Comparison of size distributions of lint particles from different printing operations

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ABSTRACT

Linting is the removal of material from the surface of newsprint grades during offset printing. Excessive linting leads to a reduction in image quality and can reduce press productivity. In this paper, the length and size distributions of lint from a large four-colour commercial web offset press, a small single-colour commercial sheet fed offset press and a laboratory pick test were measured. The lint removed on the large commercial press at the first colour was smaller in both area and length than at application of the last colour. The lint removed in the last printing station of the large commercial press had similar distributions in area and length to the lint removed in the small commercial printing press. The area and length of the lint removed in the small commercial press did not depend on the tack of the ink. As was expected, the pick test removed far more lint than either commercial press. The length and area of the lint was also far larger than the material removed as lint on the commercial press. This disparity between the size distributions of the lint produced in the commercial and laboratory pick test suggests that the results of the pick test cannot be assumed automatically to be relevant to linting in commercial offset printing.

KEYWORDS

Offset printing, lint, particle size, laboratory printing, image analysis, newsprint, improved newsprint

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 to accumulate on the blanket and plate.

Lint primarily consists of three different derivatives, which can be removed from the surface during printing. First the lint consists of particles, which are not bonded to the surface at all. Their origin is mainly from 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 paper. 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 (*7*).

Linting causes a deterioration in 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. Lint can also travel from the blanket onto the plates and back into the ink and fountain solution trains, causing additional print quality issues.

A close examination of the composition of lint reveals four different types of particles - 'Fines' or ray cells, fibre fragments of all sizes, 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*).

Despite considerable effort over a number of years, there is no easy means of predicting the linting propensity of a given paper in a particular press. Methods that can be used to characterise linting can be divided into laboratory tests, such as the IGT pick test (or other measurements of surface strength) and actual trial printing runs. Lindem and Moller (*7*) investigated both types of methods as they used a small Heidelberg offset press and IGT pick tests as predictive trials for lint by comparing the quantity of lint and the composition of lint. None of the methods for predicting lint seemed to correlate well with each other. No attempt to measure the type and dimensions of the lint material was made in their study.

The purpose of this work is to compare quantitatively the differences between commercial and laboratory printing, by examining how the nature of lint changes with the printing process going from small scale to large scale. Lint collected from two pressrooms, a Heidelberg GTO-52 single colour offset press, used as a quality control test, and a large four colour web offset press will be compared to the lint obtained from pick experiments using an IGT Printability tester.

EXPERIMENTAL

Printing trials

Two sets of offset lithographic printing trials were done. The first was done on a small commercial printing press, a Heidelberg GTO-52 at Norske-Skog Research and Development in Boyer, Tasmania.

These printing trials were performed at 50% relative humidity and 25°C using Norstar 52gsm improved newsprint produced by Norske-Skog at Boyer. The

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paper was printed on A3 sheets. There were two printing areas in the plate of solid and 50% tone at 155 lpi. The data presented in this paper was collected from the 50% tone printed area. The nip printing pressure was 8.1 MPa. The fountain solution used was 2% Alcofix. The press was run at 8000 impressions per hour.

Both cyan and black coldset inks were used for the trials. The inks used were from several different manufacturers. The tack values were measured on a Thwing-Albert Electronic Inkometer operating at a water bath temperature of 32.2°C and a speed of 800 rpm and are listed in Table 3. For each trial, lint was collected after 7000 impressions.

The second set of trials was performed on a large 4-colour Man-Roland Geoman press running at approximately 10ms^{-1} and 137,000 copies were printed. The paper was Nornews 45 gsm. The paper was printed coldset in a 4-colour tower unit in the sequence cyan, magenta, yellow and black. The inks were commercially available newsprint inks with tacks listed in Table 3. Lint samples were collected from the blankets in contact with both the top and bottom sides of the paper. Full-colour images were selected from both the top and bottom sides of the paper. Samples were taken from the same position on the blanket for the different colours.

Sample Collection and Preparation

For each printing trial, lint was collected from the printing blanket by washing the blanket using a Domtar lint collector. This collector is a tray that is held firmly against the offset blanket area when sampling was done. To collect the samples, the lint and the ink within the area were collected by washing and brushing the blanket with 5% aqueous iso-propanol solution. For good removal, the blanket needs to be washed rigorously.

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 with 0.45 µm pores, which was weighed to estimate the grams per square metre of lint. 1 ml of the remaining sample was then diluted with distilled water, stirred and then filtered through a glass filter, dried and analysed by light microscope and image analysis. This process is explained below.

An Olympus BX 60 light microscope was used with 5 times magnification to capture images of the lint. For each sample, 20 images were captured. A typical image is shown in Figure 1. Prior to capturing the images, a white balance operation was performed using a clear glass paper. Each of the images covers 7.6 mm^2 out of 1134 mm^2 of the total glass filter area.

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 based on their area. The classes are listed in Table 1.

Table 1.
Particle classes for image analysis

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

The number of classes was limited to 16 due to software limitations. 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.

IGT Pick Experiments

The IGT pick experiments were performed using the IGT printability tester AIC2-5 at the National Printing Laboratory, Monash University following a modified ISO 3783 method.

Six unique samples of Norstar 52 gsm improved newsprint from Norske-Skog,

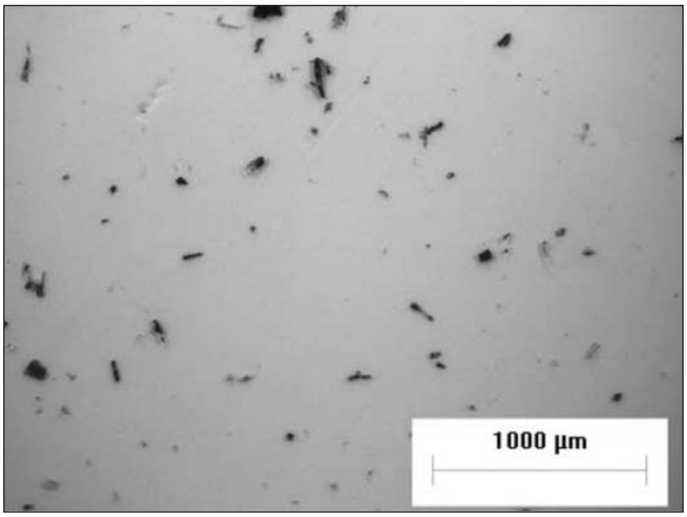

Fig. 1 Typical image of lint particles on filter paper.

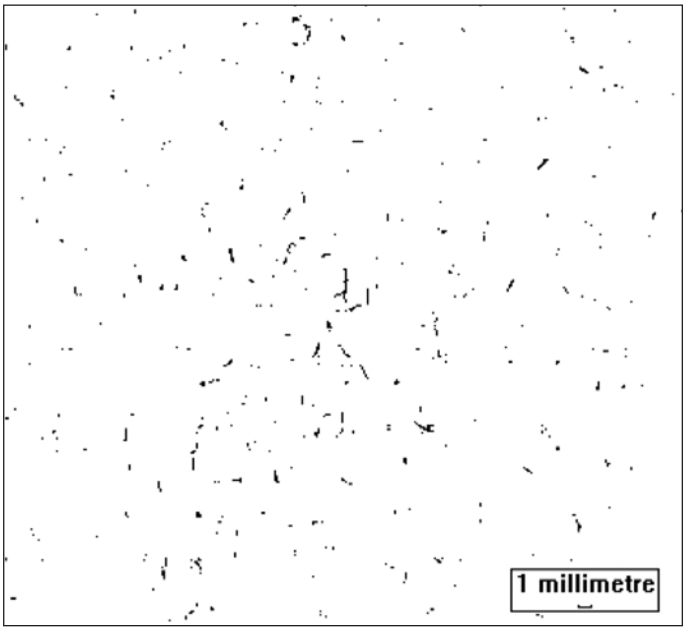

Fig. 2 Typical scanned image of IGT printed paper showing picked fibres (to show picked fibres, the colour image was converted to grey scale, inverted and then converted to black and white).

Boyer mill were tested on the top side and bottom side with 3 replicates for each sample. In the results that follow, these samples are labelled B1-B6. These samples were from different batches than were tested in the trials on the Heidelberg printing press.

Paper samples were cut into strips of 340 mm x 55 mm and mounted on the printing sector of the IGT printing unit. The papers were printed using an IGT 408002 normal tack ink. An ink volume of 0.2 ml was applied to the inking rollers of the IGT inking unit. After the ink was evenly distributed on the inking rollers the 50 mm wide rubber printing disc was brought into contact with the inking rollers. Next, the inked disc was placed on the printing unit against the paper sample and the printing was done in a constant speed mode at a speed of 4 m/s. The applied load of 800 N produces pressures which are far larger than the nip pressures in commercial printing press, i.e. both for the sheet-fed Heidelberg GTO-52 and the 4-colour Man Roland Geoman web printing press. The IGT test conditions produce forces on the surface, which greatly exceed those typically experienced in commercial printing presses.

Sample preparation and image analysis of samples from IGT pick experiments

A Hewlett Packard Scanjet 6300C Flatbed scanner operating at 1200dpi was used to capture the images. A typical example of a captured image is shown in Figure 2. A 1: 1 image was captured (sized 4.8 x 10 cm) at the bottom of the printed image as this represented the area of most lint removal. The images were then analysed by image analysis software, Image Pro 4.5. The images were analysed by selecting a threshold to isolate the white lines in the printed surface, which were where lint had been picked out of the surface.

It was immediately apparent that the size of the lint removed in the IGT Pick experiments was much larger than that removed in the printing press. Accordingly, new larger size classes were selected for the sorting of the lint identified from image analysis of the picking experiments. The first two of the new classes, numbers 17 and 18, cover the whole range of lint particle size used in the analysis of the lint from the Heidelberg and commercial printing presses. The area classes used for this analysis are shown in Table 2.

Table 2.
Size classes used for analysis of lint from the IGT experiments

Class	Min Area (μm²)	Max Area (μm²)
17	0	50,000
18	50,000	100,000
19	100,000	150,000
20	150,000	200,000
21	200,000	250,000
22	250,000	300,000
23	300.000	350,000
24	350,000	400,000
25	400,000	450,000
26	450,000	500,000
27	500,000	550,000
28	550,000	600,000
29	600,000	650,000
30	650,000	700,000
31	700,000	750,000
32	750,000	1,000,000

RESULTS AND DISCUSSION

In the results that follow, the percentage distribution of lint into area and length classes is plotted. The calculations were done for each sample, by calculating the total length and area of lint and calculating the percentage of this area or total lint length that could be assigned to lint particles in the different size classes. The x-axis values of both the length and area plots are the average values of length and area, respectively, of the particles in the different classes.

Table 3.
Percentage of Lint Coverage Area

Ink Supplier	Colour	Tack	Number of Copies	Total % Lint Coverage Blanket	% Paper Surface Re-moved that has stayed on the blanket
1	Black	13.5	7000	16.65	0.00237
2	Black	9	7000	20.93	0.00299
2	Black	6	7000	8.04	0.00114
3	Black	4.6	7000	7.82	0.00111
4	Black	~4	137000	55.41	0.00040
4	Black	~4	137000	23.73	0.00017
2	Cyan	13.5	7000	9.34	0.00133
2	Cyan	9	7000	9.20	0.00131
2	Cyan	6	7000	1.83	0.00026
4	Cyan	~4	137000	25.60	0.00018
4	Cyan	~4	137000	29.58	0.00021

Area and length distributions of lint from large commercial press and from Boyer Heidelberg GTO52.

Table 3 summarises the results for the printing experiments. For each data set the total surface area of the lint was calculated. This was then converted to a percentage of the blanket area that was covered in lint (second column from the right) and to the percentage of the paper surface area that was removed as lint (right column) that has stayed on the printing blanket. It should be noted that this will represent only a part of the total lint removed from the paper surface, as some of the lint particles will transfer back to the paper and some will move onto other parts of the printing press, such as the printing plate.

The data marked Comm. (Figs. 3-6) were obtained from the two printing blankets of the large commercial newspaper press. The data with various tacks were obtained

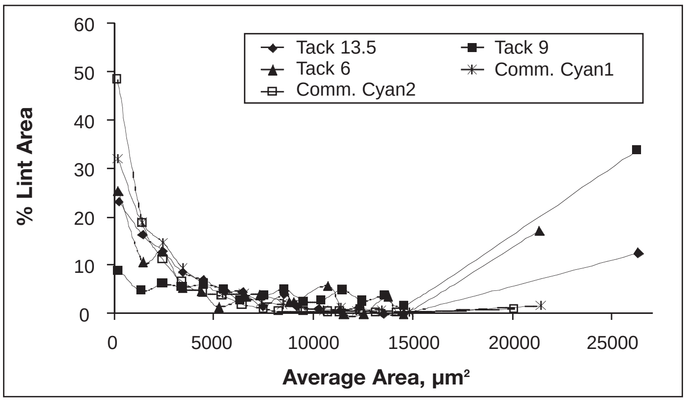

Fig. 3 Area distribution of lint particles produced in two printing operations using cyan ink.

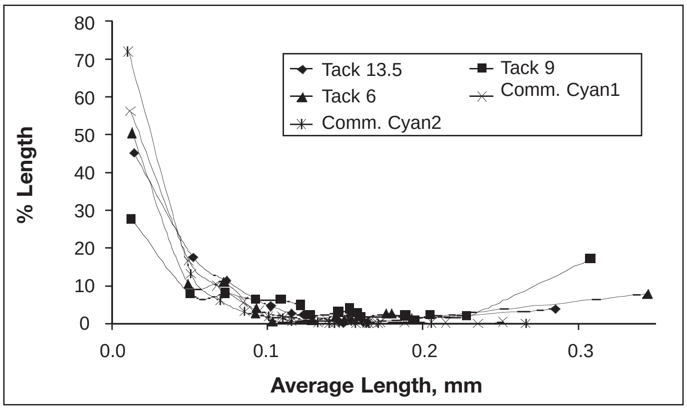

Fig. 4 Length distributions of lint particles shown in Figure 3.

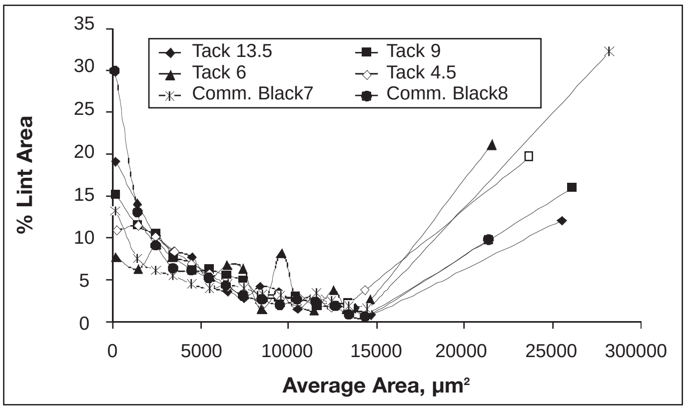

Fig. 5 Area distribution of lint particles produced in two printing operations using black ink.

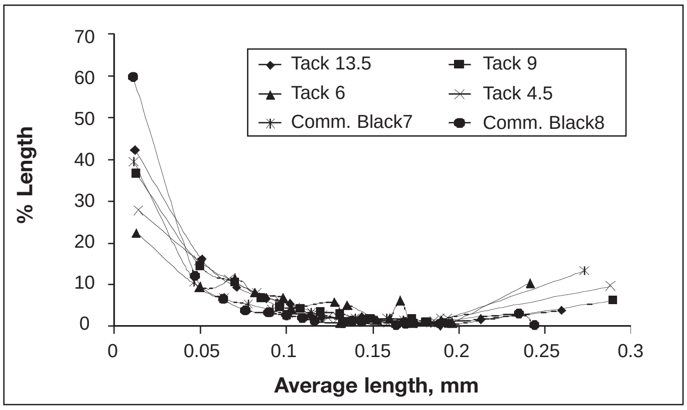

Fig. 6 Length distributions of lint particles shown in Figure 5.

with the indicated tack inks on the Heidelberg GTO52 Press at Norske Skog Boyer. Both sets of data were obtained from a screen printed area. The commercial inks used were coldset inks with approximate tacks of 4.

The data in Figures 3-6 appear to show a parabolic type distribution of the lint either when lint area (Figs 3 and 5) or particle length (Figs 4 and 6) are examined. The shape is however, somewhat misleading as it arises from the selection of the size classes for image analysis. Due to the limitations of the software to sixteen size classes, the last size class includes all of those lint particles that are greater than 15,000 µm^2. Thus the points for the largest size class are well separated from the rest of the points and show a larger percentage area than for the points in the preceding size classes only because of the larger range of measurement. If the size classes had been uniformly distributed then the data would have shown the same negative exponential type distribution that the rest of the data displays, providing enough lint particles had been measured to obtain reliable results.

The data in Figures 3-6 show some very interesting trends. Firstly, there seem to be relatively little differences between the lint produced in the different tack and colour inks used in the Heidelberg press. The similarity between the lint distributions from the cyan and black trials on the Heidelberg is not surprising. The Heidelberg press is a single colour press and therefore simply changing the colour of the ink, everything else being equal, should not change the distribution of the lint particles. However, the lack of a clear effect of ink tack is somewhat surprising as it had been expected that the use of higher tack inks might produce an increase in the size of the lint particles that were removed in the press as well as in the amount of lint. However the highest percentage of large lint particles is observed for the tack 9 ink in Figure 3 and for the tack 6 ink in Figure 5. The reasons for the lack of dependence on ink tack of lint size and amount are not clear, but may be related to the differences in the uptake of the fountain solution in the different tack inks. This is an area that will be the subject of future investigation.

There are some very clear differences seen in the area distributions for the lint from the cyan and the black blankets on the commercial press, where cyan was the first colour printed and black was the last. It can be seen that, in comparison to the cyan runs on the Heidelberg, there are very few large particles removed as lint. In contrast, the lint from the black blankets has approximately the same area and length distribution as that produced in the Heidelberg press, whichever ink was used to perform the printing trial. This is consistent with the changes in character of the lint as the paper moves through a multi-colour press as the cyan was the first colour printed on this press and the black was the last. As has been previously observed, the lint removed on application of the first colour is likely to be predominantly small fragments, only loosely bound into the surface, such as dust from slitter operations. The application of the fountain solution in the application of each colour then roughens and weakens the surface of the newsprint, increasing the likelihood that larger, better bonded particles will be removed, later in the printing process. There is, as yet, no means of quantitatively predicting how the character of the lint will change as it passes through the printing process.

Area and length distributions of IGT lint

The area distribution of lint removed from the surface in the IGT pick experiments is shown in Figure 7, while Figure 8 shows the length distributions of the lint particles shown in Figure 7. It can be seen that there is very little difference from sample to sample in either the length or area distributions. The shape of the distributions in both area and length are somewhat different from those shown from the lint washed from the blanket in Figures 3-6, as Figures 7 and 8 both show the percentage

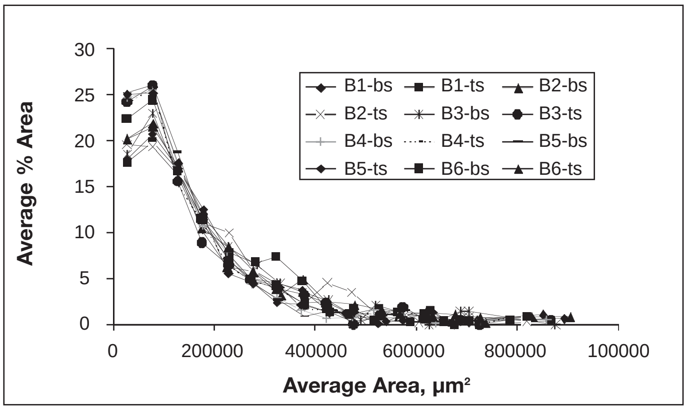

Fig. 7 Area distribution of lint particles measured from IGT pick experiments on the top and bottom sides of six samples of improved newsprint.

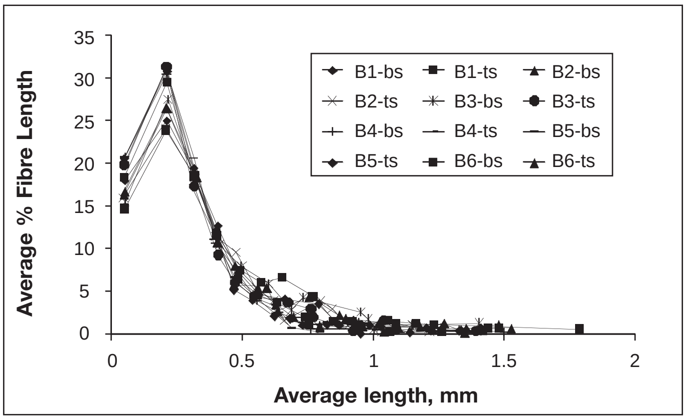

Fig. 8 Length distributions of lint particles shown in Figure 7.

area and length distributions rising to a maximum for Class 18 before falling. The origin of this peak is not currently known.

When the results of the IGT experiments are compared to the lint removed during printing, it can be seen that the IGT experiments remove much larger lint particles than either of the two sets of printing press experiments. Figures 2, 7 and 8 show that a considerable amount of the material removed from the surface in the pick test has been complete or near complete fibres, with lengths up to 1.5 mm whereas the lint removed in the printing experiments is much shorter and has a much smaller area. The arithmetic average length of the lint removed in the IGT test was typically 0.18mm, compared to average sizes ranging from 0.013 to 0.024mm for the commercial press and 0.021 to 0.035mm for the small Heidelberg press.

When the total area of the lint in all classes is summed, then it is possible to estimate the total fraction of the surface, which has been removed as lint. For the IGT experiments, this was on average 2.4%. That is, on average fibres had been pulled from 2.4% of the total surface area in the single printing run of the IGT experiment. As is shown in Table 3, the equivalent areas for the Heidelberg trials were only 0.001 to 0.003%, provided it is assumed that all lint particles removed from the paper surface had remained on the blanket. For the commercial newsprint measurements the lint removed was an order of magnitude smaller than the Heidelberg measurements, since similar amounts of lint were pulled out after 7,000 copies on the Heidelberg press as were removed after 137,000 copies on the commercial press. These differences may have been influenced by lint migration away from the blanket during the trial on the large commercial press.

Discussion

Both the IGT and the Heidelberg printing trials have been used as quality control tests to try and predict linting. The results, which have been presented here, suggest that the IGT test may have only limited utility in predicting linting. This is because the IGT pick test removes much more lint that is much longer and wider than the lint removed on the printing press. These differences would be even greater if we had compared the solid tone lint from the commercial presses with the IGT data which is measured on a solid print. This is because in offset printing, the solid tone lint was considerably smaller than the lint obtained at 50% screen tone, which was presented in this paper.

For the IGT test to be useful, it must be assumed that the amount of long fibre removed in the IGT pick test is proportional to the amount of shorter material removed as lint during offset printing. This is not something that can be tested from these results, as the same material was not tested in each experiment, although previous work has suggested that the relationship between picked fibres and lint is not straight-forward (*1*). Some limited work has been done comparing the total IGT lint area of the samples presented in this work, with the mass of lint accumulated on the blanket in Heidelberg printing trials (*6*). No strong correlation between the two was found.

It seems reasonable that if mechanical pulp fibre development in refining changes due to, for example, an increase in refining energy, then this is likely to affect the bonding of the fibres into the network more than it will the bonding of the fines onto the fibres. Improvement of the bonding of the fibres into the network should reduce fibre removal in the IGT experiments, but may not change linting in printing as it is not these fibres that are removed as lint. A change in fibre development in refining would also change the proportions of fibres and fines, as would a change in the furnish- eg increased substitution of recycled fibres. All of these factors could affect the proportionality between long fibre removal in IGT experiments and the linting of fine material during printing.

The results do show that testing the paper on the small Heidelberg press is potentially useful as a means of characterising its linting tendency. The lint length and area distributions, shown in Figures 5 and 6 show good agreement between the Heidelberg and the commercial press. This suggests that any change in the lint distribution measured in the Heidelberg test may be reflected in the performance of the paper, when printed commercially. This proposition will be tested in future work.

CONCLUSIONS

The length and size distributions of lint from a large commercial offset press, a small commercial offset press and a laboratory pick test were measured. The lint removed in the large commercial press was smaller in both area and length in the first printing station compared to the last. The lint removed in the last printing station of the commercial press had similar distributions in size and length to the lint removed in the small commercial printing press. The size and area of the lint removed in the small commercial press did not depend on the tack of the ink. The reasons for the lack of dependence on ink tack of lint size and quantity are not clear, but may be related to the differences in the uptake of the fountain solution in the different tack inks. This is an area that will be the subject of future investigation. As was expected, the pick test removed far more lint than either commercial press. The length and area of the lint was also much larger than the material removed as lint on the commercial press. This disparity between the size distributions of the lint produced in the commercial and laboratory pick test suggests that the results of the pick test cannot be assumed automatically to be relevant to linting in commercial offset printing.

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