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

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ABSTRACT: The effects 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 fivefold when the take-off angle was increased from 27° to 153°. The increase in take-off angle also increased the size of particles that were removed as lint. 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.

Application: Lint can be reduced by changing web leads in the press to avoid large take-off angles.

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 fibers and fines to be removed from the surface of paper and accumulate on the blanket and plate.

Lint primarily consists of two classes, which can be picked up from the surface during printing. First, lint consists of particles, which are not bonded to the surface. 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" [3]. Occasionally the terms "dust" and "lint" have been used interchangeably in the literature. The composition of lint has changed over the years from stiff, unfibrillated fibers and shives [4] to deposits dominated by ray cells and fines [5]. Recently, filler [6] and fines have become more significant components of lint. Lint occurs when material is removed as the tacky ink film splits at the exit of the printing nip. This material can then deposit on the surface of the offset blanket or it can travel further into the printing process [7]. Linting reduces image quality when the build-up of lint deposits on the blanket is nonuniform. This is more likely to occur as the lint particle size increases. Lint particles deposited on the plate can also produce visible spotting on solid tones.

Offset processes are especially prone to linting problems because of the tackiness of inks. Additionally, use of multicolor 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 removal of larger particles as lint [2].

Linting can be affected by printing and papermaking variables. In this paper, we will mainly discuss printing press variables. We will also consider the effect of the two sidedness of paper. Parameters previously discussed 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 than a fourdrinier machine [3].

Linting has been generally observed to increase with the increasing ink tack and viscosity [3, 8]. However, the actual magnitude of the lint increase is not clear. It is generally accepted that linting also increases with printing speed [3,8]. 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, 8]. This mechanism is believed to be more relevant to the high speed presses generally used to print newspapers. It is also 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 toward a higher tone [3]. Another researcher reported that the maximum lint occurs at some ink level and at 50% tone [8].

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, has less lint accumulation than the opposite side [3, 8].

Recently we reported a method of analyzing 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 [9]. 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 linting.

EXPERIMENTAL

Printing trials

Two sets of offset lithographic printing trials were done. The first set of trials was done on a large commercial printing press, the Man-Roland Uniset (**Figure 1**). This web-fed four-color press can print a maximum of 96 newspaper pages.

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. Separate lint measurements were made at 0%, 25%, 50%, 75%, 100% screen tone, at a 100 lines per inch (lpi) line ruling, after 25,000 copies had been printed for each of the black inks listed in **Table I**. The press was run at 25,000 copies an hour. To test two-sidedness of the paper as well as the effect of print take-off angle, the measurements were duplicated on two printing units, shown in **Figs. 2 and 3**. The vertical lines in these figures indicate the orientation that the paper would have if the take-off angle for both sides was 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 and right sides of the machine correspond to the bottom (BS) and top (TS) sides of the paper, respectively.

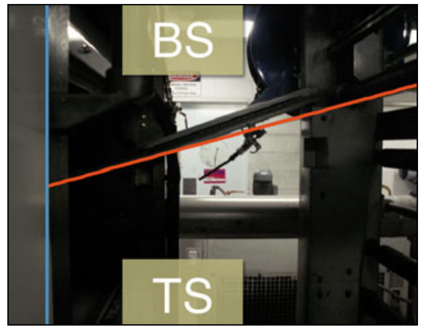
TRIAL	COLOR	BRAND	TACK
Heidelberg GTO-52 Man-Roland Uniset	Black	A	4
Heidelberg GTO-52	Black	A	6
Heidelberg GTO-52 Man-Roland Uniset	Black	A	9
Heidelberg GTO-52 Man-Roland Uniset	Black	A	13.5
Heidelberg GTO-52 Prüfbau Deltack	Black	B	13.5

I. Inks used for Heidelberg GTO-52 and Man-Roland Uniset trials.

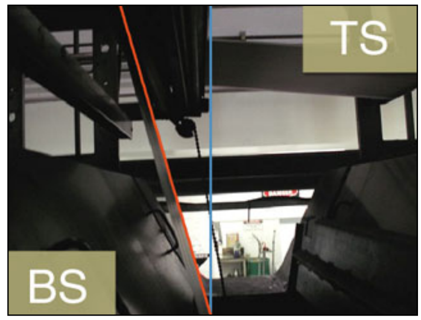
1. Man-Roland Uniset large commercial press.

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.

The second set of the trials was performed using a Heidelberg GTO-52



2. Bottom unit of Man-Roland Uniset.

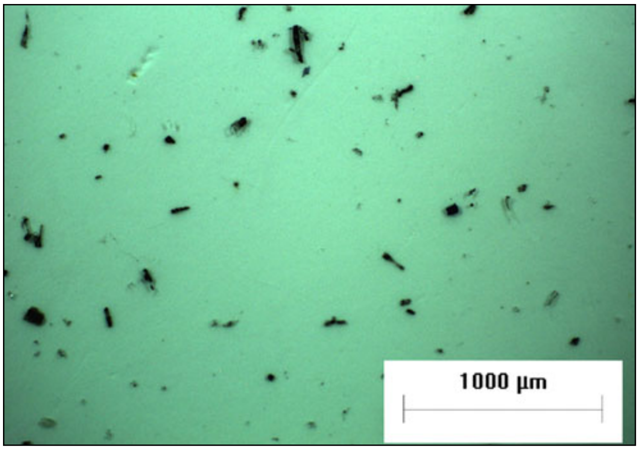


3. Top Unit of Man-Roland Uniset.

4. Heidelberg GTO-52 sheet fed press.

(**Fig. 4**), a small sheet-fed offset lithography printing machine that can run a maximum size of A3. In these trials a speed of 8,000 copies per hour and a nip pressure of 6 MPa was used, together with an A3 printing plate with solid in the top half and a tone pattern, at 150 lpi, in the bottom half of the plate.

To start up the machine, ink and water were run for a period of 60 s to achieve stable emulsification. We measured the volume of fountain solution used (5% fountain solution in distilled water) during printing by recording the volume in a measuring cylinder, which



5. Typical image of lint particles on mixed cellulose ester filter paper.

acted as the fountain solution reservoir. A print density of 1.0 was targeted for each trial. We controlled this by measuring the print density with a Gretag densitometer and 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. For each trial, lint was collected after 7000 impressions.

Trials were conducted to examine the effect of ink tack and screen tone on lint.

Inks and paper

Several black coldset inks from two manufacturers were used for the trials. These are listed in Table I. The tack values were measured by the manufacturers. For all trials, we used Norstar, an improved newsprint with a brightness of ISO 74, produced by Norske-Skog Boyer, Australia.

Sample collection and preparation

For each printing trial, we collected lint from the blanket in two ways. First, 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. In our second method of collecting lint we washed the blanket with a brush and used a Domtar lint collector, a tray held firmly against the offset blanket area when taking the sample. We used a 5% aqueous iso-propanol solution for the brushing. For good removal, the blanket needs to be washed rigorously. After each lint sample was collected, we also used tape to determine how much lint was left on the blanket. We found that around 10% of the sample weight still remained on the blanket. However, almost all the leftover sample was ink rather than lint. Repeat measurements on Heidelberg printing trials have shown that the reproducibility of the both measurement methods is ±15% [3]. Each printing plate was designed so that each printing tone area was large enough to enable collection of lint by both methods.

Samples washed from the printing blanket were topped up with water to 100 mL to simplify the calculations. One milliliter of the sample was then diluted with distilled water, stirred and filtered through a mixed cellulose ester filter, dried, and then analyzed by light microscope and image analysis.

We used an Olympus BX 60 light microscope with 50 times magnification to capture images of the lint. For each sample, 20 images were captured. A typical image is shown in **Fig. 5**. Before capturing the images, we performed a white balance operation using a clean glass fiber filter paper. Each of the images covers 7.632 mm² out of 1134.119 mm² of the total glass filter area.

Image analysis

We then analyzed the images using an analysis package called Image Pro 4.5. An automatic 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. These classes are listed in **Table II**. 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, because there are only a few very large particles. Even with the extended range, these large particles still occur at a rate of much less than one particle per image measured.

RESULTS AND DISCUSSION

For the first series of trials on the Man-Roland Uniset, our experimental matrix consisted of five screen tones (0%, 25%, 50%, 75%, and 100%), three black coldset inks with tacks 4, 9, and 13.5, replicated on two print couples with different

Class	Min Area (µm²)	Max Area (µm²)
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

II. Particle classes for image analysis.

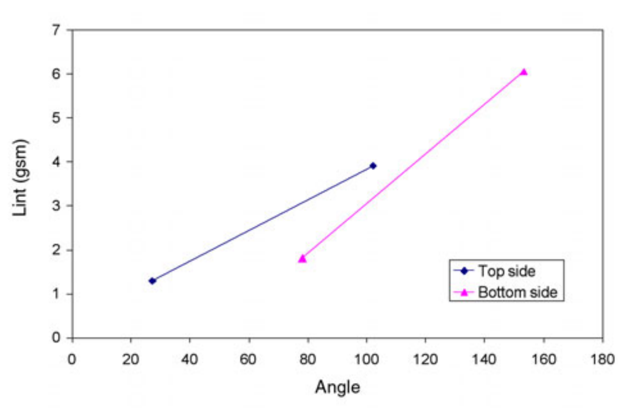
take-off angles for the top and bottom sides, for a total of 60 measurement points. After the trial was done, an ANOVA analysis was applied to all experimental results. The outcome is shown in **Table III**. The most significant factors influencing the lint are highlighted in bold. In this table, "side" 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 (Figs. 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.

From the statistical analysis, the most significant printing parameter affecting lint results was the two-way interaction of side-print couple, followed by side, screen, print couple, and tack. The effects of side and print couple will be discussed first.

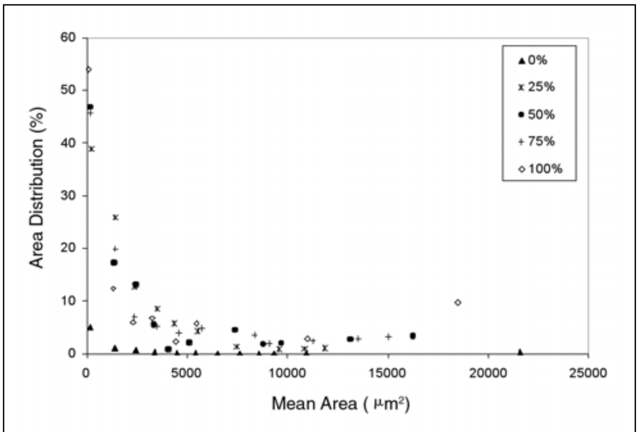
Effects of take-off angle, paper side, print couple

Figure 6 shows the effects of side and take-off angle. These results were generated by averaging all data obtained for each take-off angle and paper side. Thus each point shown here is the average of 15 data points. 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°).

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 **Figs. 7 and 8,** respectively. These figures show the results of the different screen tones when printing with tack 4 ink. The total percent area adds up to 100%. **Figure 10** shows the comparable size distributions obtained on the Heidelberg press after printing with the same ink.



6. Effect of paper side and take-off angle on linting



7. Man-Roland Uniset. Lint area distributions of different screen tone - top side printed with 27° take-off angle and tack 4 ink.

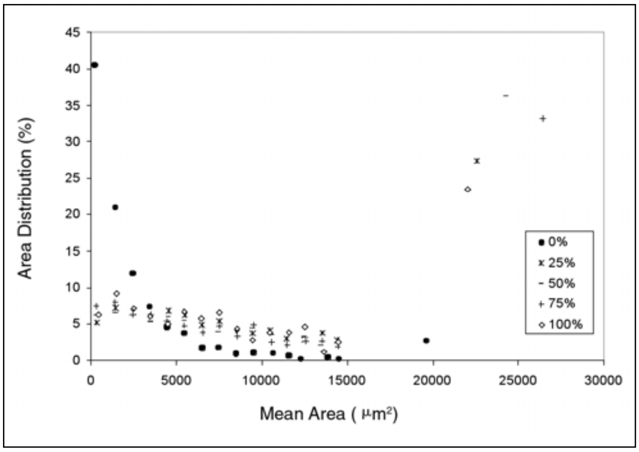
Source	Sum-of-Squares	df	Mean-Square	F-ratio
TACK	**10.15**	**2**	**5.07**	**7.61**
SIDE	**26.43**	**1**	**26.43**	**39.62**
PRINTCOUPLE	**9.81**	**1**	**9.81**	**14.71**
SCREEN	**43.29**	**4**	**10.82**	**16.23**
TACK*SIDE	15.07	2	7.54	11.30
TACK*PRINTCOUP	8.92	2	4.46	6.69
TACK*SCREEN	11.64	8	1.45	2.18
SIDE*PRINTCOUP	**180.47**	**1**	**180.46**	**270.58**
SIDE*SCREEN	13.24	4	3.31	4.96
PRINTCOUP*SCREEN	8.71	4	2.18	3.26
TACK*SIDE*PRINTCOUP	3.61	2	1.80	2.71
TACK*SIDE*SCREEN	6.98	8	0.87	1.31
TACK*PRINTCOUP*SCREEN	7.91	8	0.99	1.48
SIDE*PRINTCOUP*SCREEN	9.78	4	2.45	3.67
ERROR	5.34	8	0.67	1

III. ANOVA using Systat of Man-Roland Uniset trial results.

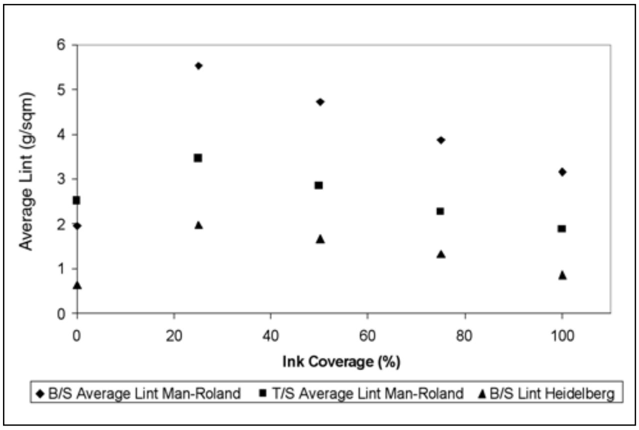
Figures 7 and 8 show that the high take-off angle has produced much larger lint. For the lint collected at 27° take-off angle, nearly half of the total area of lint is in the smallest size class, while for the 153° take-off angle the largest area class contains by far the most lint, except for the non-image area (0% print tone) lint.

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

We tested this hypothesis using a Prüfbau Deltack, an instrument that measures the force required to split the ink film at the exit point of the printing nip. While the printing nip configuration is fixed in the instrument, it is possible to simulate



8. Man-Roland Uniset. Lint area distribution of different screen tones – bottom side printed with 153° take-off angle and tack 4 ink.



9. Effect of ink coverage on linting.

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 IV**. All measurements were conducted using 0.1 mL of the black tack 13.5 ink from manufacturer B, listed in Table I.

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 from an increase in the force required to split the ink film,

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

IV. Effect of printing speed on average tack force measured by the Deltack for printing 52 gsm Norstar newsprint.

as well as an increase in the thickness of the ink film. The ink film thickness increases at higher speeds as the printing cylinder has less time in contact with the paper. Thus less ink will enter the paper 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 and 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 we made no measurements of linting for the same take-off angle for both sides. For this set of data, it does appear that the top side of the paper is linting more freely than the bottom side, but 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 differences exist between the top and bottom surfaces of the sheet from this paper machine.

Effect of ink coverage (printing tone)

Figure 9 shows the effect of printing tone for the Man Roland Uniset and Heidelberg trials.. Each data point from the Man Roland Uniset trial is the average of the lint measurements obtained for the combined set of three ink tacks and two print couples. In the Heidelberg trials only the bottom side of the paper was tested. Note that only 7,000 copies were printed for the Heidelberg trials compared with 25,000 copies for the Man-Roland trials. Also note that different batches of Norstar were printed in the two sets of trials.

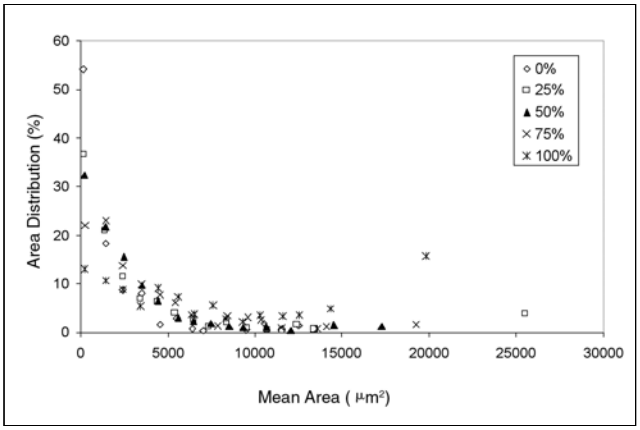
All three data sets show identical trends, with the 25% tone always yielding the highest lint regardless of the test. The blank (0%) and solid (100%) gave the lowest lint for all three data sets.

Figure 10 shows lint distributions measured for different screen areas for the Heidelberg test experiments. These can be compared with size distributions produced in the Man Roland Uniset, for the take-off angles of 27° and 153° shown in **Figs. 7 and 8**. 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°.

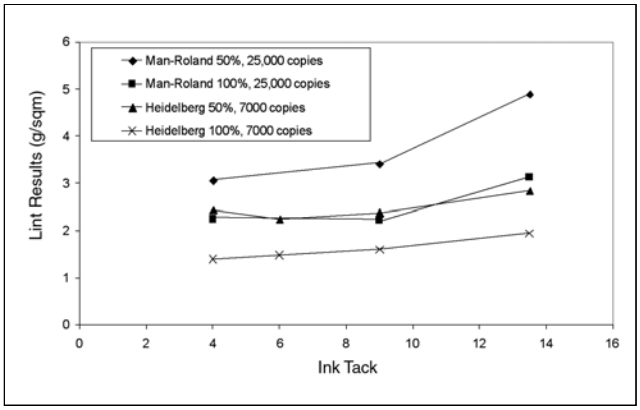
We could not discern a trend in Figs. 7, 8, and 10 with respect to the size of the lint particles and screen tone.

Effect on ink tack

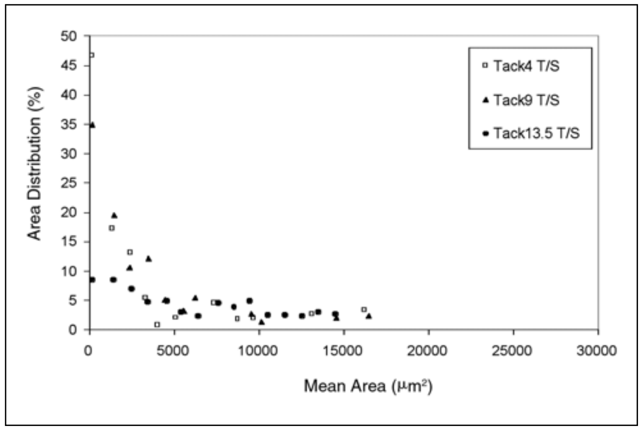
Figure 11 shows the effect of ink tack on the lint measured



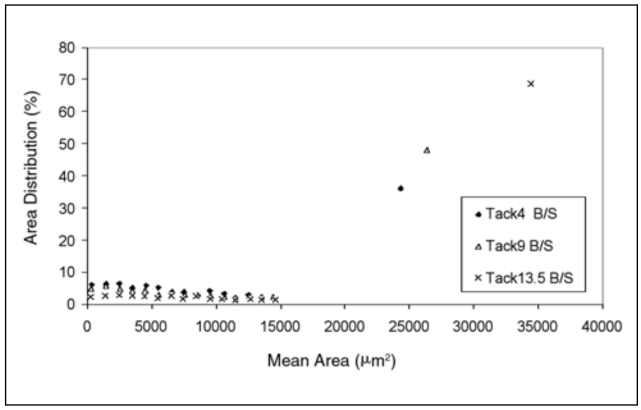
10. ***Heidelberg lint area distribution of different screen tone – 52 gsm improved newsprint, bottom side, tack 4.***



11. ***Effect on linting of ink tack between Heidelberg and Man-Roland trial.***



12. ***Man-Roland Uniset lint area distribution as a function of ink tack at 50% printing tone at a 27° take-off angle.***



13. ***Man-Roland Uniset lint area distribution as a function of ink tack at 50% printing tone at a 153° take-off angle.***

after printing with 50% or 100% screen. Results are shown for 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 the given screen tone.

Figure 11 shows general agreement between the Heidelberg and Man-Roland trials. There is little change in the amount of lint, when the ink tack was 4, 6, or 9. However, tack 13.5 ink produced higher lint, compared with the lower tack inks.

Figure 12 and **Fig. 13** plot the lint area distributions for the lowest and highest take-off angle for 50% tone and the three 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 in 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 compared with 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 equivalent shear rate in our printing trials, we note the printing blanket diameter of the Heidelberg GTO-52 is about 30 cm and the blanket roller of the Man-Roland Uniset is about 40 cm. Ink film splitting thickness is of the order of a micrometer and the shear rate for the two presses can be estimated at 10^6 s^{-1} for the Heidelberg press and 10^7 s^{-1} for the Man-Roland Uniset, given 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 relevant to the press under investigation. The Inkometer tack may therefore not be a good predictor of lint as the 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 effects on offset lithographic printing. A Heidelberg GTO-52 and A Man-Roland Uniset were used to do printing trials. ANOVA Systat was done, showing that printing take-off angle, tack, print coverage (tone), two sidedness of the paper were among the significant print parameters affecting linting in offset lithographic printing.

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

We investigated the effect of screen percentage on linting and determined 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. We found no large difference in lint results between ink tack 4, 6, and 9. However the tack 13.5 gave a somewhat higher result.

The effect of ink tack was probably small because ink is shear thinning, and the Inkometer used to determine ink tack measures tack at much lower shear rates compared with the shear rate in the printing nip of the presses tested here. **TJ**

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INSIGHTS FROM THE AUTHORS


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Linting is an important quality issue in printing of newsprint. Understanding the factors that can affect linting is significant to newsprint manufacturers, one of whom supported this research.

The work described here is part of a larger ongoing project examining the most important printing press variables affecting linting.

The most difficult aspect of our research was to develop a method of reliably preparing lint particles for image analysis—imaging the particles and measuring their size and area.

Our most surprising finding was that take-off angle had a very large effect on linting, while ink tack did not. The next step will be to explain why ink tack does not have a strong effect on linting.

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