Inkjet Printability of Newsprint: Effects of Starch-based Coatings

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Inkjet is one of the most common non-impact printing technologies available today. Due to its ability to print on a wide variety of substrates, inkjet technology is promising for short run printing of newsprint. To be able to do this, the quality of newsprint grades needs to be improved. The objective of this work was to study how different starch-based coatings influence print-through and print quality of coated and inkjet printed newsprint. We tested coatings based on oxidized potato and hydrophobic maize starch in presence and absence of nano-structured calcium silicate and clay. They were applied at low weight using a laboratory-scale bench coater. As references, untreated newsprint and newsprint samples treated with only water were used. All samples were characterised using microscopy and standard testing methods for paper, and subsequently printed with a Canon inkjet printer using water-based inks. Print quality was evaluated in terms of print-through, colour reproduction and dot and line quality. The results show that coating newsprint with clay or a novel nano-structured calcium silicate material significantly reduces print–through and improves print quality. This was achieved with minimal change in colour gamut.

1. Introduction

Inkjet is one of the most common non-impact printing technologies available. In terms of function, inkjet technology offers the broadest spectrum of applications with the largest selection of inks, substrates and formats. Due to its ability to print on a wide variety of substrates, inkjet printing looks promising as a complementary technology to offset for short run printing of newsprint and is especially attractive for decentralised printing. Traditional offset technology is based on the use of large web presses, printing plates, highly viscous inks and smooth paper substrates. In recent times, most newspapers have been printed by offset, but offset is not efficient for short runs (e.g. small scale, on-demand printing) because the cost effectiveness of offset is related to large print volumes (Kipphan, 2001a). In offset printing the inked image is transferred (or "offset") from a plate to a rubber blanket, then to the printing surface. However, inkjet technology is quite different to offset. Inkjet technology does not require a printing form for the transfer of ink to the paper and is not dependent on surface roughness in same way as offset; instead the ink is ejected directly onto a substrate from a jet device driven by an electronic signal (Kipphan, 2001a, 2001b; Oittinen & Saarelma, 1998). Most inkjet inks have low viscosity and low surface tension, which puts high demands on the substrate's porosity and absorbency characteristics. The quality of the print is highly dependent on droplet spreading, which is controlled by both ink properties (surface tension and viscosity) and absorption properties of the substrate (surface tension, roughness, and porosity) (Martin, 2005). The ink needs to be immobilised quickly on the surface of the paper (Jaffe, Luttman, & Crooks, 1982; McManus et al., 1983). However, the high absorbency of the ink into the sheet can lead to poor optical print density and print-through and dimensional instability of the sheet (e.g. cockling). On the other hand, if the ink is not absorbed quickly enough, it may spread laterally, resulting in colour-to-colour bleed, edge raggedness, and line broadening. These requirements are contradictory, and an optimum between them can be achieved by manipulating the sheet's porosity and absorbency characteristics, by either sizing or coating (Oliver, D'souze, & Hayes, 2002). Furthermore, the smoothness of the substrate is not of major importance for inkjet printing (except for its influence on gloss) as it is for most other printing methods (Babinsky, 1998).

One of the major ink/paper interaction effects is print-through. It is an optical disturbing effect that appears on the reverse side of printed areas and is caused by the ink (Larsson & Trollsås, 1972). The magnitude of the print-through depends on properties of the ink and paper (Larsson, 1981). Several studies have been made regarding ink/paper interaction in both inkjet (Hladnik, Cernic, & Bukosek, 2008; Nilsson & Fogden, 2008; Tiago et al., 2010; Vikman, 2003a, 2003b) and offset printing (Eriksen & Gregersen, 2005, 2006; Gregersen, Johnsen, & Helle, 1995; Larsson, 1981; Larsson & Trollsås, 1972) and a general conclusion would be related to the importance of controlling ink spreading, ink holdout, ink penetration and paper opacity. Newsprint papers have been developed for highly viscous offset inks, and it would be challenging to print the same type of papers using low viscous inkjet inks. Similar manufacturing technology or treatments of newsprint as those of the inkjet specific papers would be necessary. Inkjet papers are normally surface sized/coated by starches, polyvinyl alcohol (PVOH), polymers and pigments to achieve a whiter and more receptive surface for inkjet printing (Tsai, Inoue, & Colasurdo, 1999). Materials such as precipitated silica, alumina forms, titanium dioxide and various polymers are used to create coatings with inkjet ink "receptor" properties. These coatings are much more expensive than conventional paper coatings for offset printing and are used for higher cost applications such as printing digital photographs. Conventional coating pigments such as calcium carbonate and clay are cheaper but because of the low liquid absorption capacity they are not commonly used for inkjet papers (Martin, 2005). An opportunity therefore exists for the development of a low cost, light weight, absorptive coating suitable for inkjet printing that can be applied to newsprint to enhance the print quality and open new market opportunities. This needs to use low cost binders and pigments with a high liquid absorption capacity. Also there should be no change in the appearance and mechanical properties of the newsprint, and good runability of the printing process should be maintained.

In the present study, the effect of different low weight coatings on inkjet printed newsprint has been investigated. Six different coating combinations based on hydrophilic potato starch, hydrophobic maize starch, nano-structured calcium silicate and clay have been applied to the newsprint using a laboratory-scale bench coater. The purpose of using low weight coatings with different functionality was to prevent ink penetration to the reverse side (clay and/or hydrophobic starch) or to control ink absorption and ink spreading on the printed surface (calcium silicate and/or hydrophilic starch) without noticeably altering appearance and mechanical properties of the newsprint. Coated newsprint samples were also compared with untreated samples and samples treated only with water to identify any rewetting effect. All samples were characterised using optical microscopy and standard testing methods for paper, and subsequently printed with a Canon inkjet printer using water-based inks. Print quality was evaluated in terms of print-through, print density, colour gamut and dot and line quality.

2. Materials and Methods

2.1 Binders and coating pigment

Binders for the pigment used for this study were two different commercial grade starches: an oxidized potato starch (OX) and a hydrophobic modified maize starch (HM). The OX-starch, Perlcoat 155, was oxidized with sodium hypochlorite (supplied by Lyckeby Starch, Sweden). OX-starch has been reported to have hydrophilic properties, excellent film forming properties, and improves the paper strength and printability (Mesic et al. 2004; Parovuori et al., 1995). HM-starch (supplied by National Starch, USA) was a waxy maize non-ionic starch modified to adjust viscosity and then treated with a very large hydrophobic group to give good surface orientation. HM-starch has been reported to improve mechanical/physical properties, moisture resistance and printability (Mesic et al., 2004; Zobel, 1990). Two different coating pigments were examined in this study, conventional clay and mesoporous calcium silicate. The conventional clay is, according to the manufacturer, a standard grade clay used for paper coating that has good coverage, high brightness, and a Sedigraph particle size of 92% < 2 µm exhibiting a flat particle shape with a high aspect ratio. The laboratory produced mesoporous calcium silicate (Si) comprises nano-size calcium silicate platelets of 5 to 10 nm thickness and up to about 300 nm across. These self-assemble into particles of about 1 to 5 µm in size each with a 3-dimensional open framework "gypsum desert rose" type structure. The particles have a high pore volume accommodating up to about 500 to 600 g oil 100 g^{-1} silicate (ASTM Oil Absorption test D281) and a high brightness (Johnston et al., 2004). Of particular interest is the ability of this nano-structured calcium silicate to readily absorb ink-jet inks when present as a functional component in paper coating formulations. The plasticizer used in this trial was glycerol.

2.2 Preparation of coating formulation

The coatings were prepared in two steps: i) preparation of aqueous starch solutions and ii) the addition of coating pigments. Aqueous solutions of the OX- and HM-starch were prepared by dispersing starch granules in de-ionized water (conductivity < 1 µS) and heating the solution at 95 °C for 30 minutes while stirring at

400 rpm with a propeller-type impeller. The starch solutions were diluted with warm water to obtain a concentration of 8 wt % and plasticizer was added at a level equivalent to 20 % of the dry starch content. Prior to the pigment addition, all starch solutions were adjusted to pH 8 by adding NaOH solution. The dry clay powder and Si-slurry were added to the starch solutions at room temperature (about 22 °C) while being stirred at 800 rpm with a propeller-type impeller for 45 min. The solids ratio of the starch to the clay was 45:55 and of the starch to the calcium silicate was 59:41. The final solids contents were about 16.5 wt% for the clay coating and 13 wt% for the calcium silicate coating.

2.3 Laboratory Coating

The substrate used in this study was a commercially available Pinus Radiata based newsprint grade with a grammage of 56 g/m^2. All coatings were applied at room temperature (23 °C) using a bench coater (K Coater M202, RK Print-Coat Instruments Ltd., Royston, U.K.) equipped with wire-wound rod number 2 at a rod speed of approximately 25 m/min. This bar applies coatings with a (nominal) wet thickness of 12 µm on a non-absorbent substrate. The coated sheets were pre-dried at room temperature until the tackiness disappeared and finally dried against a hot glossy metal plate at 105 °C. The dry weight of the coating layers was determined gravimetrically. Six samples (200 × 190 mm) were coated for each coating formulation. The coatings evaluated are shown in Table 1.

2.4 Laboratory Printing

Printing was performed using a Canon inkjet printer PXIMA iP4500 at constant printing condition (RH = 50% & T = 23°C). The printer was equipped with four cartridges of dye based ink (CLI-8C, CLI-8M, CLI-8Y and CLI-8BK) and one cartridge of pigment based ink (PGI-5BK). Beside default ink control and colour management system (programmed by the manufacturer) the following printer settings were used: plain paper, high print quality, normal colour intensity, no colour correction and normal brightness. Four of six coated samples were randomly selected and printed. For evaluation of print-through, strike-through, print density and line quality, details printed with non-composite (pure) black ink were used. As a default ink colour control system was used it is assumed that the black ink was a combination of non-composite dye black ink (CLI-8BK) and non-composite pigment based ink (PGI-5BK).

2.5 Print quality evaluation

Print-through (PT) is measured as print density on the reverse side of printed sample (Oittinen & Saarelma, 1998) and is defined as the logarithm of the ratio of the reflectivity of the reverse side of unprinted area (R_∞) of the substrate to the reflectance factor (RPT) of the reverse side of printed area, (Eq. 1). According to Larsson (Larsson, 1981), PT in offset print can be considered to be sum of three components, show-through (which is highly correlated to opacity), pigment penetration and the vehicle separation component.

Table 1: Coatings evaluated

Treatment	Treatment name
Untreated	UT
Water	W
Starch –glycerol	SG
Starch – glycerol – clay	SGC
Starch – glycerol – nano-structured calcium silicate	SGSi

As inkjet inks are quite different to offset inks, we are not able to take into consideration the contribution from the vehicle separation component. In this work we consider print-through as the product of two properties: opacity and ink penetration. Reflectance and opacity were measured using a L&W Elrepho spectrophotometer (AS/NZS 1301.436. 2005 and AS/NZS 1301.454. 2006). Ink penetration to the reverse side of the printed sheet is expressed as strike-through (ST) (Oittinen & Saarelma, 1998) and was studied using a Personal Image Analysis System (PIAS-II from Quality Engineering Associates (QEA), Inc., USA). As the show-through has not been measured in this study, we have been evaluating how opacity, ST and porosity, influence total PT.

$$PT = log \frac{R_\infty}{R_{PT}} \qquad (1)$$

Strike-through (ST), expressed as the area fraction (AF) in % of ink present on reverse side to that covered by black ink, was measured from reflectance images with a pixel resolution of 5 µm, captured using the PIAS-II. The images were 8-bit grayscale where 0 = black and white = 255. The percentage grayscale (Gp) of the unprinted side was determined at a pixel level according to equation (2):

$$G_p = (G_b - G_i)/(G_u - G_i) \times 1000 \qquad (2)$$

Where:
Gb = the greyscale value for the reverse side of the printed sheet;
Gi = the mean greyscale value for the print side of the printed sheet;
Gu = the mean greyscale value for the reverse side of the unprinted sheet.

Gp ranges from 0 to 100, where 0 = the greyscale value of the ink and 100 = the greyscale value of unprinted sheet. In this case a threshold value of 35 was used as the upper limit to determine black ink spots.

For evaluation of optical print density (Dp) of the top side of printed areas, reflectance measurements were used. Dp is defined as the logarithm of the ratio of the reflectivity of the unprinted area (R_∞) of the substrate to the reflectance factor of the printed area (Rp) [equation (3)] (Kipphan, 2001c). Dp is given as the mean value of 6 measurements.

$$D_p = log \frac{R_\infty}{R_P} \qquad (3)$$

For evaluation of colour gamut and line and dot quality a Personal Image Analysis System (PIAS-II from QEA) was used. Two dimensional colour gamut value in the a*b plane is obtained from the a* and b* values measured on 6 square areas (22 x 22 mm) printed with cyan, green, yellow, red, magenta and blue inks. This is a simplified top projection of the full 3-dimensional colour gamut volume in L*,a*,b* space (Svanholm, 2007). Line raggedness is defined as geometric distortion of an edge from its ideal position (Figure 1a). It is measured as the standard deviation of the residuals from a line fitted to the edge threshold calculated perpendicular to the fitted line (ISO – 13660).

For evaluation of dot quality the dot circularity was used. Six blocks with nine 105 µm dots printed with cyan ink were used for evaluation of dot circularity (Figure 1b). Dot circularity (C) is given by equation (4).

$$C = \frac{p^2}{(4\pi A)} \qquad (4)$$

Where p = the dot perimeter and A = area of the dot. Note that for a perfectly circular dot, circularity = 1. For dots of any other shape, circularity > 1, while for very small dots, the circularity measurement may be inaccurate and therefore has a value < 1.

2.6 Confocal microscopy

The Confocal Laser Scanning Microscope (CLSM) used in this study was a Leica TCS NT (Leica, Wetzlar, Germany) equipped with fluorescence channel using a Argon-Krypton laser with 488, 568 and 647 nm wave-lengths. The cross-sections for the CLSM were prepared from strips, 8 x 20 mm, printed with yellow ink and then embedded in epoxy resin (Mecapres MA2, PRESI, France). The use of yellow ink made it possible for the ink penetration to be studied by CLSM without the addition of a fluorescence agent.

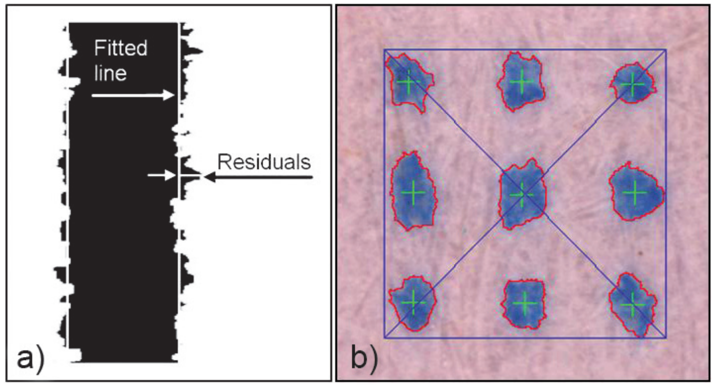

Figure 1: Schematic description of line raggedness (a) and method for evaluation of dot circularity (b).

The embeddings were cured at room temperature for 12 hours prior to grinding and polishing. Grinding and polishing was performed using a Mecapol P230 device (PRESI, France).

2.7 Grammage of coating layer and porosity

Grammage of coating layer, the coat weight, was determined according to TAPPI standard test method T410 om-98. Parker Print Surf (PPS) porosity was measured according to TAPPI standard method T547 pm-88.

3. Results and Discussion

The coat weight and PPS porosity are shown in Table 2. In the calculation of coat weight, the base sheet grammage was assumed to be constant, while in reality the grammage was probably not exactly the same for all base sheets causing a "projected" variation in coat weight. Taking that in consideration we can conclude that the coat weight was approximately in the same range for all coated samples. It is interesting to notice that despite different coatings, all treatments were nearly the same in appearance. This supports our hypothesis that low weight functional coatings can control ink penetration and ink spreading without significantly altering appearance and mechanical properties of the news print.

The samples treated with water (W) showed a significant increase in porosity (76% more than UT), as expected, because re-wetting without calendering causes paper to be more bulky and porous. The coatings containing clay (SGC) showed more than 30 % lower porosity than the untreated sample. The other coatings did not show any significant change in porosity. Clay, with a high aspect ratio has a pronounced orientation of the pigment particles parallel to the surface. This type of clay is used in coating to serve as a mechanical barrier to liquids and gases (Andersson, 2008; Kugge et al., 2008; Mesic, Kugge, & Jarnstrom, 2010), which is a potential reason for the low porosity.

Precipitated silica pigments which have a network chain type structure are often used for coatings that require a porous structure to control liquid penetration in the substrate. These typically have oil absorption values of about 200-250 g oil 100 g^{-1} silicate. The nano-structured calcium silicate used here has approximately twice this liquid absorption capacity and this is reflected in relatively high porosity values for the SGSi coatings when compared to SGC (Johnston et al., 2004; Svanholm, 2007).

All samples showed good printer runnability in terms of paper sheet feeding and absence of ink smearing from print head to the substrate.

3.1 Print-through

Figure 2 presents print-through (PT). There was no correlation between porosity (Table 2) and PT. As the purpose of using coatings with different functionality was to prevent ink penetration to the reverse side or to control ink absorption and ink spreading, it is interesting to note that there were no significant differences in performance when comparing clay with calcium silicate or comparing hydrophilic (OX) starch with hydrophobic (HM) starch. Only the coatings containing pigment (SGC, SGSi) in general showed significant reductions in PT whereas those without pigment (SG) were in the same range as the untreated sample (UT) and samples treated with only water (W). This behaviour suggests that PT is probably related to some other properties (e.g. chemo-physical properties) than just to ink holdout and ink penetration. More information on how PT could be related to different factors is presented further in this document.

Figure 3 presents the opacity of the samples. In general there is no substantial difference in opacity between treated and UT samples. There are no significant differences in performance when comparing clay with calcium silicate or comparing hydrophilic (OX) starch

Table 2: Coat weight and porosity of coated substrates.

	Coat weight (g/m²) mean ± s.d.		PPS Porosity (ml/min) mean ± s.d.	
UT	n/a		278 ± 26	
W	n/a		490 ± 18	
	OX	HM	OX	HM
SG	2.27 ± 0.54	2.68 ± 0.48	274 ± 15	344 ± 7
SGC	3.21 ± 1.26	3.94 ± 0.58	189 ± 23	197 ± 16
SGSi	2.77 ± 1.1	2.39 ± 0.54	282 ± 14	299 ± 5

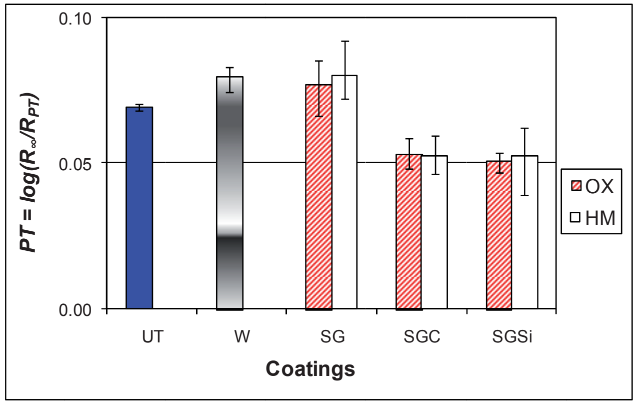

Figure 2: Print-through (PT) on the reverse side of the sample printed with pigment black ink. Error bars indicate range of value around the mean.

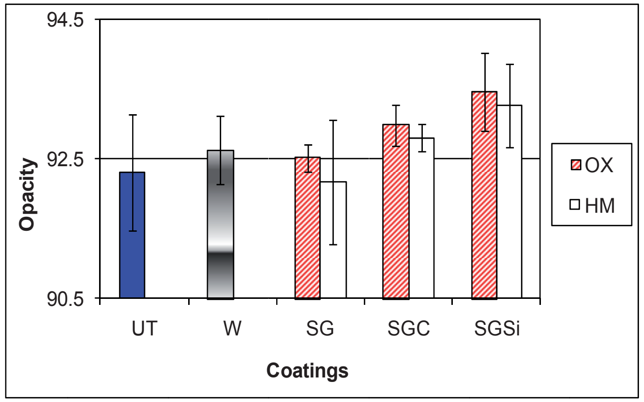

Figure 3: Opacity of unprinted samples. Error bars indicate standard deviation.

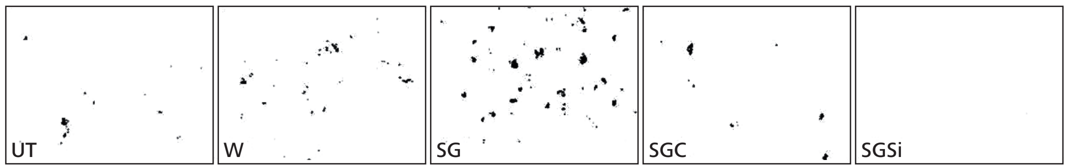

Figure 4: Representative picture of the reverse side of untreated and OX coated- and printed substrates. The black colour in the picture represents ink arising fromtion.

with hydrophobic (HM) starch. However, there are some trends showing that coatings containing pigments results in higher opacity than all other samples. There is a very general correlation of opacity with PT (Figure 6a) indicating that the higher opacity values exhibit the lowest PT and vice versa. This ties in with the accepted theory that PT is inversely correlated to the opacity of the substrate. De Grâce (De Grâce, 1993) showed that, for offset printed newsprint, approximately 80% of print-through could be accounted for by opacity. However, as inkjet inks are quite different to offset inks, De Grâce's theory cannot be fully related to our results.

As the strike-through (ST) also contributes to PT (Larsson, 1981; Larsson & Trollsås, 1972; Oittinen & Saarelma, 1998), characterisation of the reverse side of printed samples was done and ink present was quantified as the area fraction (AF) in % of black ink coverage (Figure 4). The ST results are plotted in Figure 5.

In general samples coated with only starch (SG) showed significantly higher ST than all other samples

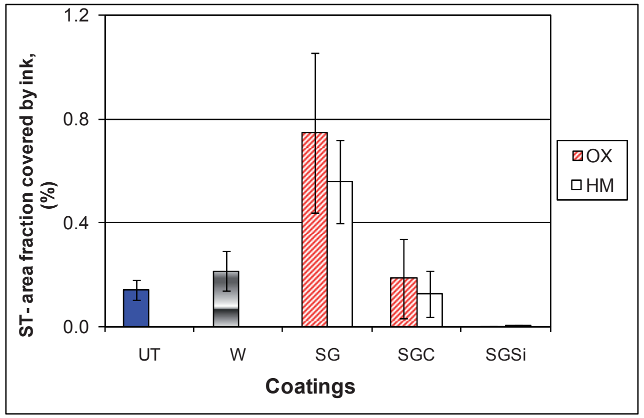

Figure 5: Strike-through expressed as a % area fraction of black ink present on reverse side of printed sample.
Error bars indicate standard deviation.

(UT, W, SGC and SGSi). Starch treatments and the consequent re-wetting on the paper caused by coating treatments can change the structure of the paper, which in turn can result in a change in opacity and ink transport through the paper. It seems that the starch has totally penetrated the paper and caused pathways for the ink to be absorbed along. Negligible ST was evident for coatings containing the calcium silicate pigment (SGSi). That was expected because mesoporous pigments similar to this nano-structured calcium silicate have been reported to create highly absorptive coating layers (Johnston et al., 2004; Kipphan, 2001b; Svanholm, 2007). By its high absorption power the ink is absorbed to the coating layer reducing the risk of uncontrolled penetration through the paper. When comparing different binders, no difference in performance could be observed between hydrophilic (OX) and hydrophobic (HM) starch. There was also no significant difference between untreated samples (UT), samples treated with only water (W) and coatings containing clay (SGC). There is also a general correlation between ST and PT (Figure 6b). Samples with a high ST gave a high PT while sample with a low ST gave a low PT confirming that ST contributes significantly to PT.

Figure 7 presents the optical print density (Dp) for substrates printed with black ink. With the notable exception of the calcium silicate coatings, the Dp for UT and all other treatments (W, SG, and SGC) was in the same range. For the calcium silicate coating Dp is more than 30% higher than for other samples. This is likely to due to the greater ink absorption of the coating due to the mesoporous calcium silicate (Johnston et al., 2004). There was no correlation between Dp and PT.

Despite different coating formulations, the reflectivity of the unprinted areas (R_∞) was approximately the same for all samples and with very small variation (69.81 ± 0.66). This was not true for the reflectivity for printed areas (RP). The average RP was 5.69 ± 1.04 with relatively

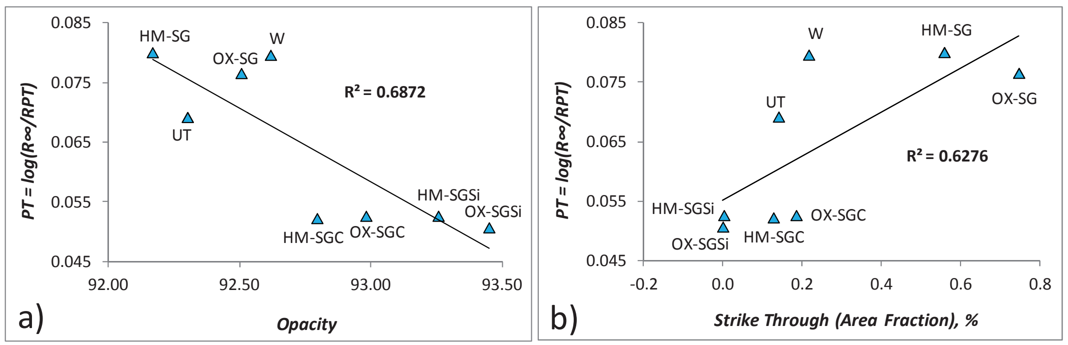

Figure 6: Correlation between: a) PT and opacity and b) PT and strike-through.

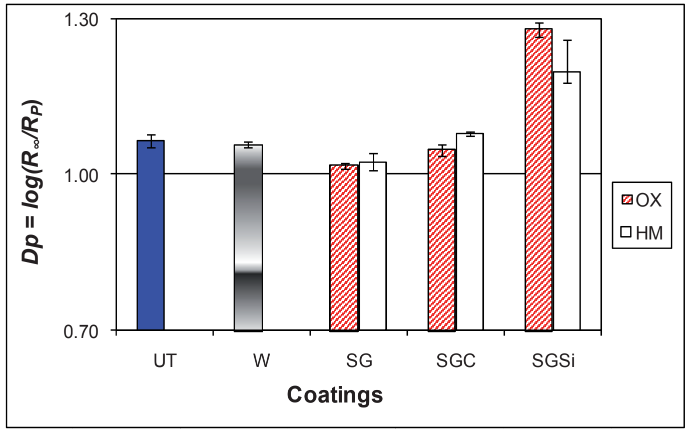

Figure 7: Print density (Dp) for substrates printed with black ink. Error bars indicate standard deviation.

large variation. The RP for the calcium silicate samples was about 39% lower than all other samples. The calcium silicate coatings gave the best ink holdout as the ink is absorbed and held at the surface by the open structure of calcium silicate. Inkjet paper coatings therefore often contain mesoporous pigment particles such as precipitated silica or in the case here, nano-structured calcium silicate, with large internal pore volume to enhance ink absorption and ink holdout (Chapman, 1997; Morea-Swift & Jones, 2000).

As according to Larsson (Larsson, 1981), for offset printed newsprint, PT is related to the amount of ink per unit volume of paper (assuming the ink is present as a homogenous layer), then it would be tempting to assume that PT trends should be related the Dp. However, this statement does not fully apply to our inkjet printed samples. We did not characterize PT at constant Dp and we do not know how much ink is printed onto the substrate but we assume that the amount of ink on the surface is the same for all prints. Only coatings containing the calcium silicate pigment show a relatively high Dp which corresponds to a relatively low PT, while all other samples show approximately the same Dp with varying PT (Figures 2 and 7). This may be related to opacity and ST in combination with different chemical/physical ink-interactions with binders and pigments. To obtain a better understanding of these different mechanisms future work should address the PT at constant Dp, chemical interaction between ink jet inks with the different coating treatments, notably the binder and pigment components.

Figure 8 presents examples of CLSM-cross-section images taken of OX-coated and printed substrates. On the images, the yellow ink appears as black. It is clearly evident from CLSM-cross-section pictures (Figure 8) that the inkjet ink penetrates further into the untreated (UT) than into paper coated with a coating containing clay or calcium silicate (SGC and SGSi). It is also evident that the

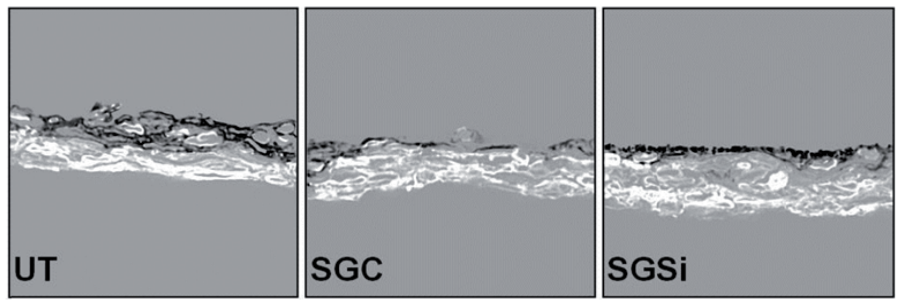

Figure 8: CLSM cross- sections of OX-coated newsprint printed with yellow ink.
The black colour shows the ink distribution in x and z directions.

distribution of the ink layer over the surface and into the substrate is more even for SGSi coatings than for SGC coatings. The reason for this, as previously mentioned, is the high absorption capacity of the calcium silicate pigment which makes it possible for the ink to be both held on the surface and absorbed by the coating layer, thereby preventing ink penetration into the paper. So, from consideration of the CLSM-cross-section images and the results presented, it is clear that pigment-coated newsprints gave a much better ink hold out resulting in less PT.

3.2 Colour reproduction – Colour gamut

The colour gamuts for newsprint with and without coatings are presented in Figure 9. In general all coatings and especially those with clay as the pigment, show slightly better colour gamut in the yellow, red and blue "directions" than for the UT samples. The HM-coatings show similar trends (not shown). However, as these differences are relatively small, we assume that the colour gamut was approximately the same for all samples. That means that irrespective of the type of coating used, we were able to reproduce the same colour for all. This is an important criteria when reproduction of the same colour quality is required.

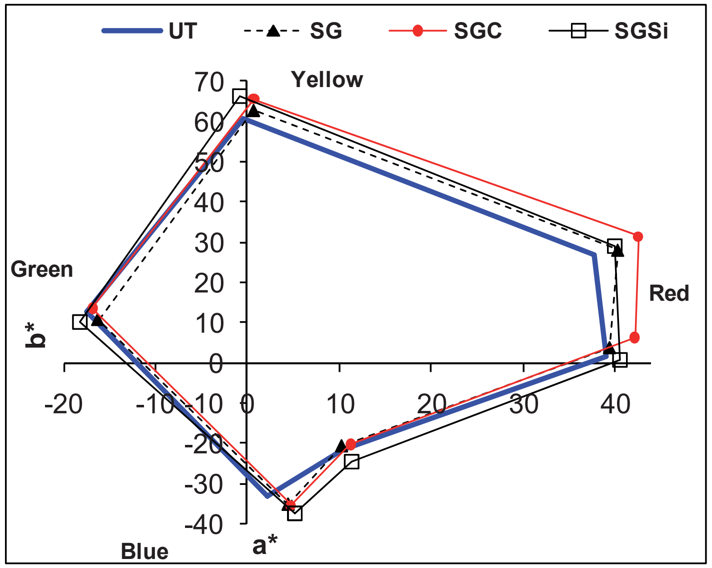

Figure 9: Colour gamut for untreated and OX coated substrates printed with inkjet. (Measured using Personal Image Analysis System PIAS-II from QEA.)

3.3 Line and dot quality

The results of the line quality (expressed as line raggedness) and dot circularity are summarised in Table 3.

In general, all coatings show a reduced line raggedness compared to UT samples. Also, the calcium silicate coatings (SGSi,) show less raggedness than the clay coatings (SGC,). This can also been seen in Figure 10 where examples of black lines printed on UT sample and coated samples are presented. Overall the lowest raggedness is shown by HM-SGSi coatings (see Figure 10g). This excellent result is a consequence of the collective effects of the better ink holdout provided by the calcium silicate and the low ink spreading due to the hydrophobic character of HM- starch.

All coatings in general show better dot circularity (lower number) than for UT substrate.

However, the best dot circularity values are again exhibited by the coatings containing the nano-structured calcium silicate pigment.

Table 3: Line raggedness of 35 μm black line and circularity of 105μm cyan dots.

	Black line raggedness (μm) mean ± s.d.		Dot circularity (cyan) mean ± s.d.	
UT	19.2 ± 2.7		2.1 ± 0.2	
	OX	**HM**	**OX**	**HM**
SG	14 ± 2	15.7 ± 3.6	1.6 ± 0.1	1.9 ± 0.2
SGC	12.5 ± 0.4	12 ± 1.3	1.7 ± 0.1	1.7 ± 0.1
SGSi	10.3 ± 1.2	10.2 ± 1.5	1.5 ± 0.1	1.7 ± 0.1

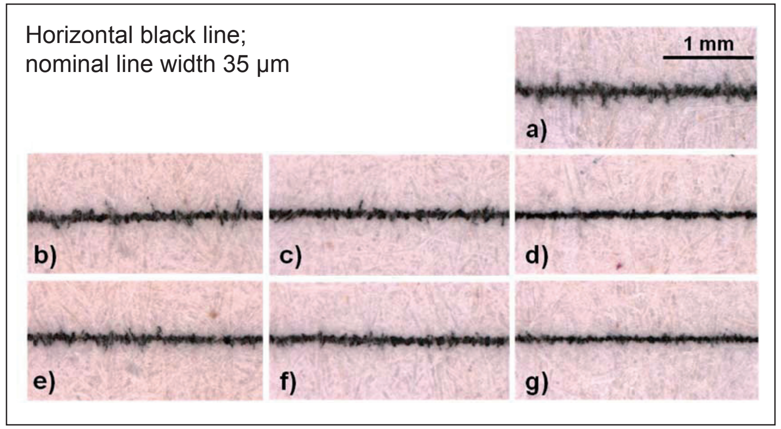

Figure 10: Optical micrographs of horizontal black lines: a) UT, b) OX-SG, c) OX-SGC, d) OX-SGSi, e) HM-SG , f) HM-SGC and g) HM-SGSi.

4. Conclusion

Coating newsprint with clay or nano-structured calcium silicate was shown to reduce print–through and improve the print quality of ink-jet printing. This was achieved with minimal change in colour gamut and good printer runnability. Coating containing nano-structured calcium silicate which has a very high liquid absorption capacity in general outperformed all other samples.
Other specific findings are:

- There were no significant differences in performance between hydrophilic and hydrophobic starch.
- The coated papers with improved opacity and a low strike-through gave a low print-through. Negligible strike-through was evident for coatings containing the calcium silicate pigment.
- CLSM-cross-section images show that the inkjet ink penetrates further into untreated newsprint than into newsprint which has been coated with formulations containing clay or calcium silicate pigments. Also the distribution of the ink layer over the surface of the paper is the most even for coated newsprint containing calcium silicate.
- All coated newsprint samples gave reduced line raggedness and a better dot circularity compared to untreated newsprint samples. The lowest line raggedness and best dot circularity was obtained with the nano-structured calcium silicate and hydrophobic starch coating.

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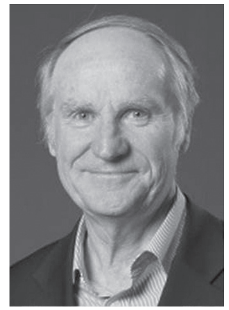

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