FACTORS AFFECTING THE PROCESS STABILITY OF A HEAT SET WEB OFFSET PRESS

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Abstract

In order to improve the colour control of a heat set web offset press, the effects of the process parameters on the stability of ink transfer on an eight unit press were investigated. The press was fully instrumented, experiments performed on normal production copy using orthogonal array techniques and the colour was measured using a spectrophotometer. This paper discusses in detail those parameters which affect process stability. Of these the press temperature and roll speeds were found to be most significant. They were also found to interact with the local image coverage in a complex manner. A theory is postulated to explain these effects based on heuristic analysis of the mechanical and fluid interactions in the duct region. Modelling work which is being used to validate this theory is briefly discussed.

Introduction

The aim of experimental investigation was to more fully understand the ink transfer mechanism and its implications for colour control on a web offset printing press. This has been carried out as part of a DTI/EPSRC Link project and collaboration has been with Jarrold Printing of Norwich (with the support of Rockwell PMC of Peterborough). The overall aims of the project have been to introduce a fuller understanding of the web offset process in order to improve productivity and quality, reduce the waste and develop a series of generic process

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models.

This paper presents the results from a series of orthogonal array experiments carried out on an eight unit web offset press. A discussion of the experimental design using orthogonal array techniques along with an overview of the findings was given in an earlier paper, Bohan et al (1995). The changes in the print are assessed using a quality characteristic and the reasons for choosing spectrophotometry is discussed. This is followed by a presentation of the criteria used to select the parameters for the investigation and an overview of the experimental programme. The results are presented and discussed in detail for the effect of web breaks, duct roll speed, CUIM roll speed, pan roll speed, fount temperature and the ink duct temperature. Conclusions are drawn and recommendations for press control are given.

Experimental Design

Experiments to investigate the effects of press operating parameters on ink transfer were designed using orthogonal array techniques. This allowed multiple parameters to be investigated simultaneously and the effect of any interactions to be assessed. This experimental technique is also advantageous as by reducing the number of experiments it will therefore minimise the time and cost. This is of commercial significance as all experiments were carried out using a production press. In addition, by reducing the time window it is possible to complete tests within the constraints of the production environment (i.e. after good copy, job changes, etc).

Traditional experimental methods including full factorial, the use of elimination and experience were evaluated, Bohan et al (1995). However, these methods had several disadvantages including

- the number of experiments required
- they do not cover full range of combinations of parameters
- the time required and the cost incurred
- they do not challenge existing ideas and methods

The experiments were carried out primarily using L8 orthogonal arrays which utilise two levels for each parameter, Taguchi and Konishi (1987). This was used to investigate the effects of four parameters. The means of assessing the effects of the changes was by the use of a quality characteristic, in the case of printing this could include ink density, CIE colour space values or image processing (dot shape).

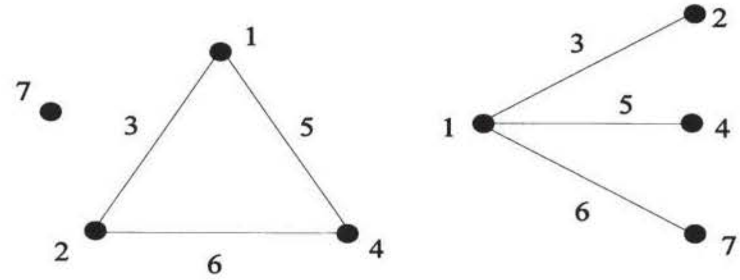


Figure 1 Linear graphs for L8 Taguchi array

A linear graph of an L8 array is shown in Figure 1. The dots represent each of the parameters with the interactions being assessed in two possible combinations. A knowledge of the process and possible interactions is of great use in the design of the experiments. This allows for the possible interactions to be detected and not eliminated as in the previous traditional experimental techniques.

To summarise, orthogonal arrays were used because:-

- They are an efficient sub factorial design for experiments.
- They solve for interactions.
- Some designs enable compounding of the interactions, i.e. to spread them across all columns so that all the columns can be used efficiently to study factors.

Quality Characteristic

The applicability and effectiveness of the orthogonal array technique is dependent upon the quality characteristic which is used to evaluate the effects of changes made on the press. The printed image consists of a set of halftone coverages which when viewed appear to give a single tone dependent upon the image composition. Print has been traditionally assessed by eye with acceptance and changes being based upon these observations. However, this is a subjective assessment based on the viewer and is not sufficiently accurate for the orthogonal array technique.

To ensure the applicability of the trials and to minimise costs no trial plates were made, all tests being carried out under normal operating conditions. To enable the results to be compared between tests most measurement were carried out using the tests strip (Gretag CMS2 and latterly the CMS3).

The experiments were carried out on a Rockwell G16 eight unit press, with the changes being made primarily on unit seven, magenta. A schematic of the press is shown in Figure 2. This unit was chosen as changes made on this would be most apparent in the editorial. The changes could be detected on solid, halftone, grey balance and trapping patches in the test strip. However, only the solid and halftones were used as these were unaffected by changes on the other units.

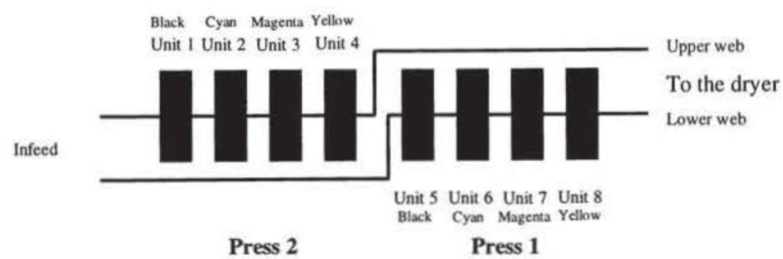


Figure 2 Schematic of a 8 unit press at Jarrold Printing

The measurements were carried out with a reflectance spectrophotometer (Gretag SPM50 with $0^0/45^0$ optics). As the operating conditions of only one unit was being adjusted it allowed the use of both density and CIE colour space values to be used in the analysis. The results presented in this paper will primarily be those obtained using the densitometric function. All data was collected from the instrument using proprietary software.

Selection of parameters

An initial parameter list of over eighty was compiled for the investigation. A review of these factors indicated that some would be impracticable to investigate using a production press. Of these, some were investigated using a single press unit located at the University, while the influence of others were evaluated using numerical modelling techniques.

The parameters which remained were divided into control and process stability parameters and were investigated using the experimental programme at Jarrold Printing.

The control parameters were those that could be set by the press crew to attain the pass copy and maintain colour control. These tend to have a large effect on the image and include parameters such as the duct roll speed. The response of these parameters will have implications for any colour control systems (either closed or open loop). The process stability parameters represent those that will vary through the duration of the run or else between jobs. The control of these will ensure a more consistent and reliable print.

Overview of the orthogonal array trials

Prior to the commencement of the experimental programme a monitoring exercise was undertaken through the duration of several print runs to evaluate fluctuations in both the printed copy and press conditions. The printed copy was measured using spectrophotometry in the editorial and on the test strip. Fourier and moving average analysis were applied to the results to determine the correct sample size. The monitoring of the press indicated which parameters varied naturally through the run and the range of values to be expected. This was carried out over a three month period.

A number of experiments were carried out and these were primarily orthogonal array experiments investigating the control and process stability parameters. These were designated Taguchi sets 1 and 2 and these are summarised in Table 1. The third set was used to investigate uncontrollable factors, such as web breaks. The effect of ink trapping between different units was evaluated in Taguchi set 4. Also listed is the type of array used to analyse the copies and the factors assigned to each of the parameters. Throughout these tests other parameters were monitored and these are listed in Table 2.

The maximum time period over which the experiments could be carried out was limited. This was the result of several factors including

- time for the press to stabilise thermally
- time for a pass copy to be achieved and any special copies removed
- press stops including web breaks, dryer problems, etc

This resulted in the maximum practical tests being L8 (2 level) or L9 (3 level) orthogonal array experiments. By design it was possible to arrange the tests such that when terminal problems occurred it was often possible to salvage results from part of the test. For example, the design of a three factor L8 experiment allowed the data collected during the first four runs to be analysed using an L4 orthogonal array.

The data from the experimental and monitored parameters were recorded primarily on computer via data acquisition systems at ten second intervals. Thermocouples were mounted to record strategic

Experiment number	Parameters investigated
Taguchi 1 L8 array	Ink key setting Duct roll speed Pan roll speed
Taguchi 2A L8 array	Pan roll speed, CUIM roll speed Temperature of fount in pan Temperature of ink in duct
Taguchi 2B L4 array	Temperature of fount in pan Temperature of ink in duct On-line blanket wash Temperature of copper roll cooling water
Taguchi 2C L4 array	Temperature of fount in pan Temperature of ink in duct
Taguchi 2D L4 array	Temperature of fount in pan Temperature of ink in duct
Taguchi 2E L9 array	Temperature duct roll cooling water Temperature copper roll cooling water
Taguchi 3A	Web Breaks, Temperature of fount in pan Temperature of ink in duct
Taguchi 3B	Ink key movement and hysteresis
Taguchi 4A, 4B	Trapping between units

Table 1 List of the main Taguchi experiments

Monitored parameters	Taguchi experiments
Ambient around reel stands, ambient behind unit 7, cooling water temperature to and from copper rolls, CUIM roll speed, duct roll speed, fount temperature in pan, frame temperature of unit 7, ink temperature in duct, press speed, roller speeds	Taguchi's 1, 2A, 2B, 2C, 2D, 2E
Ambient outdoors, chill water temperature, humidity, ink temperature on duct roll, ink temperature on copper rolls, ink temperature on rubber rolls, pan roll speed	Taguchi's 2A, 2B, 2C, 2D, 2E
Conductivity of fount in pan, fount temperature in recirculation unit	Taguchi's 2A, 2B, 2C, 2D
Paper temperature	Taguchi's 2B, 2C, 2D
Web tension	Taguchi 1

Table 2 Monitored parameters for Taguchi experiments 1, 2A, 2B,2C, 2D, and 2E

temperatures on and around the press and also across its width. In addition, temperatures of coolant water to and from the press was monitored. Ink temperatures were also recorded using infra red thermometry in both the ink duct and down through the ink train. The instrument was calibrated to ensure the measurements of ink temperature and not the roller bulk temperature. The roller speeds were captured using inductive probes with slotted discs being mounted on the appropriate rolls. The fount conductivity and the environment humidity were monitored manually.

Taguchi's 2B, 2C and 2D were all carried out during a single day and were originally planned as one experiment. Taguchi 2B was intended to be an L8 experiment to investigate the effects of changes in the temperatures in the fount (factor C), ink in the duct (factor B) and the copper cooling water temperature (factor A), refer to Table 3. Factor D was left blank to give an indication of the noise in the experiment. The duct temperature was controlled by using heated water in the duct roll.

Column	1	2	3	4	5	6	7	Q C
Factor	A	B	-	C	-	-	D	
Run No.								
1	1	1	1	1	1	1	1	
2	1	1	1	2	2	2	2	
3	1	2	2	1	1	2	2	
4	1	2	2	2	2	1	1	
5	2	1	2	1	2	1	2	
6	2	1	2	2	1	2	1	
7	2	2	1	1	2	2	1	
8	2	2	1	2	1	1	2	
avg L1								
avg L2								
|L1-L2|								

Column	1	2	3	Q C
Factor	A	B	-	
Run No.				
1	1	1	1	
2	1	2	2	
3	2	1	2	
4	2	2	1	
avg L1				
avg L2				
|L1-L2|				

Table 3 Taguchi L8 and L4 orthogonal array

As an example of experimental difficulties, but a condition which did not typify press operation, in the tests completed an on line blanket wash was carried out after run 5, at which samples were collected before and after. A flame out in the drier following run 6 meant the press was stationary for 2 hours. The first four sets of data could be analysed for the temperature of the fount and ink using an L4 array and are referred to as Taguchi 2B. The analysis array is shown in Table 3. Also available was information with respect to the effect of an on line blanket wash and changes in the copper roll cooling water temperature. Once the press resumed operation and had stabilised runs 5 to 8 were completed, Taguchi 2C. The ink duct temperature was lower for at the start of this experiment when compared to Taguchi 2B and hence the starting ink key positions were different. As a check a repeat experiment was carried out, Taguchi 2D, in which the press was allowed to stabilise and runs 8 to 5 were carried out in this reverse order.

Results and discussion : Duct roll speed and ink key setting

The effect of changes in the duct roll and ink keys was assessed during the first set of trials, Taguchi 1. They were used to confirm existing theories regarding the press control system and to evaluate the effectiveness of carrying out orthogonal array experiments on a press while in production. The duct roll speed was altered at the press controller and the ink keys also from the control console. The experiment was carried out using an L8 format with pan roll speed being the other parameter investigated. Column 7 was left empty as this would give an estimate of process noise, see Table 3.

The parameters were altered during a production run and as such the range by which they could be changed was partially determined by the requirement to produce acceptable copy. A delay of five minutes was incorporated between the changes taking place and the collection of copies to allow the press conditions to stabilise. This time was significantly longer than the crew believed would be required for the changes to take place. The ink key setting levels were recorded for the job as it was being printed (level 1) and +2 steps, which corresponds to a key opening (level 2). Similarly, the duct roll speed was that appropriate for the job at level 1 (38 rpm) and increased to level 2 (41 rpm).

The results from the analysis of the measurements are presented in Table 4. The average printed density (magenta filter) and the ink key setting in line with the measurement patch are also shown. Patches were chosen in both the high and low coverage areas of the job. The results from both the halftone and grey balance patches mirrored those from the solid patches and as such it was decided these should be removed from subsequent measurement routines. Large density changes were detected from the changes in the ink key setting with the ink density increasing as the key is opened. However, the results were not even across the width of the web with the changes at the smaller key setting having a much larger influence on the ink density. This would indicate the response of the ink flow through the key mechanism is not linear with key opening position. Numerical modelling of the duct key system supports this proposition.

	Solid 1	Solid 2	40%	Grey balance 1	Grey balance 2
Ink key setting	30	15/16	17	32	17
Average density	1.67	1.44	0.53	1.00	0.94
Duct roll speed					
Density change	0.098	0.063	0.025	0.045	0.034
Ink key setting					
Density change	0.139	0.234	0.041	0.070	0.078

Table 4 Change in printed ink density with respect to changes in the duct roll speed and ink key setting

Increasing the duct roll speed increases the ink density. The ink changes detected appear to have a relationship with respect to key opening, such that as the speed is increased so the quantity of ink increases proportionately across the web. Therefore, by attempting global ink changes across the width of the web by use of the ink key or the duct roll speed will produce varying effects dependent on the type of movement made and the coverage being printed. Neither method provides an effective means of carrying out a global even increase in ink density.

Results and discussion : CUIM roll speed

The effect of changes in the CUIM speed were analysed at two speeds, 57 rpm and 85 rpm, in Taguchi 2A. This was an L8 experiment, Table 1, with the CUIM changes being analysed as factor C (column 4), in Table 3. The press was allowed to stabilise from the changes made for five minutes before any samples were collected. These were gathered with the folder shifted to allow the test strip to be measured.

The test strip was measured for colour change at four positions across the web for solid density and for a 40% and 80% halftone. The results were in good agreement across the web with an average density difference of 0.248 being detected, Table 5. The plate scanned coverage in line with the solid measurement patches are similar at 16%.

	Solid 1	Solid 2	Solid 3	Solid 4	40%	80%
Density change	0.288	0.217	0.266	0.221	0.218	0.064
Average density	1.685	1.677	1.699	1.693	1.240	0.518

Table 5 Change in printed ink density with respect to changes in the CUIM speed

These results showed an ink density increase with an increase in the CUIM roll speed. These indicate the CUIM could be used as an effective metering system for altering the flow of ink to the ink train as it appears relatively independent of other parameters. The ink density change is even across the width of the web. However, as the printing conditions are also even (including coverage) this result does not determine whether this would be the best means by which global colour changes could be attained.

Results and discussion : Pan roll speed

The influence of changes in the pan roll speed were investigated during Taguchi's 1 and 2A. The upper and lower limits for the speed were chosen during production, as those that would not cause a catastrophic failure of the image due to either scumming or wash out. The speed of the roll was increased by 20rpm in both tests, with the actual speeds being 240rpm and 260rpm in Taguchi 1 and 193rpm and 213rpm in Taguchi 2A. The influence on the ink density was measured on the test strip and analysed using L8 arrays in both experiments, the results are shown in Table 6.

The results show the effect of changes applied to the pan roll speed have a minimal effect on the printed ink density. The values obtained show fluctuations in directional effect and magnitude. These variations appear random with no secondary effect. The magnitude of the changes are small, normally less then 0.02, which from other experiments, was determined to be a value below which results become insignificant. No detectable change has been found in either solid, halftone or grey balance patches for changes in the pan roll speed. The implications for press control are such that the pan speed does not need to be controlled as closely as practised presently as its impact on the printed matter is minimal other than catastrophic failure due to scumming and was out, etc.

	Solid 1	Solid 2	40%	Grey balance 1	Grey balance 2	n/a
Taguchi 1						
Density change	-0.015	0.008	0.002	-0.005	-0.009	n/a
Average density	1.67	1.44	0.53	1.00	0.94	n/a
Taguchi 2A						
	Solid 1	Solid 2	Solid 3	Solid 4	40%	80%
Density change	-0.009	0.012	0.012	-0.030	0.028	0.011
Average density	1.685	1.677	1.699	1.693	1.240	0.518

Table 6 Variation of ink density with respect to the pan roll speed

Results and discussion : Fount temperature

This parameter has been investigated in several orthogonal array experiments, primarily Taguchi's 2A, 2B, 2C and 2D. A temperature rise of 6 °C was used in all the tests with an increase from 16°C to 22°C for Taguchi 2A and 14 °C to 20 °C for the other tests. This range was determined by the fount chillers performance envelope. The results are shown in Table 7.

The results from Taguchi 2A show no significant effect of changing fount temperature on the printed ink density in either the solid or halftone areas. The values obtained are small and show variations in direction and magnitude. To confirm these results the parameter was included in the proposed Taguchi *2B* experiment, which resulted in the Taguchi's 2B, 2C and 2D.

There is no effect on the ink densities caused by changes in the fount temperature in Taguchi 2D, with all of the values being smaller than 0.02. This agrees with the results from the earlier experiment. However, the results from Taguchi 2C show larger values but with a change in direction of the ink density for the same temperature change. The results from 2B show an increase in ink density as the temperature of the fount is increased. The changes were slightly higher towards the centre of the web, where the coverage was high.

Taguchi 2A						
	Solid 1	Solid 2	Solid 3	Solid 4	40%	80%
Density change	0.008	-0.009	-0.017	0.027	-0.018	-0.007
Average density	1.685	1.677	1.699	1.693	1.240	0.518
Taguchi's 2B, 2C and 2D						
			Solid 1	Solid 2	Solid 3	Solid 4
Density change, Taguchi 2B			0.0499	0.0506	0.0328	0.0461
Density change, Taguchi 2C			0.0320	-0.0123	-0.0463	n/a
Density change, Taguchi 2D			0.0192	0.0015	0.0135	0.0069
Average density, Taguchi 2B			1.238	1.328	1.313	1.291
Average density, Taguchi 2C			1.175	1.593	1.258	n/a
Average density, Taguchi 2D			1.176	1.349	1.299	1.265

Table 7 Variation of ink density with respect to the fount temperature

The copper roll cooling water was set high only in Taguchi 2B. This may explain the effect seen in this experiment as the press is running at higher overall temperatures and the fount is used in this instance to control the temperatures of the ink in the roller stack.

Results and discussion : Duct roll temperature

The effects of changing ink duct temperature on the printed image was investigated in all Taguchi's from 2A through to 2G. This was a result of different effects being observed from the trials, these differences not only being in magnitude but also in direction. Those from Taguchi 2A indicated significant results (density changes up to 0.14) but these varied in intensity across the width of the web. Taguchi's 2B, 2C and 2D again did not produce consistent findings with no density changes being found for some patches and much larger (up to 0.5) on others across the web. Taguchi 2E provided a further set data on the effect of the ink temperature changes. Three set levels of temperature were used to investigate any non linear effects that might be occurring. However, the results in this experiment showed that as the ink temperature was increased the printed ink density would decrease. This was in direct opposition to the finding from the earlier experiments, not only in magnitude, but also in direction.

The temperatures of the frame, ambient and font were similar between Taguchi's 2A, 2B, 2C, 2D and 2E. The range of temperatures that the ink experienced was larger in 2E. This would explain a difference in magnitude but not a reversal in the ink density. The use of a tint, ink type and make were also similar. The paper that the job was printed on is significantly lighter for Taguchi 2E and there was some alcohol in the fount solution. However, by referring to the scanned coverage opposite each of the measurement patches it can be shown that these vary between 5% and 35%. A graph of the scanned coverage against a |L1-L2| effect per set temperature change in the ink is shown in Figure 3. The different responses detected are related to the scanned coverage on the plate, in the area of interest. For areas of low coverage the ink density decreases as the ink temperature increases with the ink density increasing in the high coverage areas. This means that when the ink duct temperature is not controlled the operators will be adjusting to achieve colour pass differently across the width of the web depending on the coverage.

The experimental evaluation of the interaction between the changes in the ink density with respect to ink duct temperature and scanned coverage is in agreement with numerical modelling which has been carried out for the blade-roll junction. In this it was calculated that for the high sliding speeds experienced during the printing process, that with an increase in temperature the flow rate (hence ink density) varies depending on the distance between the ink blade and duct roll which must reflect the level of coverage. A part of these results is presented in Table 8. In Table 8, h1 = film thickness, T_DK = duct temperature, P = blade load, T = temperature, Q = ink flow, T_B = blade maximum temperature, T_f = ink film temperature and U_1 = sliding speed. The exact relationship between the ink density, scanned coverage and temperature change is also dependent on the press speed.

The three levels used to evaluate the effect of ink temperature change in Taguchi 2E can also be used to evaluate the type of response. These results are shown in Figure 4 and show an approximately linear relationship between the printed ink density and temperature change.

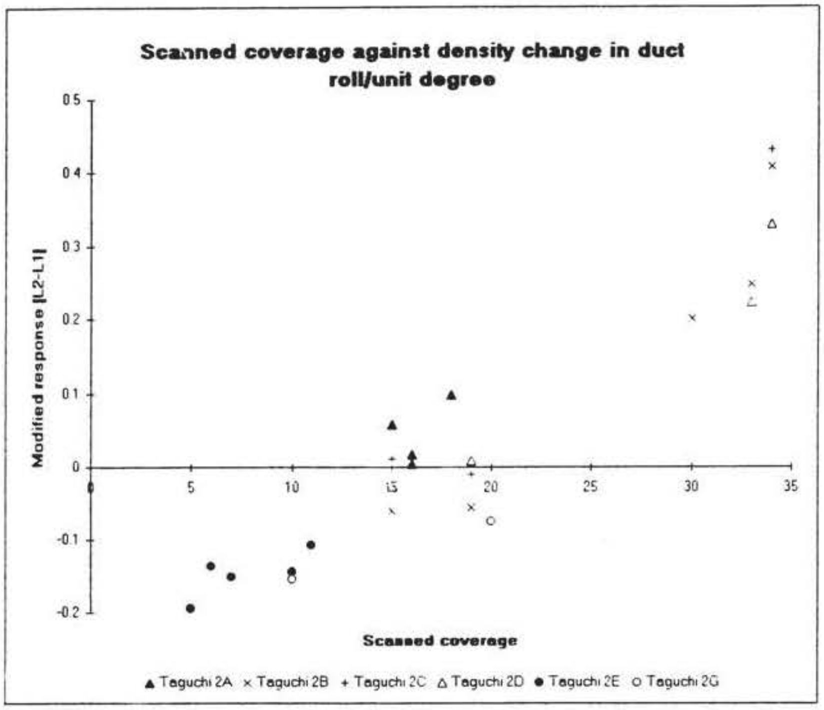


Figure 3 Scanned coverage against density change caused by a 10 degree shift in the temperature of the ink duct

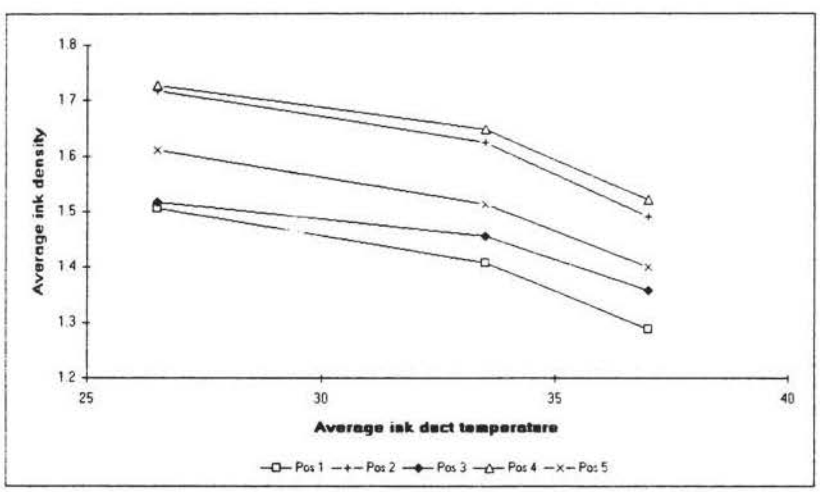


Figure 4 The change in ink density with duct roll temperture, Taguchi 2E

h1 (mm)	T_DK	P (N)	T (K)	Q (l/s)	T_B (K)	T_f (K)
0.08	303	1048	315.1	0.0337	340	344.6
0.32	303	300	306.9	0.0959	345	-
0.08	313	766	320	0.025	338. 8	343.2
0.32	313	209	315	0.1006	336	-

Table 9 Minimum film thickness and duct temperature effects on global trends, U_1=10.0 m/s

Results and discussion : Web breaks

A press stop due to events such as web breaks, folder and drier problems are a cause of lost productivity and increased costs. The effect of these stops on the copy is also of importance for colour control and as such these need to be investigated and evaluated.

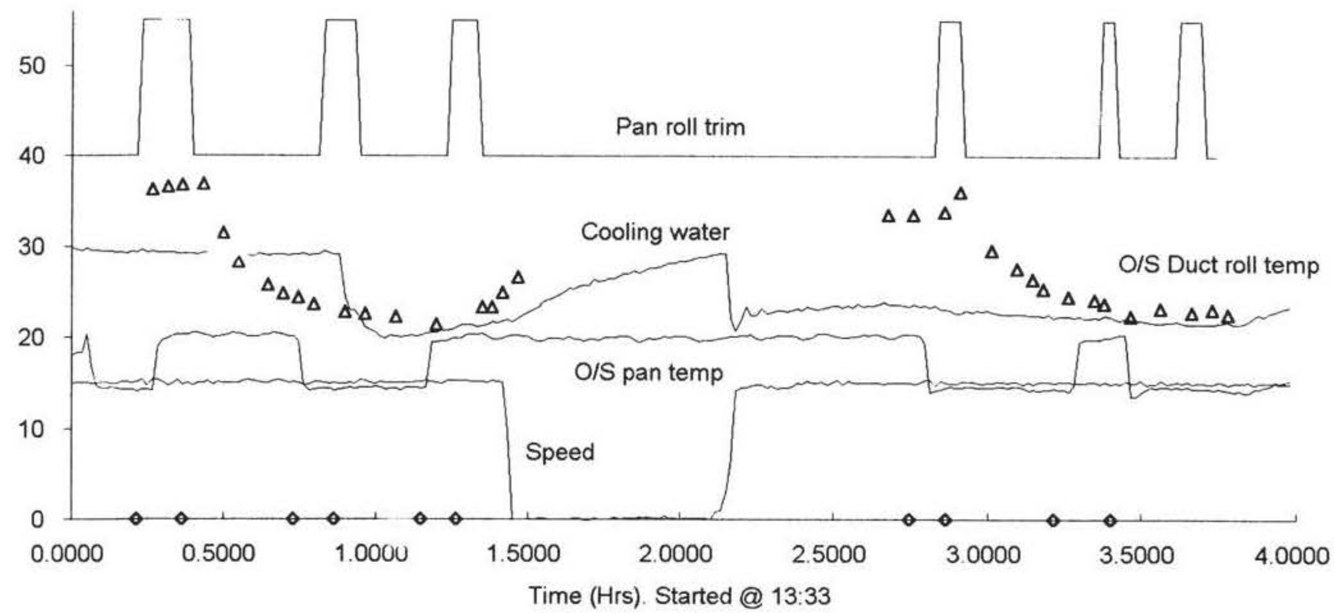
As these events are random in their occurrence it was not possible to design at test specifically, but rather use the results from a Taguchi trial in which one occurred. The test was originally designed as an L8 array, Table 3, to investigate the effects of changes in the pan roll speed (D), fount temperature (C), duct roll temperature (B) and the copper roll cooling water temperature (A). However, after run 6 a web break occurred and the press was stationary for ¾ of an hour. The press was restarted and the experiment completed with run 7 and 8. Once complete, runs 5 and 6 were repeated as 5A and 6A to evaluate the influence of web breaks.

The experimental data indicated that the press conditions were similar for runs 5A and 6A to those in the experiment before the occurrence of the web break, Figure 5. Analysis of solid magenta density values showed a difference of 0.16 between the two sets of samples, Table 10.

Run No	Density before web break	Density after web break	Difference
5	1.016	1.180	0.164
6	0.094	1.105	0.161

Table 10 Ink density difference with respect to web break

FIGURE 5 JARROLD PRESS CONDITION TAGUCHI 3A
Runs 5 & 6 Repeated Due To Web Break



The analysis of the first four runs using an L4 array show much smaller density changes caused by changes in any of the parameters. These approximate to a 0.06 change in the printed ink density. Figure 5 shows that the parameters used in the experiment are similar between runs 5 and 6 when compared to 5A and 6A. The majority of the temperatures that were monitored were also similar for both tests. Several rolls within the inking train were monitored using the infra red gun. These results showed the press to have achieved a thermal equilibrium with respect to the rolls under investigation. There was a slight increase in the final equilibrium temperature of some of the rolls in the inking train (1^{o}C to 2^{o}C) but this was not large enough to merit such a large change in ink density.

When a web break occurs the press stops and the ink keys close. This will be followed by a wash up of the press. It is believed that is a combination of the control and hysteresis in the ink key mechanism and the effects of the blankets wash that are the cause of the changes detected.

The implications for the printer are such that following a web break there needs to be a change in the operation of the press to obtain good copy resulting in waste productivity.

Closure

Changes in the CUIM roll speed, the ink key setting and the duct roll speed all affect the printed ink density. The duct roll temperature also changes the printed ink density. The relationship detected for the duct roll temperature to ink density relationship is in general agreement with the findings from the numerical modelling. The change that occurs is dependent on the image being printed and hence the scanned coverage. At low coverages the ink density decreases as the ink temperature increases while at the higher temperatures the ink density will increase.

For a more consistent, reliable and stable printing it is recommended that wherever possible the CUIM roll speed and the duct roll temperature are kept constant throughout a print run. This will result in the print operators having to spend less time adjusting for the correct ink densities while the press stabilises. The temperature of the ink in the duct through the duration of a run under normal operating conditions will vary by approximately 15 degrees and take approximately 2 hours to stabilise. With the use of temperature control this can be reduced to approximately three quarters of an hour and with feedback control it should be possible to improve this even more.

No major effect in the ink density has been detected by changing either the fount temperature or the pan roll speed. The effect of the fount temperature starts to become significant as the temperature of the press increases. It was shown on press that any changes in the water levels above or below a critical level will cause a catastrophic and wholly unacceptable change in the printed image. The changes made in the pan roll speed have been relatively small due to the requirement to produce saleable copy throughout the duration of the trials. However, these limits are broader than those originally accepted by the printer.

The web break has a very large effect on the ink density and image. There are a large number of parameters which change when this occurs. This includes the thermal changes in the press and surrounding area. Also it has been shown that an on-line blanket wash will significantly affect the printed ink density, Taguchi 2B.

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