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Investigation of the effect of press and paper variables on linting during the offset printing of newsprint

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ABSTRACT

The effect of printing take-off angle, ink tack, print coverage (printing tone) and paper two sidedness on linting in offset printing were investigated with printing trials conducted on a small commercial Heidelberg GTO-52 and a large commercial Man-Roland Uniset press.

The take-off angle at which the web exits the printing nip was found to have the largest influence on lint, with the lint weight increasing five fold when the take-off angle was increased from 27^o to 153^o. The increase in take-off angle also increased the size of particles that were removed as lint.

The maximum linting was found to occur at a print coverage of 25%. The lint produced was approximately independent of ink tack when tack ranged from 4 to 9. However lint increased when the ink tack was increased to 13.5.

INTRODUCTION

Linting is considered to be one of the more serious paper related problems in the offset printing of newsprint *(1, 2)*. It is defined as the tendency of the fibres and fines to be removed from the surface of paper and accumulate on the blanket and in the ink and fountain solution trains.

Lint primarily consists of three different classes, which can be picked up from the surface during printing. Firstly, lint consists of particles, which are not bonded to the surface at all. Their origin is mainly in the slitting of the web into reels. These particles are referred to as "dust". Thereafter there are particles that are weakly bound. The better their anchorage in the surface the later in the printing process they are removed. These are classified as "lint". Finally there are fibres, which are bound in the surface but which because of moistening lose their binding ability. This phenomenon is described as water-induced linting or "wet-pick" *(3)*. The terms “dust” and “linting” have been sometimes used interchangeably in the literature. The composition of lint has changed over the years from stiff, unfibrillated fibres *(4)* to deposits dominated by ray cells and fines *(5)*. Recently, filler *(6)* and fines have become more significant components of lint.

Offset processes are especially prone to linting problems because of the tackiness of inks and the use of multicolour printing places greater stress on the surface of sheets. Studies have shown that the application of higher surface forces in printing is generally associated with the removal of larger particles as lint *(2)*.

The offset lint problem usually manifests itself when loosely bound material is removed by tacky inks when the ink film splits at the exit of the printing nip. This material can then deposit in a layer on the surface of the offset blanket or it can travel further back into the printing process and contaminate the plate and the ink and fountain solution trains, causing additional print quality issues *(7)*. Linting reduces image quality when the build-up of lint deposits on the blanket is non-uniform. This is more likely to occur as the lint particle size increases.

A close examination of the composition of lint reveals four different types of particles - fines and ray cells, fibre fragments, shives and filler particles. Improvements in equipment and processes have led to a decrease in the amount of fibres and shives, whereas the amount of ray cells has relatively remained constant. Thus the size of lint has decreased over the years. However, irrespective of the size, the common characteristic is their low bonding potential *(8)*.

Linting can be affected by both printing and papermaking variables. In this paper, we will mainly be discussing printing press variables, but we will also consider the effect of the two sidedness of the paper. Parameters that have been discussed before in the literature include printing speed, two sidedness, ink tack and viscosity, ink level, fountain solution consumption, take-off angle, print tone and ruling.

The effect of sidedness is heavily related to the type of former used to produce the paper. A gap former produces paper with less two sidedness compared to a Fourdrinier machine *(3)*.

Linting has been generally observed to increase with the increasing ink tack and viscosity *(3, 9)*. However, the actual magnitude of the lint increase is often not specified, and the accuracy of the measurement is debatable. Some studies from trials in commercial presses have reported an increase in the lint on the blanket with increasing print density, while others have not. This may be explained by the difficulties of controlling the water-ink balance *(3)*.

It is generally accepted that linting increases with printing speed *(3, 9)*. It has also been suggested that at slow printing speeds, ink tack is mainly related to filament elongation, while at high printing speeds ink tack is related to the maximum force transferred to the paper surface before ink splitting *(3, 9)*. This mechanism is believed to be more relevant to the high speed presses generally used to offset print newspapers.

The use of more fountain solution is known to decrease the amount of lint. Increasing the fountain flow to the plate reduces lint build-up on the blanket in both the non-printing area and half-tone, while not affecting the solid area lint *(3)*. It has also been reported that increasing the fountain solution flow will decrease lint only on the first printing unit, with little effect in the subsequent units *(9)*. However increasing the fountain solution flow on the second and subsequent printing units will be effective in reducing back-trap lint, which is lint that has migrated from the first printing station.

It is known that the tone percentage in the plate has a very strong effect on the lint. One researcher reported that maximum lint accumulation is between 33% and 67% tone value and when the inking level is increased, the maximum in linting is shifted towards a higher tone *(3)*. Another researcher reported that the maximum lint results occurs at some ink level and at 50% tone *(9)*. We have conducted trials on large commercial presses and found that the maximum lint with printing tone ranged from 10 to 50% tone, depending on the trial.

The effect of screen ruling on linting has also been debated with Parker and Lebel in Hoc *(3)* claimed that there was no effect between 65 to 100 lpi on linting. However Larsson and Trollsa in Hoc *(3)* claimed that linting increased linearly with screen ruling between 65 to 100 lpi, independently of tone value .

It is believed that take-off angle has a strong effect on lint. The paper side printed at a lower take-off angle, because it is partially wrapped around the blanket cylinder, causes less lint accumulation than the opposite side *(3, 9)*.

Recently we reported a method of analysing lint deposits by brushing the lint particles in suspension from the printing blanket, filtering the particles to separate them from the suspension and then measuring particle area and shape with microscopy and image analysis *(10)*. In this paper, we have used this technique, together with measuring the weight of lint deposited per unit area with tape pulls, to investigate the influence of press variables such as take-off angle and ink tack on the lint deposits.

EXPERIMENTAL

Printing trials

Two sets of offset lithographic printing trials were done. The first set of trials was done in a large commercial printing press. This was a Man-Roland Uniset (Figure 1), a web-fed press with a maximum speed of 30,000 copies/hour. It is capable of 4-colour printing and can print a maximum of 96 newspaper pages.

Figure 1. Man-Roland Uniset Large Commercial Press

The first trial was performed to investigate the effects of print take-off angle, ink tack, print tone and the two sidedness of the paper. For this trial only one colour printing was done and only a 100 lpi ruling was used with a speed of 25,000 copies per hour.

Separate lint measurements were made at 0%, 25%, 50%, 75%, 100% screen tone after 25,000 copies had been printed for each of the different inks listed in table 1. In order to test two-sidedness of the paper as well as the effect of print take-off angle, the measurements described above were duplicated on two printing units, which are shown in Figures 2 and 3.

In Figures 2 and 3, the vertical line indicates the orientation that the paper would have if the take-off angle for both sides was the same at 90°. The angled lines on these two figures indicate the actual path of the paper on the two printing units. In both figures, the left hand side of the machine is the bottom side of the paper (BS), while the right hand side of the machine is the top side of the paper (TS).

For the paper that was run through the bottom printing unit (Fig.2), the take off angle for the bottom side of the paper was 153° measured from the horizontal axis, while for the top printing unit (Fig.3), the bottom side of the paper had a take-off angle of 78°. In each case, the take off angle of the top side is then 180°- the bottom side take off angle.

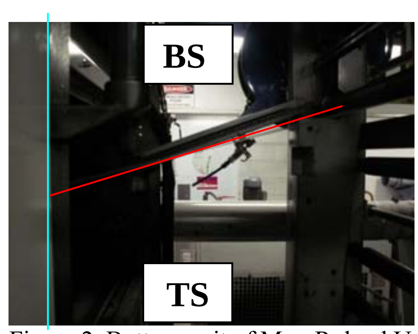

Figure 2. Bottom unit of Man-Roland Uniset

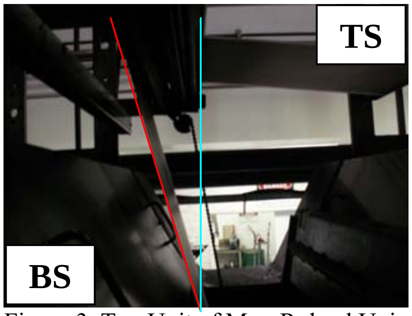

Figure 3. Top Unit of Man-Roland Uniset


Figure 4. Heidelberg GTO-52 in Norske-Skog, Tasmania

The second set of the trials was performed using a Heidelberg GTO-52 (Figure 4), a sheet-fed offset lithography printing machine that can run a maximum size of A3. In this small commercial trial a speed of 8000 copies per hour and a nip pressure of around 6 MPa was used, together with the printing plate shown in figure 5. The plate is of A3 size, with a solid in the top half and a 50% tone at 150 lines per inch in the bottom half of the plate.

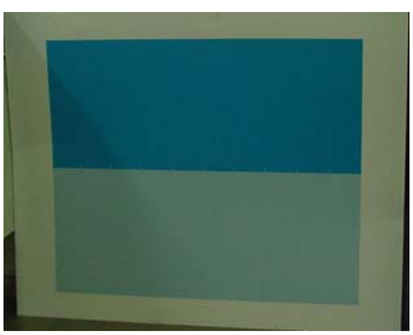
Figure 5. Standard printing plate used in Heidelberg GTO-52

To start up the machine, ink and water were run for a period of 60 seconds in order to achieve stable emulsification. The volume of fountain solution used (5% fountain solution in distilled water) was measured during printing by recording the volume of fountain solution in a measuring cylinder, which acted as the reservoir for the fountain solution. A print density of 1.0 was targeted for each trial. This was controlled by measuring the print density with a Gretag Densitometer and by adjusting the ink sweep speed and ink duct opening based on the results. Every 500th copy of printed paper was also weighed to estimate how much ink was printed on the paper. A moisture meter was also used to monitor the relative amount of water on the plate during printing. For each trial, lint was collected after 7000 impressions.

Trials were conducted to examine the effect of ink tack and screen tone and in order to compare how these measurements with the results obtained from the large commercial press trial.

Inks and Paper

Several black coldset inks were used for the trials. These are listed in Table 1. The inks used were from two different manufacturers. The tack values were measured by the manufacturer and confirmed in our laboratory on a Thwing-Albert Electronic Inkometer operating at a water bath temperature of 32.2°C and a speed of 800 rpm.

The paper tested for all trials was Norstar, an improved newsprint with a brightness of ISO 74, produced by Norske-Skog Boyer, Australia.

Trial	Colour	Brand	Tack
Heidelberg GTO-52 Man-Roland Uniset	Black	A	4
Heidelberg GTO-52	Black	A	6
Heidelberg GTO-52 Man-Roland Uniset	Black	A	9
Heidelberg GTO-52 Man-Roland Uniset	Black	A	13.5
Heidelberg GTO-52 Prüfbau Deltack	Black	B	13.5

Table 1. Inks used for Heidelberg GTO-52 and Man-Roland Uniset Trials.

Sample Collection and Preparation

For each printing trial, lint was collected from the printing blanket in two ways. In the first method, tape with a known area was adhered to the blanket with a roller before being pulled off, removing the lint on the blanket as well as any residual ink. The weight of the tape before and after lint collection was noted so that the lint weight per unit area of blanket could be calculated.

The second method of collecting lint was by washing the blanket with a brush and using a Domtar lint collector, a tray that is held firmly against the offset blanket area when taking the sample. To collect the samples, the lint and the ink within the area were brushed from the blanket using 5% aqueous iso-propanol solution. For good removal, the blanket needs to be washed rigorously. After each lint collection, tape was also used to check how much lint was still left in the blanket. It was found that around 10% of the sample weight was still left on the blanket. However, almost all the leftover sample was ink instead of lint. Repeat measurements on Heidelberg printing trials have shown that the reproducibility of the both measurement methods is ±15% *(11)*.

Samples washed from the printing blanket were topped up with water to 100 ml to simplify the calculations. Half of the sample was drained through filter paper, which was then weighed to estimate the grams per square metre of lint. 1 mLof the remaining sample was then diluted with distilled water, stirred and then filtered through a glass filter, dried and then analysed by light microscope and image analysis.

An Olympus BX 60 light microscope was used with 50 times magnification to capture images of the lint. For each sample, 20 images were captured. A typical image is shown in Figure 6. Prior to capturing the images, a white balance operation was performed using a clean glass fibre filter paper. Each of the images covers 7.632mm^2 out of 1134.119 mm^2 of the total glass filter area.

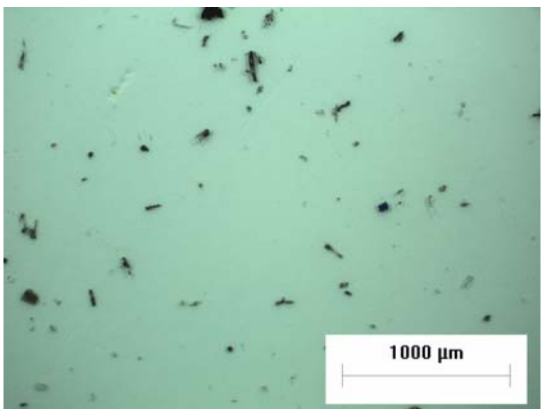

Fig 6. Typical image of lint particles on filter paper.

Image analysis

The images were then analysed using Image Pro 4.5. A manual threshold was applied to each image to select the lint particles. The area, length, width and roundness of each particle were measured for each lint particle. The lint particles were then sorted according to area and grouped into 16 classes. The classes are listed in Table 2. The number of classes was limited to 16 as this was the maximum allowed by the software. The last class in the list covers a much wider area range than the others. This was because there are very few large particles. Even with the extended range, these large particles still occur at a rate of much less than 1 particle per image measured.

Class	Min Area (µm^2)	Max Area (µm^2)
1	0	1,000
2	1,000	2,000
3	2,000	3,000
4	3,000	4,000
5	4,000	5,000
6	5,000	6,000
7	6,000	7,000
8	7,000	8,000
9	8,000	9,000
10	9,000	10,000
11	10,000	11,000
12	11,000	12,000
13	12,000	13,000
14	13,000	14,000
15	14,000	15,000
16	15,000	100,000

Table 2. Particle classes for image analysis

RESULTS AND DISCUSSION

The first series of trials were done on the Man-Roland Uniset, as described in the experimental method. In these trials, 0%, 25%, 50%, 75% and 100% screen tones and 100 lpi screen ruling were used. Black coldset inks with tack 4, 9, 13.5 were separately tested with a speed of 25,000 copies per hour. The measurements were duplicated in the top and bottom print couple that had different take-off angles for the top and bottom sides by virtue of the web leads that were selected.

After the trial was done, an ANOVA analysis was applied to all experimental results using the Systat statistical analysis package. The outcome is shown in table 3. The most significant factors influencing the lint are highlighted in bold. In this table, 'side' means whether the trial paper was printed on the top or bottom side. 'Print couple' means the top or bottom print couple of the press (Figures 2 and 3), each of which has a different take-off angle. 'Screen' means the screen tone, i.e. 0%, 25%, 50%, 75% or 100% and tack refers to the ink tack.

Source	Sum-of-Squares	df	Mean-Square	F-ratio
TACK	**10.148103**	**2**	**5.07405**	**7.607377**
SIDE	**26.427207**	**1**	**26.4272**	**39.621535**
PRINTCOUPLE	**9.809127**	**1**	**9.80913**	**14.706536**
SCREEN	**43.291557**	**4**	**10.8229**	**16.226439**
TACK*SIDE	15.073463	2	7.53673	11.29960074
TACK*PRINTCOUP	8.923763	2	4.46188	6.689568525
TACK*SCREEN	11.641663	8	1.45521	2.181750578
SIDE*PRINTCOUP	**180.47473**	**1**	**180.475**	**270.58045**
SIDE*SCREEN	13.235743	4	3.30894	4.960990478
PRINTCOUP*SCREEN	8.710023	4	2.17751	3.264670738
TACK*SIDE*PRINTCOUP	3.614803	2	1.8074	2.70978469
TACK*SIDE*SCREEN	6.978937	8	0.87237	1.3079142
TACK*PRINTCOUP*SCREEN	7.911137	8	0.98889	1.482616707
SIDE*PRINTCOUP*SCREEN	9.78169	4	2.44542	3.66635082
ERROR	5.33593	8	0.66699	1

Table 3. ANOVA using Systat of Man-Roland Uniset trial results.

From the statistical analysis shown in Table 3, the most significant printing parameter affecting lint results was the two way interaction of side*print couple, followed by side, coverage, print couple, and tack. The effects of side and print couple will be discussed first.

Effect of Take-off Angle, Paper Side and Print Couple

Figure 7 shows the effect of side and take-off angle. These results were generated by averaging all of the data obtained for each take off angle and paper side. Thus each point shown here is the average of fifteen data points as five different screen tones and three different ink tacks were tested for each combination of take-off angle and paper side. The critical importance of these two factors acting together is indicated as the highest average lint result (bottom side with take off angle of 153°) is approximately five times the smallest average lint result (top side with take off angle of 27°).

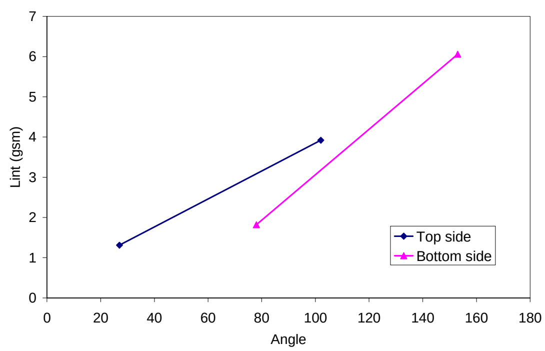

Figure 7. Effect of Paper Side and Take-Off Angle on Linting

The distributions of the sizes of the lint particles are shown for the highest lint (Bottom side and 153° take off angle) and lowest lint (Top side with 27° take off angle) in Figures 8 and 9, respectively. The total % area sums to 100. Figures 8, 9, and 11 show the size distributions for the lint distributions obtained at different screen tones with the tack 4 ink.

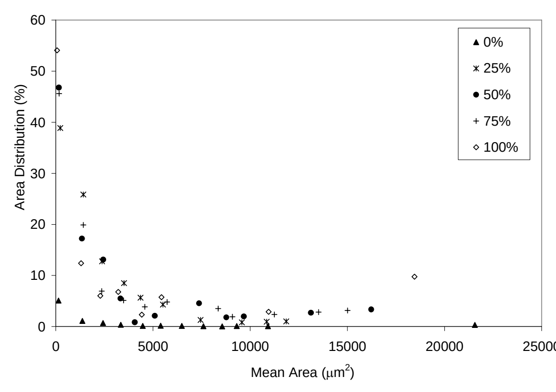

Figure 8 Man-Roland Uniset. Lint Area Distributions of Different Screen Tone- top side printed with 27° take off angle and tack 4 ink.

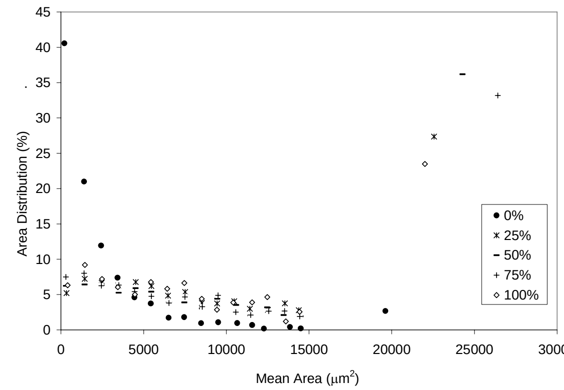

Figure 9 Man-Roland Uniset. Lint Area Distribution of Different Screen Tones- bottom side printed with 153° take-off angle and tack 4 ink.

Figures 8 and 9 show that the high take-off angle has produced much larger lint. For the data collected at 27° take-off angle, nearly half of the total area of lint is in the smallest size class, while for the highest take-off angle, the largest area class contains by far the most lint, except for the non-image area (0% print tone) lint.

The side with the higher take-off angle has a higher rate at which the blanket surface and the paper will separate coming out of the printing nip, provided all other press variables are constant. It seems likely that the change in the take-off angle increased the force imposed on the surface, which in turn increased the amount of lint and the size of the lint particles.

This hypothesis was tested using a Prüfbau Deltack with an ultra-low force sensor with a range of 0.2-1.4N. This is an instrument that measures the force required to split the ink film at the exit of the printing nip. While the printing nip configuration is fixed in the instrument, it is possible to simulate a change in take off angle by altering the speed at which the tests are conducted. A sample set of results are shown in Table 4. All of these measurements were conducted using 0.1 mL of the black tack 13.5 ink from manufacturer B, listed in Table 1.

Print Speed	Tack Force (N)		
	Roll A	Roll B	Roll C
0.5	0.43	0.39	0.38
1.0	0.72	0.63	0.69
1.5	1.08	0.90	0.89
2.0	1.33	1.21	1.05

Table 4. Effect of Printing Speed on average Tack Force measured by the Deltack for printing 52 gsm Norstar

The Deltack experiments showed that the tack force required to split the free ink film was strongly related to the print speed. The increase in tack force with print speed arises both from an increase in the force required to split the ink film, as speed increases, as well as an increase in the thickness of the ink film that is split. The ink film thickness increases at higher speeds as the printing cylinder has less time in contact with the paper and thus less ink will enter the pores, leaving a thicker free ink film requiring more force to split. Measurements made on the Deltack have shown that the tack force increases as more ink is used for printing, but all other conditions are held constant.

On any given press, the ink-film splitting rate will depend on the diameter of the printing rollers, the rotational speed as well as the take-off angle itself.

The effect of the paper side is difficult to separate completely from the effect of the take-off angle, as no measurements were made of linting for the same take-off angle for both sides. For this set of data it does appear likely that the top side of the paper is giving more lint than the bottom side, however the design of this experiment does not allow this effect to be quantified.

The paper tested was produced on a horizontal gap former, which is known to produce a sheet with some two-sidedness. However, it is not clear what the differences are between the top and bottom surfaces of the sheet produced by this former, which have caused these differences in linting.

Effect of Ink Coverage (Printing Tone)

Figure 10 shows the effect of printing tone for the Man Roland Uniset trial. Each data point is the average of the lint measurements obtained for the combined set of three ink tacks and two print couples. For comparison, results are also shown from a series of measurements with different ink coverage made on the Heidelberg press. These measurements were for printing the bottom side of the Norstar paper that was tested. Please note that only 7000 copies were printed for Heidelberg compared with 25,000 for the Man-Roland and that different batches of Norstar were printed in the two sets of trials.

All 3 data sets show identical trends, with the 25% tone always yielding the highest lint regardless of the test. The blank (0%) and solid (100%) gave lowest lint for both results from Man-Roland and Heidelberg.

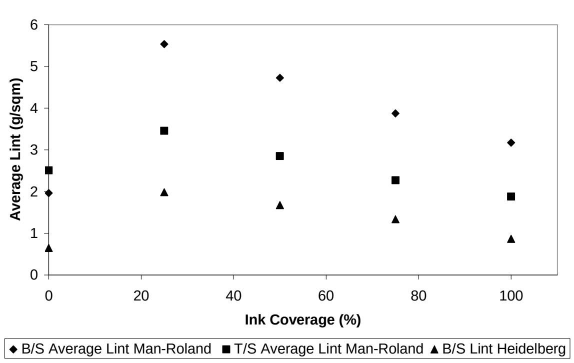

Figure 10. The Effect of Ink Coverage on Linting

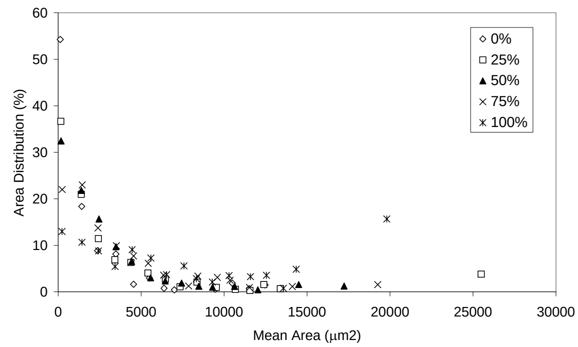

Figure 11. Heidelberg Lint Area Distribution of Different Screen Tone- Norstar 52 gsm, bottom side, tack 4.

Figure 11 shows the lint distributions measured for different screen areas for the Heidelberg test experiments. These can then be compared with the size distributions produced in the Man Roland Uniset, for the take-off angles of 27° and 153° shown in Figures 8 and 9. The data in these figures show that the size distributions of lint produced by the Heidelberg sit between those produced at 27° and 153° on the Man-Roland Uniset. The Heidelberg produces lint distributions in which the smallest lint particles still comprise the largest percentage of the total area, but in which there are some lint particles in the largest area class. This is consistent with the estimated take-off angle of the Heidelberg press of 70°.

There was no trend that could be discerned in Figures 8, 9 and 11 with respect to the size of the lint particles and ink coverage.

Effect on Ink Tack

Figure 12 shows the effect of ink tack on the lint measured after printing either with 50% or 100% screen. Results are shown for both the Heidelberg GTO-52 sheet-fed press and the Man-Roland Uniset commercial web-fed press. The Man Roland Uniset results are the average of all measurements that were done at 50% screen tone.

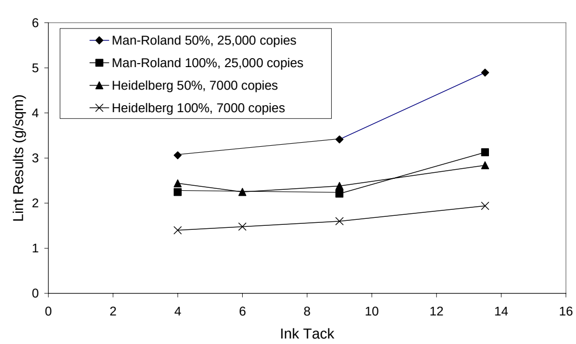

Figure 12. The Effect of Ink Tack between Heidelberg and Man-Roland Trial towards Linting

Figure 12 shows general agreement between the Heidelberg and Man-Roland trials. There is very little change in the amount of lint, when the ink tack was either

4, 6 or 9. However, tack 13.5 ink produced higher lint compared to the lower tack inks.

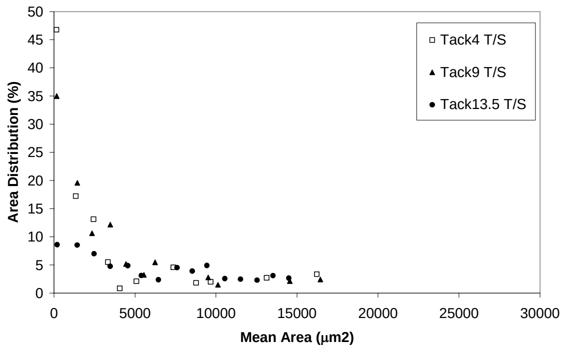

Figure 13. Man-Roland Uniset Lint Area Distribution as a function of ink tack at 50% Printing Tone at a 27° degree take-off angle

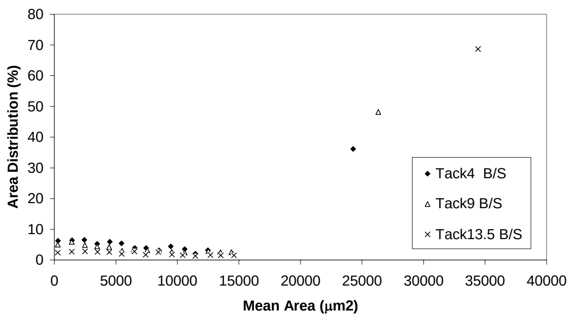

Figure 14. Man-Roland Uniset Lint Area Distribution as a function of ink tack at 50% Printing Tone at a 153° degree take-off angle

Figures 13 and 14 plot the lint area distributions for the lowest and highest take-off angle for 50% tone and the 3 different ink tacks that were used in the Man Roland Uniset trials. The results show relatively little difference in the shape of the area distribution between the measurements with the different tack inks. There is some suggestion for the data with the highest take-off angle of 153° that the increase in the ink tack has increased the percentage and size of the lint particles in the largest size class. However the effects are relatively small in comparison to the differences in the distributions arising from the change in take-off angle.

We are then faced with attempting to explain why the effect of ink tack has been relatively small in these results. The tack values given here were measured using an Inkometer, which measures the ink tack based on a specific rotational speed and specific temperature of the roller. The ink industry normally uses 800 rpm and 32.2°C for the temperature of the roller.

The instrument consists of three rollers. The diameter of the central brass roller is around 7.9 cm. The standard ink industry measurement condition of 800 rpm corresponds to 3.35 m/s. The standard ink weight used in the test is 1.67 grams. If we assume that the ink film splits in the middle, then the shear rate in the Inkometer is approximately $3x10^5$ s^{-1}.

To estimate the equivalent shear rate in our printing trials we note that the printing blanket diameter of Heidelberg GTO-52 is around 30 cm and the blanket roller of Man-Roland Uniset is around 40 cm. The ink film splitting thickness is of the order of a micrometre and therefore the shear rate for the two different presses can be estimated as 10^6 s^{-1} for the Heidelberg press and 10^7 s^{-1} for the Man Roland Uniset, given that the press speed is 1 m/s for the Heidelberg and 10 m/s for the Man Roland Uniset.

It is generally accepted that at high rates, inks are shear thinning, where the apparent viscosity will fall as the apparent shear rate increases. Thus it is important to perform the measurements at a shear rate that is relevant to the press under investigation. The Inkometer tack may therefore not be a good predictor of lint as rheological state of the inks are quite different in the lab instrument and in the press.

CONCLUSIONS

Various printing parameters were tested to investigate their effect towards offset lithographic printing. Heidelberg GTO-52 and Man-Roland Uniset were used to do the printing trials. ANOVA Systat was done and showed that printing take-off angle, tack, print coverage (printing tone), two sidedness of the paper were among the significant print parameters affecting linting in offset lithographic printing.

Lint increased greatly with take-off angle. The side with higher take-off angle has higher rate of ink film splitting, since the side with the higher take-off angle travels longer distance compared with those of the other side with the same amount of time. The higher rate of ink-film splitting increases the stress that is applied to the surface of the paper.

The effect of screen percentage on linting was investigated and it was determined that the maximum amount of lint accumulated at 25% screen tone.

Ink tack was found to have a relatively small effect on the amount of lint. There was no large difference in lint results between ink tack 4, 6, and 9. However tack 13.5 gave a somewhat higher result.

The small effect of ink tack was explained as arising from the nature of the measurement of ink tack. Ink is shear thinning, and the Inkometer used to determine ink tack measures tack at much lower shear rates compared to the shear rate in the printing nip of a commercial printing press.

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