Quantification of piling

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Abstract

Piling problems can occur in many lithographic printing applications. It involves the build up of material on the blanket surface which leads to unacceptable print quality. To remedy the problem the blankets need to be cleaned during the production. This cleaning takes time and materials to complete, adding cost to the production. The aim of this work program has been to understand the performance of a heat set web offset press with respect to piling, to allow subsequent optimization.

This paper presents results from a large experimental programme evaluating the problem of piling. There are a number of different techniques available for the measurement of piling, which are discussed and compared experimentally during the program. The parameters assessed include paper, blankets ink and fountain solution. A design of experiment approach was required for the trial to facilitate the analysis, reducing the number of trials by seventy five percent. The results show the impact of the different process parameters on the piling and the print quality.

Introduction

Piling is a significant printing problem in many different lithographic applications and can adversely affect both the quality of the product being produced and also the productivity of the facility. The purpose of this paper is to examine in greater detail some of the factors that give rise to piling in a commercial heat set web printing operation and evaluates the type of piling that is occurring.

Piling is the buildup of unwanted material on the surface of the printing blanket. This buildup may occur at any position and will vary with time and the materials

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used. Piling can be described in many different manners, dependent on the perspective from which the issue is being addressed. In this paper it is defined as a buildup of material (that may include ink, paper, fountain solution etc.) on the printing blanket. The actual material that is part of the build up has not been identified, but rather the level of the buildup.

There are many factors that can affect the level of piling on a print production job; some of these are shown in Figure 1. This is a complex transfer that can be affected by many the dynamics of the nip contact at both the substrate / blanket and blanket / plate contact points. There are many interactions occurring between the different factors and as these are changed the level of piling can also change.

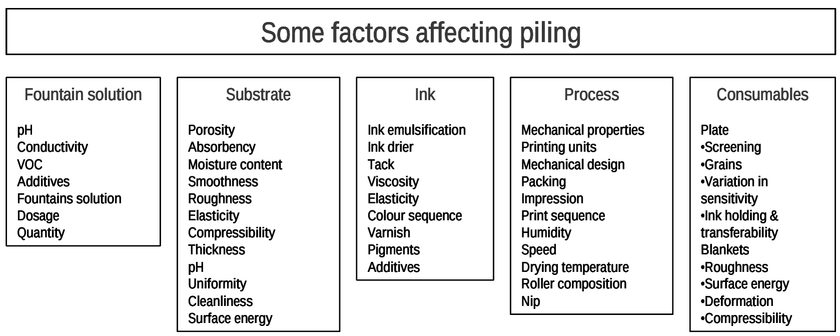

Figure 1: Factors that may affect piling.

There are different forms of piling that can occur and the mechanisms that drive them can alter. There are three main types of piling that can be characterized by their position on the blanket and are referred to as image, non-image and downstream piling. Image piling normally manifests itself on the trailing edge of the print and can be identified by missing sections in the printed product, Figure 2. Non-image piling is a buildup of material in the non-image areas of the print, either in low tonal coverage's or else in complete non image area. Different mechanisms drive this formation and in the tonal areas can give rise to a mottled effect. Downstream piling is the buildup of ink and material on subsequent units after printing. This is when the transfer is preferential to the blanket surface rather than the paper. A typical example of black build up on the yellow unit is shown in Figure 2.

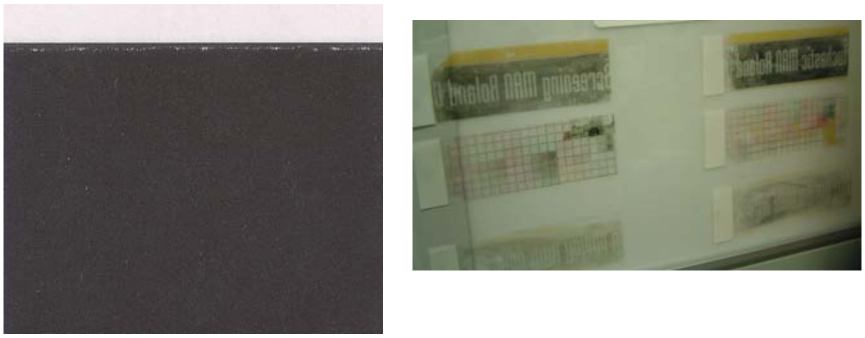

Image Piling Downstream piling

Figure 2: Example of different forms of piling.

This paper describes the experimental design used to carry out the evaluation, followed by the trial protocol and a discussion of measuring method used for the piling. The repeatability of the trials are commented on and results from the black unit are discussed in detail. Comments are made on the results obtained from the other units.

Experimental procedure

The experimental program evaluated the impact of paper (4 levels), blankets (4 levels), fountain solution (4 levels), and paper (4 levels) on piling. These did not all vary continuously and were at discrete levels. To evaluate all possible combinations would require 192 press trials, without including any repeat trials. This would be unacceptable in terms of the number experiments, the time required and cost involved. A design of experiment approach was used [1], [2] to limit the number of trials. Several different methods were evaluated including factorial, orthogonal array, Plackett Burman. However, none of these could adequately evaluate the number of levels in an optimal manner, with respect to either the total number of trials or allowing interactions to be evaluated. A D-optimal design was selected for the analysis. This used 48 trials to evaluate the main parameter effects and also the main interactions, the experimental trial plan is shown in Table 1.

Std	Run	Block	Factor 1 A:Paper	Factor 2 B:Fountain Solution	Factor 3 C:Ink	Factor 4 D:Blanket
23	44	Block 1	Level 2 of A	Level 1 of B	Level 1 of C	Level 1 of D
13	46	Block 1	Level 3 of A	Level 3 of B	Level 1 of C	Level 1 of D
42	16	Block 1	Level 2 of A	Level 4 of B	Level 1 of C	Level 1 of D
27	41	Block 1	Level 1 of A	Level 1 of B	Level 1 of C	Level 2 of D
45	36	Block 1	Level 2 of A	Level 3 of B	Level 1 of C	Level 2 of D
48	10	Block 1	Level 1 of A	Level 4 of B	Level 1 of C	Level 2 of D
37	1	Block 1	Level 3 of A	Level 1 of B	Level 1 of C	Level 3 of D
38	7	Block 1	Level 2 of A	Level 2 of B	Level 1 of C	Level 3 of D
24	23	Block 1	Level 1 of A	Level 2 of B	Level 1 of C	Level 3 of D
10	39	Block 1	Level 3 of A	Level 2 of B	Level 1 of C	Level 4 of D
8	2	Block 1	Level 1 of A	Level 3 of B	Level 1 of C	Level 4 of D
41	32	Block 1	Level 3 of A	Level 4 of B	Level 1 of C	Level 4 of D
32	42	Block 1	Level 3 of A	Level 2 of B	Level 2 of C	Level 1 of D
25	33	Block 1	Level 1 of A	Level 3 of B	Level 2 of C	Level 1 of D
7	45	Block 1	Level 3 of A	Level 4 of B	Level 2 of C	Level 1 of D
40	34	Block 1	Level 3 of A	Level 1 of B	Level 2 of C	Level 2 of D
29	6	Block 1	Level 1 of A	Level 2 of B	Level 2 of C	Level 2 of D
14	25	Block 1	Level 2 of A	Level 2 of B	Level 2 of C	Level 2 of D
34	4	Block 1	Level 2 of A	Level 1 of B	Level 2 of C	Level 3 of D
44	14	Block 1	Level 2 of A	Level 2 of B	Level 2 of C	Level 3 of D
30	31	Block 1	Level 3 of A	Level 3 of B	Level 2 of C	Level 3 of D
18	13	Block 1	Level 1 of A	Level 1 of B	Level 2 of C	Level 4 of D
21	8	Block 1	Level 2 of A	Level 3 of B	Level 2 of C	Level 4 of D
3	11	Block 1	Level 2 of A	Level 4 of B	Level 2 of C	Level 4 of D
17	12	Block 1	Level 3 of A	Level 1 of B	Level 3 of C	Level 1 of D
26	30	Block 1	Level 2 of A	Level 2 of B	Level 3 of C	Level 1 of D
33	21	Block 1	Level 1 of A	Level 4 of B	Level 3 of C	Level 1 of D
35	47	Block 1	Level 3 of A	Level 2 of B	Level 3 of C	Level 2 of D
20	43	Block 1	Level 1 of A	Level 3 of B	Level 3 of C	Level 2 of D
47	38	Block 1	Level 3 of A	Level 4 of B	Level 3 of C	Level 2 of D
36	27	Block 1	Level 1 of A	Level 1 of B	Level 3 of C	Level 3 of D
43	48	Block 1	Level 2 of A	Level 3 of B	Level 3 of C	Level 3 of D
22	5	Block 1	Level 2 of A	Level 4 of B	Level 3 of C	Level 3 of D
11	40	Block 1	Level 2 of A	Level 1 of B	Level 3 of C	Level 4 of D
16	18	Block 1	Level 1 of A	Level 2 of B	Level 3 of C	Level 4 of D
5	19	Block 1	Level 3 of A	Level 3 of B	Level 3 of C	Level 4 of D
31	24	Block 1	Level 1 of A	Level 1 of B	Level 4 of C	Level 1 of D
15	35	Block 1	Level 1 of A	Level 2 of B	Level 4 of C	Level 1 of D
12	15	Block 1	Level 2 of A	Level 3 of B	Level 4 of C	Level 1 of D
19	26	Block 1	Level 2 of A	Level 1 of B	Level 4 of C	Level 2 of D
6	29	Block 1	Level 3 of A	Level 3 of B	Level 4 of C	Level 2 of D
46	9	Block 1	Level 2 of A	Level 4 of B	Level 4 of C	Level 2 of D
9	20	Block 1	Level 3 of A	Level 2 of B	Level 4 of C	Level 3 of D
28	37	Block 1	Level 1 of A	Level 3 of B	Level 4 of C	Level 3 of D
39	28	Block 1	Level 3 of A	Level 4 of B	Level 4 of C	Level 3 of D
2	22	Block 1	Level 3 of A	Level 1 of B	Level 4 of C	Level 4 of D
4	17	Block 1	Level 2 of A	Level 2 of B	Level 4 of C	Level 4 of D
1	3	Block 1	Level 1 of A	Level 4 of B	Level 4 of C	Level 4 of D

Table 1: Experimental design used

The protocol for each of the press trials was set to ensure repeatability. The press was warmed to ensure consistent temperature throughout the duration of the trials. The temperature was monitored in two locations on each unit, in the ink duct using a temperature probe and on the blanket surface using a non contact pyrometer.

The minimum water settings were found before the start of each trial and these were then incremented by a set amount. The blankets were cleaned and the trial started. The same numbers of copies (39,000) were produced in each trial with the press speed and settings controlled throughout this period. If there was a sign of catch up on the printed product, then the water levels were increased and these increases were recorded. The press was stopped after 39,000 copies and the piling on the blankets for each of the units was then evaluated.

The image used for the evaluation is a split test form incorporating a 25 micron stochastic screening and a 150 lpi conventional screen, shown in Figure 3. This was repeated on both the upper and lower units of the press. The measurement areas used for the profilometry and tape pulls are highlighted. The solid bands in the center section were to help differentiate the two screening methods while printing and to help with the water supply.

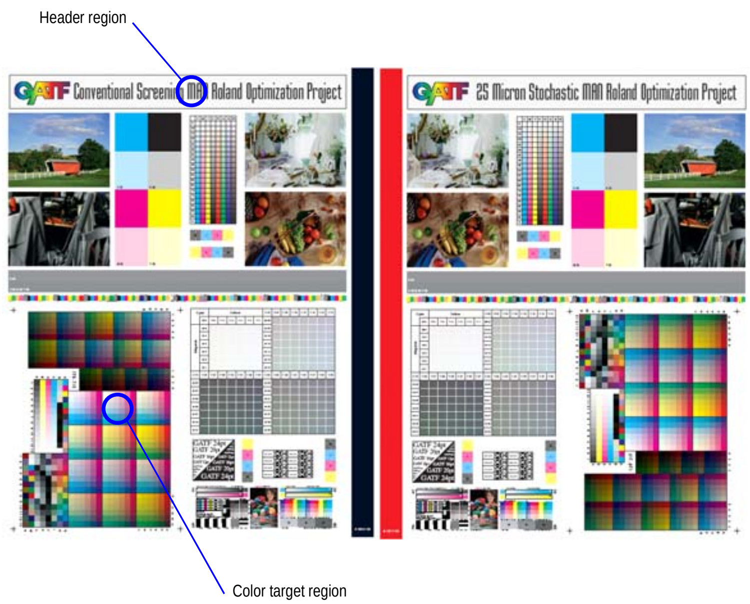

Figure 3: Image used for the trial

To ensure a fair comparison between the stochastic and conventional screening, the color balance needed to be adjusted as the two screenings types have very different tonal reproduction curves. A number of pre-trial tests were completed and the plate curves adjusted for the stochastic region to obtain a balanced image between the two screens. In this procedure the tonal reproduction was matched, as was the grey balance.

There are a number of different techniques available for the measurement of piling; those which were used during the program are listed below:

- Visual (photographs etc)
- Human (feel the blanket)
- Tape pulls
- Profilometry

The human evaluation of the piling was made by the same operator and also referred back to a roughness reference gauge before these evaluations were recorded. Tape pulls were taken from the areas highlighted in Figure 3 and these have been evaluated for the quantity of material removed and also for the type of material. These results will be reported on in a subsequent publication.

The results in this paper focus on those obtained using profilometry. These were also taken from the areas highlighted in Figure 3. A typical profile obtained from the experimental program is shown in Figure 4 from the header region. This shows the transition across text in a light tonal region. This allowed the build up of material to be quantified numerically. Two measurement areas are discussed in the paper, those being in a light tonal header region and also in a color target at the transition between two tonal patches. These measurements were carried out for each of the screening areas on top of the unit, while for the bottom blanket of each unit measurements were made in the header region only for each screening. This resulted in 48 measurements per trial. For each of the areas assessed two repeat measurements were made adjacent to each other. Any errors in measurements were immediately apparent in the trace obtained and in these cases further supplemental measurements were taken. These errors were normally due to movement of the profilometer while taking the measurement, positioning of the instrument not parallel to the blanket cylinder or a dirty probe tip.

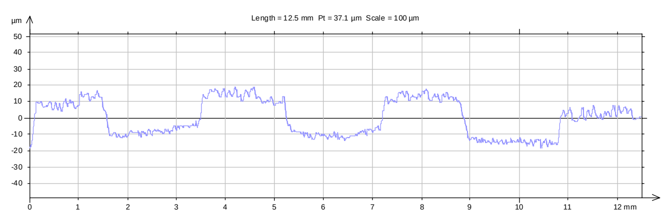

Figure 4: Profile obtained of piling on the blanket surface

Results and discussion

The results will initially present some of the material testing carried out on the consumables. The repeatability of the press trials will then be presented. This will be followed by a discussion of the profilometry data from the upper black unit. Following this a brief discussion of the results from the yellow unit will be made.

All the materials used for the investigation were commercially available. Three papers were used for the trial and these covered a wide range of those used commercially, from a grade #2 to a grade #5. Characteristics of the paper are shown in Table 2. The largest differences in the papers related to the basis weight and opacity, where paper three had lower values.

Level	Grade	Basis weight	Gloss 75 degrees	Brightness	Opacity
1	#3	44	66	88	88
2	#2	47	64	93	89
3	#5	30	42	70	86

Table 2: Paper characteristics

The inks were measured to obtain many of their characteristics including viscosity, tack, strength, water pick up. The ink tacks showed that inks were correctly tack rated and that inks one and four had higher tack values. The viscosities of these inks were also higher. The ink strengths varied between each of the ink sets and also between colors within each of the sets.

The water pick ups were measured for each ink / fountain solution combination. There were differences between each of the fountain solutions, but the largest differences were seen between the ink sets, Figure 5. The most significant effect is the large water pick up that was obtained from ink two and this was evident in the print production.

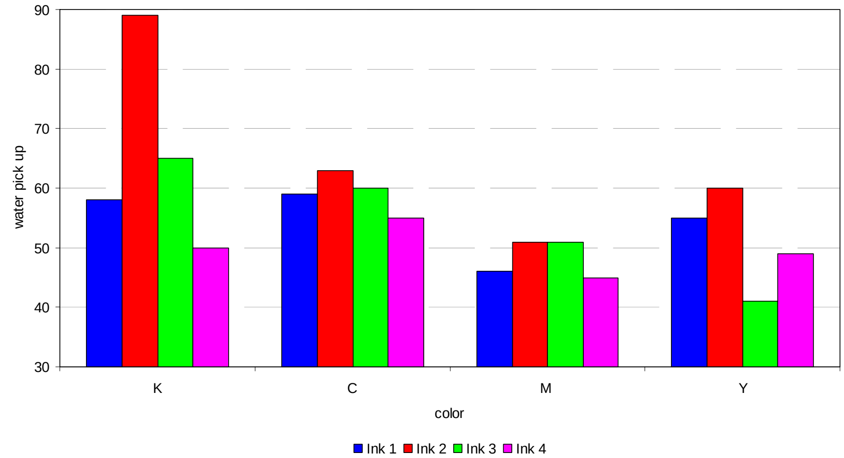

Figure 5: Ink water pick up for fountain solution 1

The details of the different blanket and fountain solutions used are shown in Table 3. The blankets have different shore hardness values, with the hardest blankets being one and three. The pH of the fountain solutions is in line with those used in North America, which is lower than those in Europe. The pH and conductivity were also measured before and after each trial with minimal differences between the start and end of each trial.

Level	Blankets		Fountain solution		
	Hardness Shore A	Roughness R_a	pH	Conductivity	VOC
1	78	0.7	3.8	2500	0.68
2	68	1.0	3.5	3100	0.64
3	80	0.7	3.8	2500	2.58
4	70	0.8	3.5	3100	0.54

Table 3: Blanket and fountain solution characteristics

One full repeat trial was completed and several partial repeat trials completed. During these both the temperature profiles through the run and also the water settings used were consistent. The complete repeat trial used a mid range configuration and none of the press crew were made aware of the trial that was being repeated (or the settings used). The blankets were assessed and compared with the original trial. In comparing the measured build up of material on the blanket surface the difference between the two trials was small, at approximately three microns. This gives good confidence in the results obtained from the investigation. The range of surface heights obtained during the investigation was from 0 microns in the best case through to approximately 70 microns in the worst case.

The analysis of the data was carried out using a commercial software package, from which an ANOVA tables could be generated indicating the significance of the different variables and interactions, Table 4. Values less than 0.05 are significant, while those with a value greater than 0.1 are deemed to be insignificant. It should be noted that a lower value does not infer a larger effect. This table gives an overview of which parameters and which interactions are significant when assessing piling. The measurement areas are denoted by the color of the unit (K, C, M, and Y) and the location. For the upper section of each unit, 4 measurement locations were used, two in the header region and two in the color target, Table 4.

	Header		**Color target**	
Screening	Conventional	Stochastic	Conventional	Stochastic
	K1	K2	K3	K4
A: Paper	0.020	0.000	0.001	0.000
B: Fount	0.037	0.002	0.000	0.930
C: Ink	0.008	0.000	0.004	0.017
D: Blanket	0.000	0.027	0.001	0.000
AB			0.000	
AC		0.091	0.090	
AD		0.016	0.008	
BC		0.038	0.005	
BD				
CD				

Table 4: ANOVA table for black unit

The ANOVA table shows that there is a difference in the areas with interactions occurring in only some of the measurement regions. As the analysis is carried out for the subsequent units the significance of the interactions increases. For this paper, we will concentrate on the results obtained from the black unit. The analysis of area K1 (header region, conventional screening) shows that there are only main effects present, Table 4, with no interactions. This makes the interpretation of the results easier. The largest effect is found with the blanket, with approximately a 45% change in the level of piling, Figure 6: Piling levels for blanket for area K1. The best performing blankets are numbers three and four, while blanket one performs the worst.

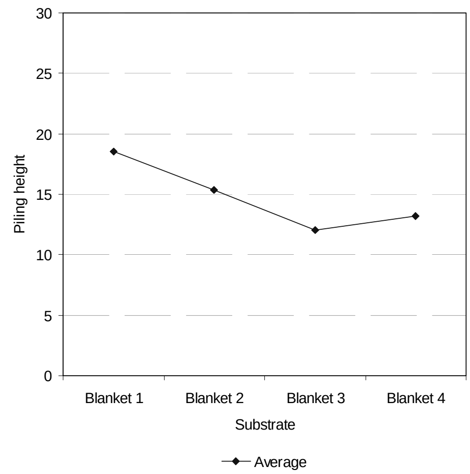

Figure 6: Piling levels for blanket for area K1

The paper also has a significant effect on the level of piling; these results are shown in Figure 7. Paper three, the grade 5 paper, shows the lowest level on piling in the measurement area. The difference between the other two papers is insignificant. The fountain solutions showed only a small amount of difference on the level of piling. However, the inks did show an impact on the piling, with ink three performing the best. With all these results it should be noted that piling is only one of the many quality characteristics that need to be optimized to obtain the best printed product.

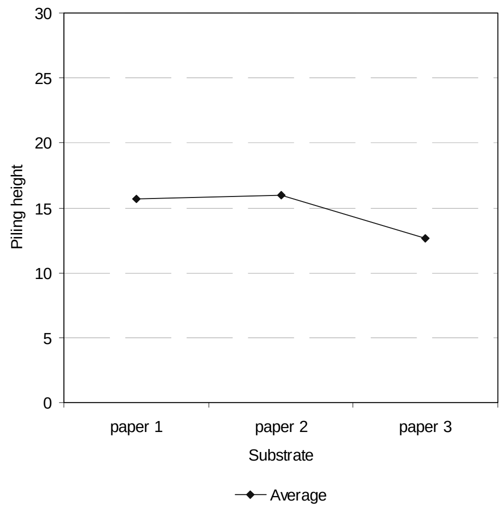

Figure 7: Piling levels for paper for area K1

The results from the header region K2 are more complex with a number of interactions present in the analysis. The paper and blanket interact with each other and the results are shown in Figure 8. The change in the level of piling with respect to the paper, for each of the blankets, does not have the same form. Discussing for each paper, it can be seen that for paper one, blanket four is clearly the best performing while a similar performance is also obtained from blanket two. For paper two, blankets two and four perform best. Finally considering paper three, the best performance is obtained with blankets one and three. On average, the best performance is evident with paper three. Considering the blankets it can be seen that blanket four is insensitive to changes in the substrate while blankets one and three are the most sensitive. The optimal selection of the consumables would be dependent on the type of production being carried out.

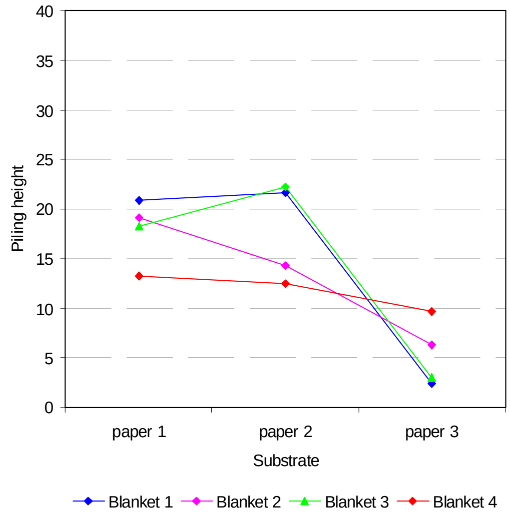

Figure 8: Piling levels for paper / blanket interaction for area K2

The ink will affect the level of piling, though there was an interaction with the substrate. The differences between the inks were apparent for papers one and two, while for paper three there was no significant difference. Ink three was the best performing while inks one and four were the worst. The effect of the fountain solution was minimal with an interaction with the ink, fountain solution one was the worst performing.

The results from these two regions, when comparing screening, showed that the largest differences (widest range) in piling were evident with the stochastic screening, though a similar / lower level could be achieved with the optimal combination of parameters. This indicates that the window of operation for the stochastic is smaller and that the choice of consumables is more critical with stochastic screening.

The results from the color target show some significant differences from that in the header region. This shows that there are to different mechanisms that are driving the formation of the piling. In the header region the piling builds up around a low tonal coverage, while in the color target region the piling is true non image piling between adjacent halftone patches. The most significant difference between the two regions is with respect to the effect of the substrate with paper three being the worst performing, Figure 9. Considering the substrate, there is not a significant difference between papers one and two (as seen in the header region), while this time there is significantly more piling with paper three. There is an interaction with the fountain solution, with solutions one and two being less sensitive to changes in the paper.

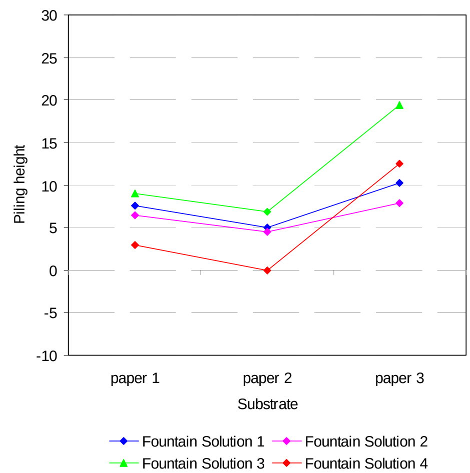

Figure 9: Piling levels for paper / fountain solution interaction for area K3

In evaluating the two measurement regions this is the most significant change, though there are other smaller changes with the performance of the parameters altering slightly. The effect of the blanket is significant, an example of the change in piling is shown in Figure 10, in the stochastic region. There is a change in the relative effects with blanket four being the best performing. Similar results are also found in the conventional screening region, though there are also interactions which slightly mask the main effect results.

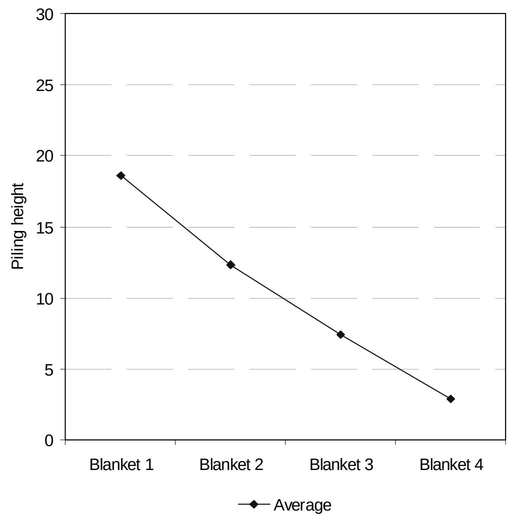

Figure 10: Piling levels for blanket for area K4

Considering the subsequent units, the impact of the interactions becomes more significant with the introduction of downstream piling. There is also an increase in the level of piling. The largest measured piling occurs on the yellow unit, which is the last color printed. It should be noted that very low levels of piling were also measured on the yellow unit for certain combinations, with no piling in certain locations. Typical results from the yellow unit are shown in Figure 11 for the paper / blanket interaction in the upper header region Y1. The best performing paper was paper three, though there were two blankets that were completely insensitive to changes in the substrate type.

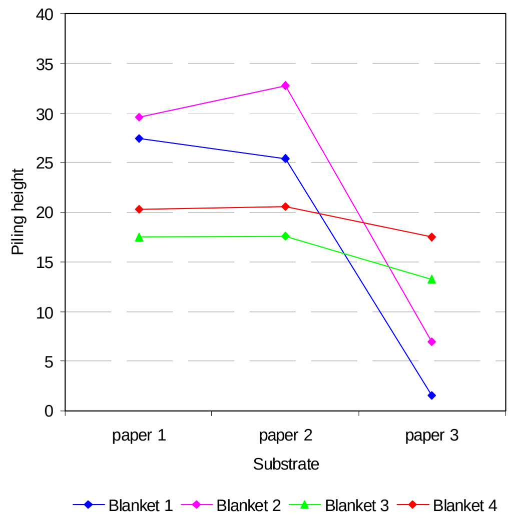

Figure 11: Piling levels for paper / blanket interaction for area Y1

Conclusions

An extensive press trial using in excess of fifty print runs to evaluate the effect of ink, blankets, paper and fountain solution on the propensity of a web offset printing press to produce piling has been successfully completed. This was carried out under controlled conditions and the piling has been quantified numerically using a profilometer, for which this paper has focused on. There are many interactions occurring between the different parameters assessed and different forms of piling were evident throughout the different press runs. The results can be summarized as:

- Excellent repeatability was obtained between the different press runs.
- The type of piling was dependent on the combination of parameters used and the magnitude was dependent on the location.
- Stochastic screening was more sensitive to changes in the parameters.
- The introduction of low halftone coverage (compared to no coverage) will significantly affect the level of piling and the significant parameters.
- The interactions occurring showed that it was necessary to evaluate the whole press configuration and not just individual parameters.
- Paper would significantly affect the level of piling, though interactions could negate its impact.
- The ink will affect not only the magnitude but also the form of the piling.
- Certain blankets configurations were more stable in performance and affected less by the other parameters.

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