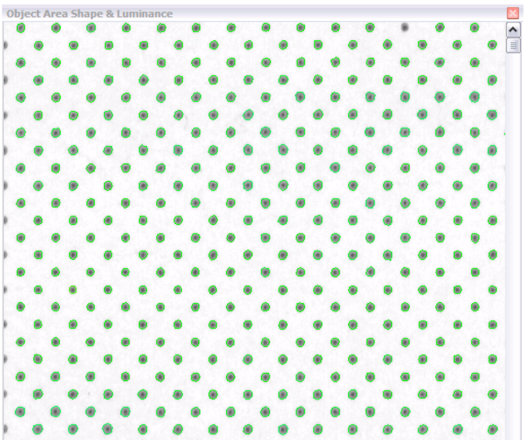

Figure 2 A dot analysis on-screen report

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)

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

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 fluting material used in the manufacturer of corrugated substrate makes a significant contribution to the quality of the print. The surface liner paper weight, surface roughness, absorbency and surface reflectance make a significant contribution to the quality of the finished print.

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.

The experimental design was selected to quickly analyse the interactions of the various components used in the normal production process. The experiment was able to provide useful information from the ten tests. The statistical analysis of the print results produced during the experiment allowed the interaction of several factors to be characterised. The analysis was carried out on forty different print samples which were produced with known print characteristics. These were then interrogated using a scanner specially modified by Verity IA® to acquire digital images of surface topography and print. The Verity IA Print Target image analysis programme 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

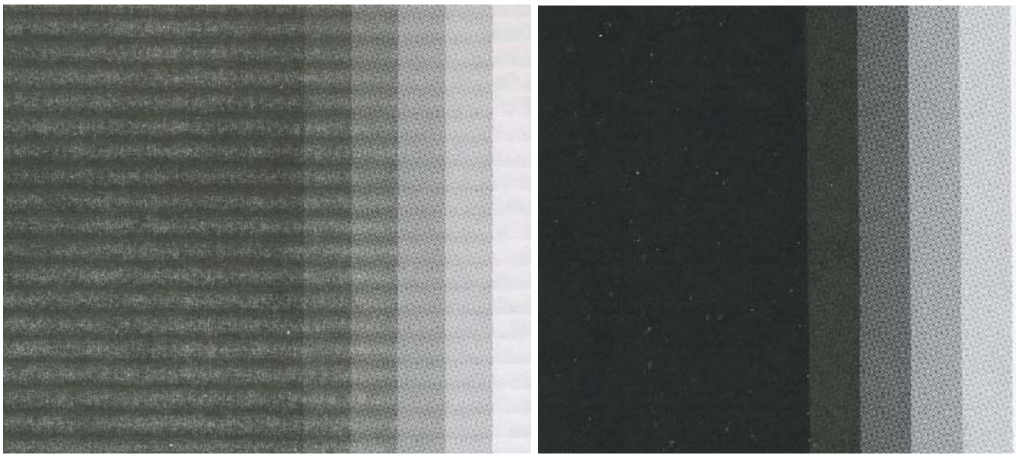

Figure 4 part of the test image

The digital test image

The test image was constructed to reflect the type of design that would be required for normal print production. The complete test sheet incorporates several independent panels. These include flat tint images in the following tint values 3% 5% 10% 20% 30% 40% 50% 60%70% 80% 90%, in 45lpi, 65lpi, 85lpi, 100lpi, the design also included a solid block positive and negative fine line and text images. The 180mm x 180mm 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. Screen ruling for the tone wedges using circular dot screen technology was set at a 7.5^{o} 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 plate making process was split into four stages namely exposure, washout, drying, 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) AWF.
The exposure unit was fitted with Phillips Cleo 360nm UV A Lamps. 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 was controlled at 25^{o}C during plates being made for the experiment.

2) AWF washout.
The washout unit was fitted with a timer which controlled all machine functions to ensure repeatability. Washout bath detergent concentration and replenishment was monitored for the duration of the experiment. The washout bath is heated to a temperature of 40c.

3) AWF dryer.
The drying unit had controlled temperature and forced air regime set at $50^{\mathbf{0}}$c.

4) AWF post exposure.
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
The AWF is a water wash liquid plate making system which is semi automatic. A 2% solution of detergent is required in 250 litres of water to make up sufficient washout solution for the plates being produced for the experiment.

Three combinations of photopolymer were selected for the experiment
The resin combination for the plate samples were all different.

Mounting tape selected for the experiment
The mounting technique that was selected for this test was constant for all of the plate to ensure consistency. The plate was 2.54mm thickness. Adhesive 0.10mm tape. Milar carrier shim 0.25mm. Foam backing 2.03mm thickness.

Waterbased Ink selected for the experiment
One batch of standard ink was used for the test. The viscosity was regularly checked during the experiment and was tested at 29 secs using a Shell cup No 4.

Anilox rollers selected for the experiment
The Anilox screen count was 260 l/cm. Volume 4.2 ~ UCA Praxair.

Printing press used for the experiment
Bobst Masterflex 203 (6 colour).
The printing condition was monitored throughout the experiment to ensure that as far as was feasible the condition remained constant.

Substrate used for the printing test
Four qualities of board were used for this experiment two coated and two uncoated. The "E" flute was White top 140g/m^2 and the "B" flute was Craft 125g/m^2**.**

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® (modified scanner) was used for the capture of the print sample image.

Software used for the sample analysis
The data values used for the statistical analysis of the print sample was assessed using the Verity IA Print Target software package from Verity 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.

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 (10) 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 was 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 design of the experiment

Test n°	Plate	Pressure		Ink Density	Remarks
1	"A"	(1) Light (2) Medium (3) Heavy	1.96 1.56 0.87	1.12 1.14 1.10	Start of the test Ink Viscosity check ~ 29 secs Ambient room temperature 26°C Time: 9.30 am
2	"B"	(1) Light (2) Medium (3) Heavy	1.96 1.56 0.87	1.11 1.12 1.11	Ink Viscosity check ~ 30 secs
3	"C"	(1) Light (2) Medium (3) Heavy	1.96 1.56 0.82	1.11 1.12 1.11	
4	"D"	(1) Light (2) Medium (3) Heavy	1.96 1.56 0.85	1.06 1.14 0.97	
5	"E"	(1) Light (2) Medium (3) Heavy	1.95 1.56 0.86	1.16 1.16 1.16	Ink Viscosity check ~ 30 secs
					Change of substrate Ambient room temperature 27°C
6	"A"	(1) Light (2) Medium (3) Heavy	3.87 3.27 2.47	1.13 1.1 1.13	
7	"B"	(1) Light (2) Medium (3) Heavy	3.87 3.27 2.47	1.1 1.15 1.15	
8	"C"	(1) Light (2) Medium (3) Heavy	3.87 3.27 2.46	1.0 1.03 1.06	Time 11.05 am Ink Viscosity check ~ 33 secs Ambient room temperature 28°C
9	"D"	(1) Light (2) Medium (3) Heavy	3.87 3.27 2.46	1.18 1.18 1.17	
10	"E"	(1) Light (2) Medium (3) Heavy	3.87 3.27 2.45	1.22 1.21 1.22	Test end 11. 20 Ambient room temperature 29°C

Experimental design
Table 2 The modified factorial design experiment

C1	C2	C3	C4	C5	C6	C7	C8
StdOrder	RunOrder	CenterPt	Blocks	Plate type	Paper type	Flute type	Pressure
7	1	1	1	-1	1	1	-1
5	2	1	1	-1	-1	1	1
3	3	1	1	-1	1	-1	1
4	4	1	1	1	1	-1	-1
6	5	1	1	1	-1	1	-1
2	6	1	1	1	-1	-1	1
8	7	1	1	1	1	1	1
1	8	1	1	-1	-1	-1	-1

The design of the experiment shown in Table 2 displays the four factors which are labeled under the column heading C5 ~ C8. The original design is a hierarchical experiment represented Light Medium Heavy printing pressure data.

By reducing the amount of data (Medium) taken from the printing machine the data for Light and Heavy was used to convert to factorial design methodology. A two level design was selected using plate “A” as a constant high level and plate “B” ”C” ”D” ”E” as low level. The two levels for the board liner were coated and uncoated. The two for the flute were “B” flute and “E” flute. The two levels for the printing pressure were Light and Heavy.

The standard flexographic printing technique was adopted for the experiment. The press used for this experiment was a standard production machine. The machine was automatically controlled by the operator from a central control console. The chamber doctor blade angle was pre-set for the duration of the experiment.

Methods for data analysis

Four of the factors monitored in the printing experiment were assigned high and low values. The Printing plate ~ The substrate liner ~The fluting type ~ The printing pressure.

The ten 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 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 empower the printer to make decisions about the normal daily production. The aim of the project was to make a simple to use device that would take the subjectivity out of the decision making process. 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 predicted performance from raw substrate coefficient generated by the image analysis software.

The ten tests that comprised the complete experiment were run over a three hour period. The tests were blocked into two groups of five test to save press time. 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 experiment

C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14
StdOrder	RunOrder	CenterPt	Blocks	Plate type	Paper type	Flute type	Pressure	Result a/b	Result a/c	Result a/d	Result a/e	Result c/d	Result c/e
7	1	1	1	-1	1	1	-1	8.98	10.55	15.63	8.59	16.80	8.59
5	2	1	1	-1	-1	1	1	18.36	15.63	19.14	21.48	19.14	21.48
3	3	1	1	-1	1	-1	1	5.59	8.59	16.02	7.81	16.02	7.81
4	4	1	1	1	1	-1	-1	8.59	8.59	8.59	8.59	8.20	8.20
6	5	1	1	1	-1	1	-1	23.44	23.44	23.44	23.44	14.45	14.45
2	6	1	1	1	-1	-1	1	29.30	29.30	29.30	29.30	15.63	15.63
8	7	1	1	1	1	1	1	10.55	25.78	10.55	10.55	11.72	11.72
1	8	1	1	-1	-1	-1	-1	17.19	14.45	16.41	18.36	16.41	18.36

Assessment of the print quality samples

The first test applied to the raw data was to see if the data gathered from the ten 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 (Gaussian Distribution) to confirm that the data gathered is statistically valid. The graph displays the results for dot gain data gathered from the five different plates used during the experiment.

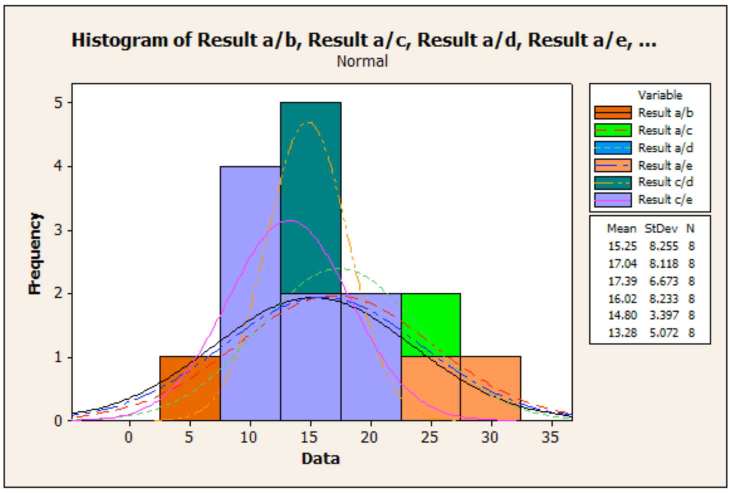

Figure 5 Histogram of frequency results from the analogue plates

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 flute marking is being assessed the plate interaction with the substrate is significant. The main effects plot also graphically displays the other factors such as the manipulation of the printing pressure on the plate to board (which crushes the flute) influencing the print result. The plot shows plate “A” as 1 and plate “C” as -1. The coated paper is shown as 1 and the uncoated paper as -1.

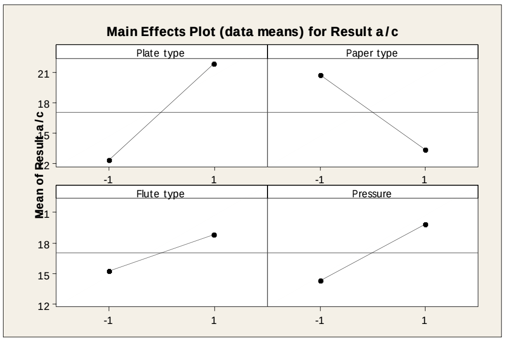

Figure 6 The main effects plot for plates “A” “C”

The results recorded from the plates “A” “C” in Figure 7 clearly shows with the possible exception of liner paper type and flute type, and pressure and flute type, the plot indicates that no other inter-dependence exists between the factors included in the experiment.

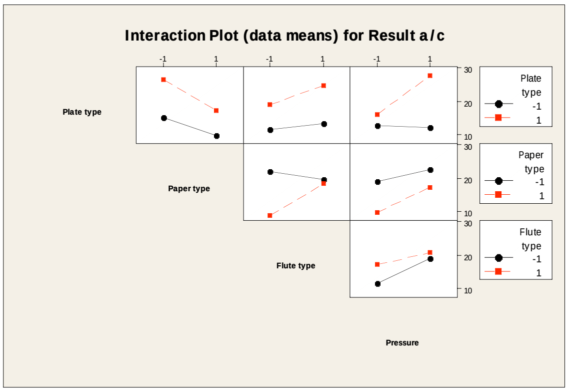

Figure 7 The interaction plot for Flute co-efficient from plates “A” “C”

The cube plot of the data from plates “A” “C” shown in Figure 8 indicates the conditions, which provokes the least amount of flute marks. It is interesting to note that “B” flute board indicated by 1 in figure 8 nutralises the plates effect and does not make any difference to the amount of flute marking both plates recording a coefficient of 8.59.

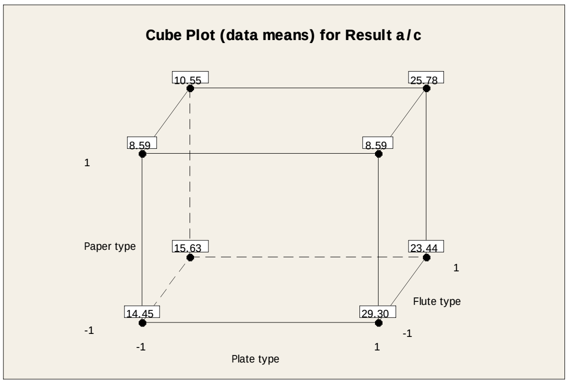

Figure 8 Cube plot can be used for process optimisation

The main effects plot shown in Figure 9 shows that when plate “C” marked as 1 on the graph is used as a common reference point for the plate a clear difference can be shown in the plate “D” performance. Plate “C” is displaying a low flute mark coefficient whilst plate “D” is displaying a high flute mark coefficient. Figure 9 also clearly indicated that board quality variation is significant. The coated substrate being shown on the graph by the number 1. As can clearly be seen the other factors being evaluated are interacting but have much less significant effect.

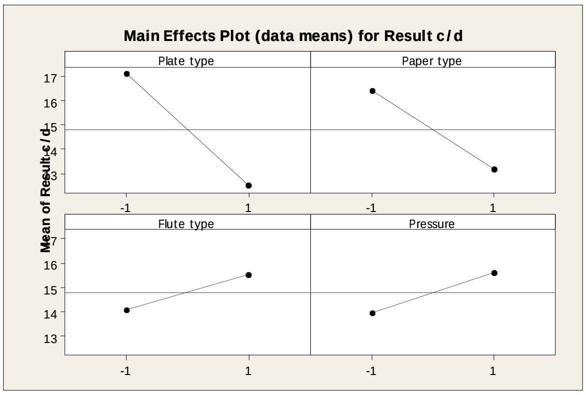

Figure 9 Interaction plot for the print density for analogue plate results

The results shown in Figure 10 indicate that an inter-dependence exists between the printing pressure and flute type when the printing plates are being evaluated.

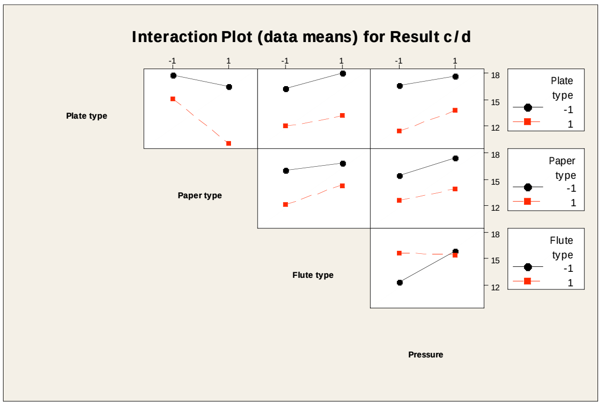

Figure 10 The interaction plot for plates "C" and "D"

The cube plot shown in Figure 11 indicates that the plate "C" indicated on the graph by the number1 will produce significantly less flute marks on "E" flute board with a coated liner.

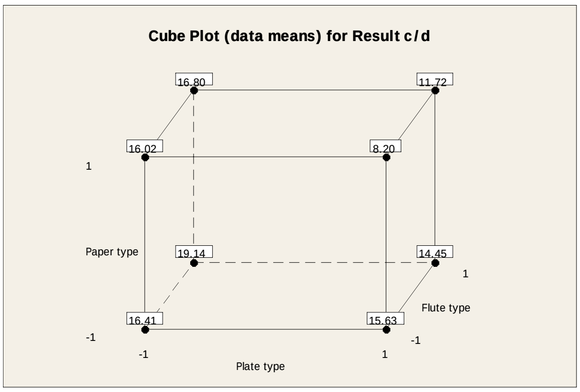

Figure 11 The cube plot for print density for digital plates

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 wash board effect on corrugated board. The Verity IA Print Target image analysis software gave accurate values for the effects caused by changing the combinations of corrugated board and different plate combinations. The accuracy of the image analysis system made it possible to predict the interaction effects of the combination of factors used in 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 best combination to reduce the wash board effect by using 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 Verity IA Print Target device can simply be analysed by the image analysis software at press side to give a very clear indication to the printer about what is possible to achieve in terms of reducing the visual negative impact of the wash board effect on corrugated halftone printing.

References

Bould, D. (2003) “ Deformation of flexographic printing plates” TAGA proceeding notes 2003, Ref: TO20216

Dreher. M (2002) “ The imaging process in flexographic plate making”. Flexo and Gravure International, Vol 1 p. 12

Galton, D (2003) “A study of the effects of the process parameters on the characteristics of photochemical flexographic printing plates”, Pigment & Resin technology, Vol. 32 No. 4, pp 235-47.

Gross, L.W. (2003) “Apparatus and methods for eliminating dot gain in flexographic printing systems”, US Pat. Appl. Publ., US20030084803 A1 20030508 AN2003:351989.

Lin,L. and Guthrie,JT (1998), “The application of computer-aided experiment design and formulation optimisation to biosensor assembly”, in Scott, A.O. (Ed.), *Biosensors for Food Analysis*, Royal Society of Chemistry, Cambridge pp61-70.

Lin,L. and Guthrie,JTand Mikac, J. (1992) “The design and analysis of experiments involving mixtures: a model based on spline interpolation”, *Surface Coating International*, Vol. 75 No 2, pp.66-73.

Moyson.P.P (2005) *Bench marking with liquid polymer plates.* FlexoTech magazine Vol 69 pp62-63.

Nagahara, S and Imahashi, S. (1999), “Photosensitive resin laminate for flexographic plate and its manufacture”, Japan Kokai Tokkyo Koho, JP 11095441 A2 19990409.

Sanome, T. (1978), “Flexographic plate making by laser optics”, *Kami to Purasuchikku*, Vol. 6 No.12,pp 19-21.

Suzuki, T., Sakurai, F., Ueno, H., Konishi, I. and Usui, T. (1994), “Photosentive compostion, photosensitive rubber plate and process for producing the plate”, PCT Int. Appl., WO 9423342 A1 19941013.

Warfford, M (1997), “Exposure levels and their influence on dot gain”, *TAGA proceeding Notes*, ref: T970908.

The author would like to acknowledge the support and guidance provided at the University of Leeds Colour Chemistry Dept, with a special note of thanks to
Prof Long Lin for his tireless support, friendship and encouragement.