Application of imaging reflectometry to studies of print mottle on commercially printed coated papers

JANET PRESTON, ANTHONY GORDON HIORNS, NICK ELTON, AND GÖRAN STRÖM

ABSTRACT: It has been well documented that homogeneous coating structures are necessary for obtaining good, mottle-free printed papers. Methods such as mercury intrusion porosimetry are widely used in the paper industry, but will deliver a bulk porosity measure, which contains contributions from both the surface layers and the bulk of the coating. One way of assessing the surface porosity is to measure its effective refractive index (RI) because the RI measured is a combination of the material RI and air.

In this work three papers coated with PCC, kaolin, and GCC were RI mapped using an imaging reflectometer. The data were then treated with a mathematical transform in order to be able to quantify the degree of variation that was taking place at each length scale. These results were then compared to the print mottle, which was evident after both lab scale printing and full scale sheetfed printing of the pilot coated papers.

The commercial mottle was quantified both visually and using image analysis and there was a reasonable correlation between these two methods. In the halftone printed area, the propensity for mottle correlated with the degree of porosity variation of the coating. However, the rankings for the full tone print areas better correlated with the short time water absorbency of the coatings. FFT band-pass analysis confirmed that the same spatial distribution of unevenness occurred in the basepaper, coating layer and printed areas.

Application: This work has highlighted the need for pigment engineering in order to achieve optimum print and paper properties. The coating porosity variations need to be minimized by good coverage of the basepaper by the coating, in order to reduce print mottle.

The mottle of a printed paper is the visible uneveness in print gloss or density and it has a serious impact upon the perceived quality of a printed surface, and is a common defect in multi-color printing [1].

During a multi-color offset printing process, ink is transferred from the blanket to the paper. At the next color station, some of the non-immobilized ink is transferred back from the paper to the blanket of that station. This process reaches an equilibrium and produces good prints of even density [2]. However if there is any imbalance in the absorption of ink components into the paper, a variation in print density and or gloss can occur and this is known as print mottle. Latex composition has been shown to have a significant influence on both back-trap mottle and fountain solution removal by the paper during commercial printing [3].

It is a commonly held belief that non-uniformities in the coating structure [7], caused by basesheet defects and poor basepaper formation, are major causes of print mottle. Poor coating coverage of the basepaper has also been linked with print mottle, and Kolseth presented results, which show a good correlation between the occurrence of mottle and coating thickness variation [4]. Another cause is thought to be uneven binder distribution [5] and Van Gilder has recently shown that clustering of latex particles can occur in the wet coating color and this may carry through to the dry coating and result in back trap mottle [6]. Kim-Habermehl et al [7] reported that print mottle was linked to the X-Y spatial distribution of surface macro-pores on the coating, and that this had a more significant influence than the number, size, and size distribution of these macropores. Chinga and Helle used electron microscopy and image analysis to study the fraction of closed area in a rectangular area of paper 0.4x0.5 mm in size and showed that the tendency for mottle correlated with the closed area variation (standard deviation) [8]. Gane suggested that print mottle may result even if a surface is homogeneous, due to a stochastic failure within the ink film [9][10]. He suggests that mottle can result from regions of the paper with good ink adhesion, and regions where adhesion failure has occurred. Poor emulsification of fountain solution by the ink or slow absorption into the coating structure can also result in a higher mottle tendency.

Nonuniformity on the scale of 0.1 – 10 mm in size has been reported as important for paper as this is the scale of paper flocs and fibres and of human perception [11]. Johansson et al suggest that a size of 1 – 8 mm is the region of interest when studying print mottle [12].

Measurement and quantification of surface porosity has proved difficult in the past. Methods such as mercury intrusion porosimetry are widely used in the paper industry, but will deliver a bulk porosity measure, which contains contri-

butions from both the surface layers and the bulk of the coating. Various stain techniques such as the K&N or red wipe tests have also been used to obtain a measure of surface porosity, but are also influenced by the roughness features of the substrate. Indeed the question is often raised concerning the differentiation between a surface roughness feature and a pore. Recent work by Shen et al [13] used a novel liquid bridge probe to determine the surface absorption uniformity for a number of coated papers. They found a good correlation between the absorption uniformity and back-trap mottle, but this did not seem to be linked to surface latex concentration uniformity.

The aim of this study was to relate the structural characteristics of the coated papers to the occurrence of print mottle. The coated papers were subjected to a wide range of analyses, including spatial variations in roughness, gloss, refractive index (RI), and coating coverage (using burnout analysis). The short time water absorbency of the papers was also assessed using Fibro DAT and MicroDAT contact angle and absorption testers. This is similar to the studies previously carried out on mottle by Lindberg and Johansson, which can be found in references [14] and [12].

METHODS

Paper preparation

Three different coating pigments were used – PCC, UK coating kaolin, and GCC. The pigment properties for these are given in **Table I**. The coated papers were prepared on a pilot coater at KCL in Finland. The coating formulation consisted of pigment, latex, CMC thickener, PVOH, and OBA. These were applied at their maximum runnable solids using a Jet applicator with a bent blade at 1000 m/min. A coat weight of 14 gm^{-2} was applied to both sides of a woodfree basepaper. The coatings were calendered using an Optiload calender at 700 m/min for 5 nips. The pressure was varied to obtain an online gloss of about 65%; pressures required were 200, 120, and 300 kN/m for the PCC, kaolin, and GCC, respectively.

Paper testing

The coated papers were conditioned at 50% relative humidity and 23°C for at least 24 hours before standard laboratory paper testing was performed. A DataColor Elrepho 3300 was used to measure the optical characteristics of the papers using D65 illumination both calibrated with UV content and with the 400 nm UV cut off filter in place; paper brightness (D65), opacity (DIN), whiteness (D65) and L,a,b (D65). TAPPI 75° gloss on Hunterlab and PPS at 1000 kPa on PrintSurf were determined.

	PCC	platey kaolin	GCC
Brightness	96.1	87.6	94.7
Yellowness (DIN)	1.4	4.4	1.4
Sedigraph (%)			
-2 µm	97.5	93	96
-1 µm	91.3	78.2	76.8
-1/4 µm	8.6	26.8	28.3
D50 (µm)	0.51	0.45	0.47

I. Pigment properties.

The dynamic water absorption of the coatings was measured using a FibroDAT 1100. A water drop volume of 3 µl was used and the drop volume, base, height, and contact angle were measured with time after application. This instrument was also used to determine the surface energy of the coatings, using bromonapthelene and water. An Emtec ultrasonic device was also used to determine the speed of water penetration into the coated papers as described by Daun [15].

The uniformity in water absorption was measured using equipment constructed by STFI-Packforsk, known as a Micro Drop Absorption Tester (Micro-DAT) [16]. Pico liter size drops are generated by a piezoelectric actuator. The drop passes a nozzle with a diameter of 50 µm and hits the paper surface with a velocity of 1.5 m/s. The drop volume used was 320 pl which gives a drop diameter of 84 µm in air. When the drop hits the paper surface it immediately (< 8 ms) forms a diameter of about 120 µm, which gives a contact area of about $7.8x10^{-3}$ mm^2. The drop height becomes about 50 µm. The contact area between the drop and the paper is constant during the course of the absorption, i.e. no further lateral spreading takes place. The change in drop size is registered using a high speed (up to 120 fps) CCD camera. The time for the drop to disappear was measured in this study. This is a combination of absorption and evaporation. Forty drops were measured for each paper and the mean absorption/evaporation time, standard deviation, and coefficient of variation (COV) were calculated.

Coating pore size distributions were determined by mercury porosimetry. Measurements were made using a PASCAL 240 Porosimeter (CE Instruments). Coated paper samples of approximately 20 cm^2 were evacuated for 10 minutes before being measured. Corrections for the compression of mercury, glassware, and oil phase were taken into account by running a blank experiment. Curve fitting programs were used in order to separate the contribution of the basepaper from the coating component. This allowed the average pore size and volume of the coating layers alone to be determined.

A burn out test was used to determine the coating color coverage of the basepaper. In this test, the paper is soaked in a solution of ammonium chloride in water and ethanol. It is then dried and heated at 200°C for 10 minutes. The blackened sample is then scanned in order to obtain a measure of coating coverage.

The DOMAS image analysis system was used to characterize the uneveness of the prints and burnout samples. The power spectrum model was used for both of these measures. The prints were also ranked visually by a panel of 8 laboratory staff. The prints were given a score out of 10 depending upon their degree of evenness, where 10 represented a high degree of mottle and 1 no mottle.

Surfoptic imaging reflectometer

The imaging reflectometer [17] is a new instrument for quantitative analysis of surface optical reflectance and appearance and is an updated version of the instrument previously described by Gate and Leaity [18]. The instrument uses imaging technology to map the 3-D angular distribution of light forward scattered from surfaces in the range ± 10° about an angle of incidence of 75°. The macro-roughness can be derived from the width of this angular distribution and is designated FWHM. It also uses polarized light at two wavelengths to determine the refractive index (RI) and optical micro-roughness (roughness features ≤ wavelength of light). Some applications for the paper industry are given in reference [19]. In this study, the reflectometer was used in mapping mode to produce maps of RI, macro and micro-roughness and gloss for both the unprinted and printed papers.

The printing trial was carried out at Lindgren & Söner in Gothenburg, Sweden, using a KBA Rapida 105 press with 6 units and 2 varnish units. The inks used were commercial inks from Sun Chemicals: Ecolith (conventional sheetfed) and SunFountain 460 was used as the fountain additive. More details from this study are given in reference [20].

Laboratory offset print testing was performed using an IGT. Prints were made both on the dry paper and on a predamped (litho) area. The color densities of all prints were measured using a Gretag Macbeth densitometer (D186 Zurich) [21]. The ink setting behavior was studied in the laboratory by following the development of the ink tack force using the Ink Surface Interaction Tester (ISIT™), (SeyGan Ltd, Lostwithiel, UK), the principle of the technique is described by Gane and Seyler [22].

The areas scanned in each of these tests, the scaling and treatment of the data are summarized in reference [23]. The scanned areas were processed using a Fast Fourier Transform (FFT), in order to determine the degree of variation occurring at different length scales. The % coefficient of variation (%COV), which is the standard deviation of the data divided by the mean value, was used to quantify the variations as in reference [14]. The 40% black halftone print data were not FFT treated, as artifacts arising from the dots themselves could invalidate any results.

	PCC	platey kaolin	GCC
TAPPI gloss 75°	64	61	64
CIE-Whiteness D65 (+UV)	103.1	87.1	100.3
Fluorescence	14.9	9.2	15.3
Brightness D65 (R457) (-UV)	86.5	81.3	83.8
Brightness D65 (R457) (+UV)	90.5	84	88
Opacity	95	96	94
PPS 1000 kPa (µm)	0.78	0.74	0.86
Refractive index (RI)	1.22	1.4	1.38
Macroroughness FWHM (°)	2.9	2.9	2.8
Microroughness (nm)	80	100	80
Hg pore size (nm)	56	42	35
Hg pore volume (cm3/kg)	39	19	16
Surface energy total (mJ/m^2)	52	49	46

II. Properties of the coated papers.

	PCC	platey kaolin	GCC
Unprinted paper gloss (75°)	63.5	61.1	64.2
100% black gloss (75°)	76.2	86.9	81.8
400% black gloss (75°)	74.3	79.6	77
Unprinted paper gloss (60°)	29.1	27.0	28.9
100% black gloss (60°)	48.3	57.2	55.9
400% black gloss (60°)	48.8	52.0	53.0
Unprinted paper gloss (20°)	11.4	11.8	11.2
100% black gloss (20°)	27.8	33.3	34.8
400% black gloss (20°)	27.1	29.4	31.1
100% black density	1.58	1.62	1.66
100% cyan density	1.25	1.24	1.26
100% magenta density	1.23	1.23	1.22
100% yellow density	1.15	1.11	1.14

III. Print gloss and density for commercially printed papers.

	PCC	platey kaolin	GCC
Print gloss (dry)	76	88	79
Print gloss (litho)	65	71	69
Print density (dry)	1.42	1.42	1.43
Print density (litho)	0.45	0.96	0.8
L/D density ratio	0.32	0.68	0.56
Ink tack development			
Time to max tack (seconds)	7	44	7
Time to half tack decay (seconds)	23	114	52

IV. Laboratory printed papers.

RESULTS AND DISCUSSION

Structure and properties of the coated papers

The coated paper properties are summarized in **Table II**. It can be seen that although the papers are similar in their gloss and roughness, they have very different porosity characteristics, with the PCC coating having the largest average pore size and volume. The surface energy of the coatings is similar, as would be expected from coatings containing the same formulation (latex and thickeners).

Printed paper properties

In the pilot print trial the papers were printed to a constant density and there was little systematic difference between the 3 coatings. The print glosses however did vary (**Table III**). The laboratory print results are given in **Table IV**.

It can be seen from Table 3 that the print gloss is higher for the kaolin coating and lowest for the PCC coating. This trend relates to the ink setting rate of these gloss papers. The PCC coating has the fastest ink setting rate, as shown by the results in Table IV, and the kaolin has the slowest ink setting rate. These results were confirmed by using a set-off test, which

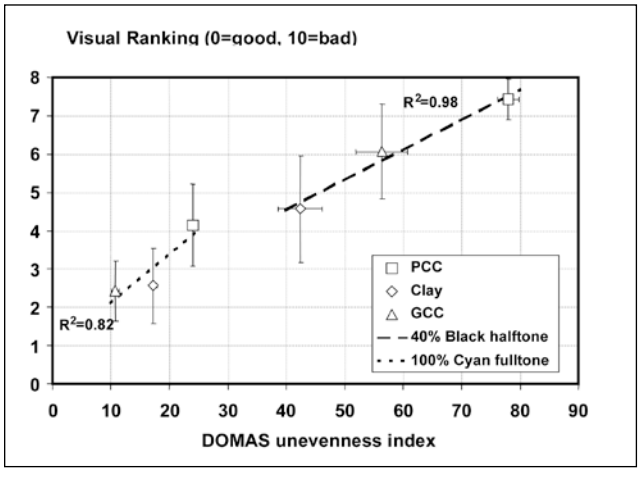
determines differences in set off density with time, until no set off occurs. The results were PCC 1.5 minutes, GCC 2.5 minutes and kaolin 4 minutes. The print gloss is generally lower for fast ink setting coatings as discussed extensively in the literature [24],[25],[26]. The ink setting rate is a relevant measurement for the study of print mottle, and it has been often noted that a very fast ink setting substrate may experience problems with backtrap mottle and piling.

Mottle analysis

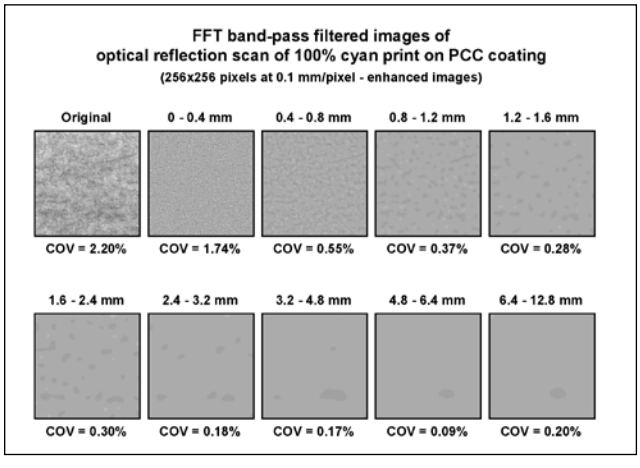
The DOMAS unevenness analysis of the pilot printed samples showed similar trends to those observed visually (**Fig. 1**). The black halftone prints showed a higher degree of mottle than the 100% cyan prints, with the PCC coating having the highest degree of mottle and the kaolin coating having the lowest. In the 100% cyan area, the prints showed less mottle tendency and it was more difficult to differentiate between the 100% kaolin and 100% GCC coating. The PCC coating was clearly the worst.

Analysis of the printed surface

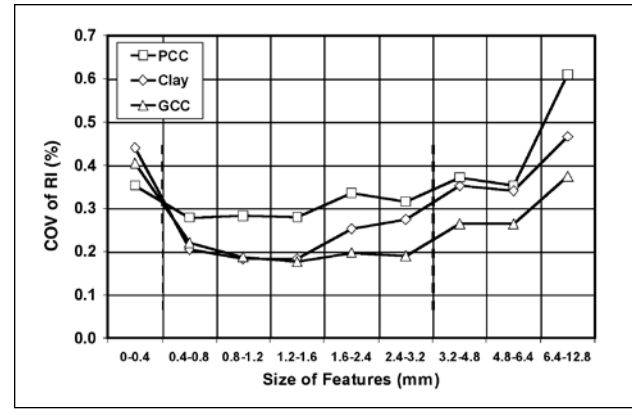
Images of the printed surfaces were characterized using an FFT band pass filter in order to determine the size at which the differences were occurring. The % COV was then calculated at each scale.



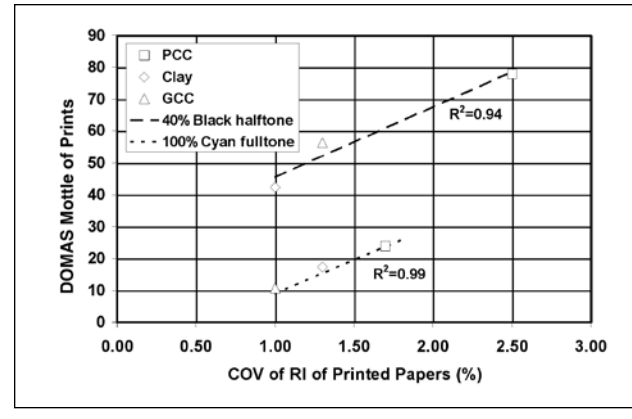
1. Visual and DOMAS mottle results for printed papers.



2. Print mottle images for 100% cyan print on PCC coating after FFT band-pass filtered images.



3. %COV of the FFT RI map of the cyan printed paper, showing a higher variation in RI at length scales > 0.4 mm for the PCC printed surface.



4. Correlation between RI COV of printed papers and DOMAS print mottle.

Figure 2 shows the images of the print mottle for the cyan printed PCC coating after it has been band pass filtered using the FFT. It can be seen that the greatest degree of mottle is occurring at relatively small length scales (<3 mm). Note that this is what the DOMAS mottle system measures, and is not necessarily what the eye sees. Similar patterns were observed for the other printed papers.

The prints were also analyzed using the imaging reflectometer and the RI COV as a function of feature size for the different cyan prints is shown in **Fig. 3**. RI is a measure of surface composition and for a printed surface is expected to be sensitive to variations in ink coverage or density. At a length scale of between 0.4 and 3.2 mm, the PCC print shows the greatest RI COV of all the pigments and this is the length scale at which mottle is most evident to the human eye [14].

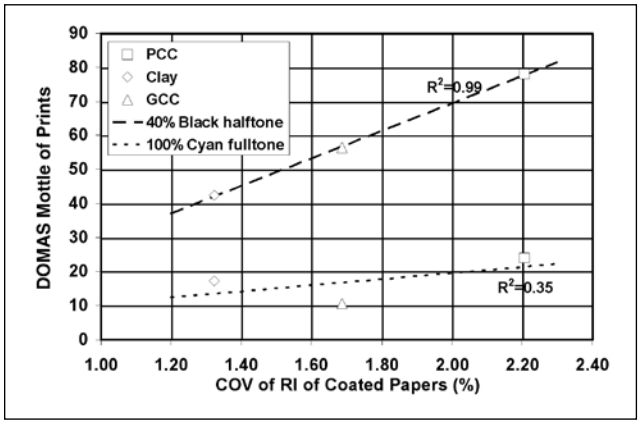
There was a good correlation between the print mottle of the DOMAS system and the printed RI COV as shown in **Fig. 4**. This data was not passed through the FFT, and is an average of all length scales. Figure 4 also illustrates the higher DOMAS print unevenness mottle that was visible with the

halftone print compared to the full tone print. An increased print mottle was also seen with a higher print RI COV. Correlations between DOMAS mottle indexes and other properties (such as micro- and macro-roughness) were poor.

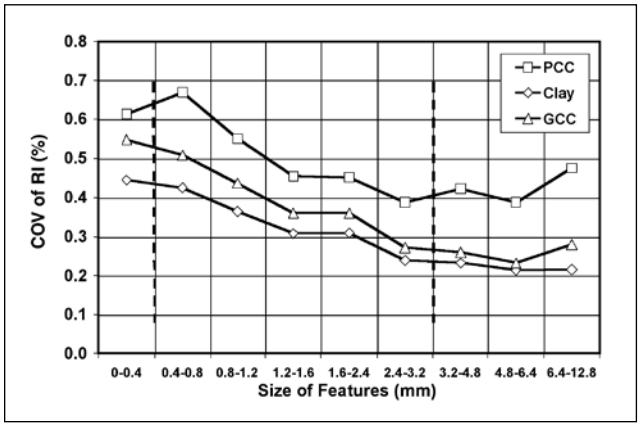
Analysis of the paper coating structure to determine the cause of the print mottle

The coating structure of the three papers before printing was similarly examined. **Figure 5** shows a good correlation between the RI COV of the coated paper before printing and the unevenness of the halftone print. In a coated paper RI is particularly sensitive to surface coating structure and in particular, surface void fraction [19]. Therefore, the fact that spatial variation in refractive index correlates with print mottle suggests that surface porosity variations may be responsible for the mottle in the case of the halftone prints. It is likely that either slightly more dot spread has occurred or that slightly different amounts of ink are transferred to the paper from the blanket from point to point, depending upon local surface porosity variations.

However, the correlation between the RI COV and the full tone mottle is poor. Therefore, some mechanism other than just spatial variation in surface porosity must be important for the mottle observed in the cyan prints. Other structural and porosity features were therefore assessed for these coatings to see which had the best correlation with the full tone mottle (as discussed below).



5. Correlation between paper RI COV and print mottle for halftone regions, but not for fulltone regions.



6. COV of coated paper RI at different length scales, showing greater variation for PCC coating at all length scales.

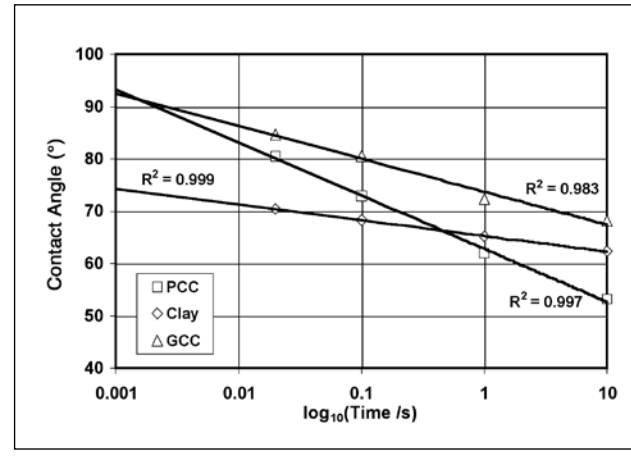
Figure 6 shows the scale of the RI variation for the coated papers. The PCC coating has a higher COV at all of the length scales measured. These data may be compared with those in Fig. 3 for the cyan printed paper. It was not possible to carry out the FFT analysis on the RI maps of the halftone printed sheets due to artifacts caused by the dot pattern.

Water absorbency at very short time-scales after application

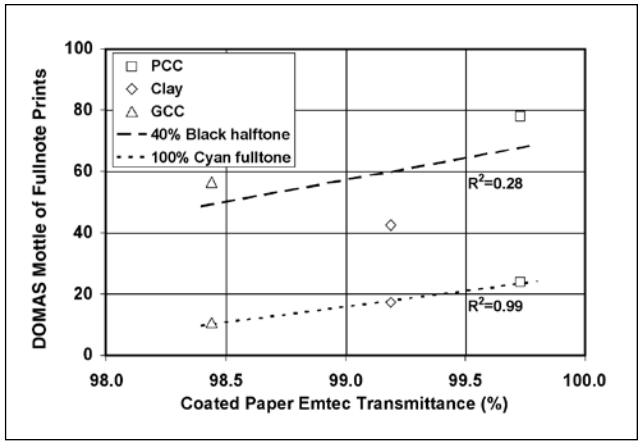
Extensive testing of the papers has shown some unusual features. At very short time-scales (<0.5 s), the 100% PCC coating has a lower water absorbency than the kaolin and GCC coatings. At around 0.5 – 2 s after water application, the PCC becomes far more absorbent than the other coatings. This would also agree with the faster ink setting rate as determined by the ink on paper tack tester, which occurs more than 2 s after printing. The water absorbency of the coatings is shown in **Fig. 7** from the Fibro DAT contact angle and absorption tester.

Laboratory printing of the coated papers showed that, for the PCC paper, there was severe rejection of the ink and a water interference mottle was observed (Table II). The predamping occurs at less than 1 s before the ink is applied on the IGT, and it is necessary for the coating to very quickly absorb this water to prevent ink rejection and mottle. This result therefore confirms those of the Fibro DAT. Similar findings have been made by Schoelkopf et al[27].

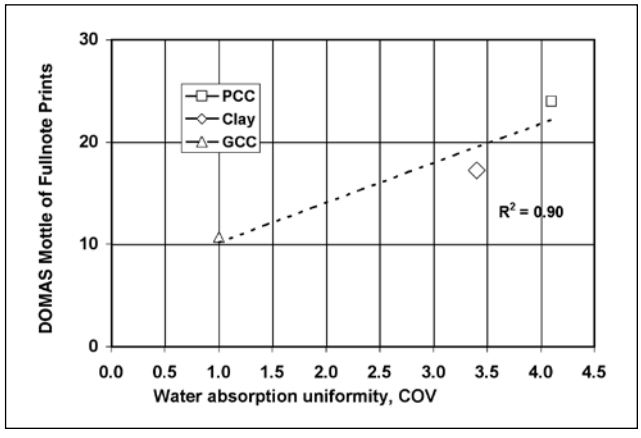
The correlation between the short time water absorbency as determined using an Emtec water absorbency tester and the print mottle is shown in **Fig. 8**. A good correlation exists for the full tone area, but less so for the halftone. In the full tone region of the print, it is therefore likely that the mottle observed is due to water interference and point to point vari-



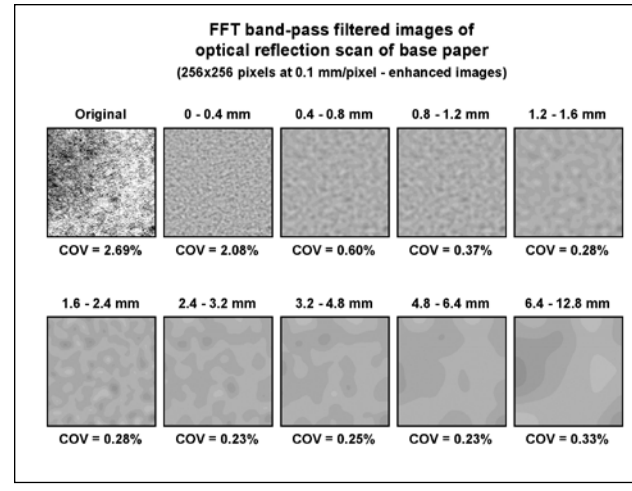
7. Fibro DAT contact angle measurements made with water. At very short times, the PCC has a higher contact angle than the other coatings.



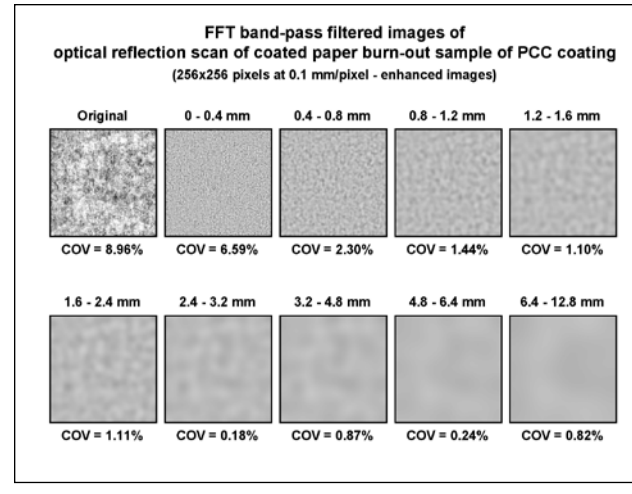
8. Good correlation between the short time-scale water absorbency and print mottle for the fulltone cyan print but not the halftone.



9. Correlation between the print mottle on the 100 % cyan print and the non-uniformity in water absorption as measured using the Micro-DAT.



10. The highest degree of variation for the basepaper occurred at the smallest length scales.



11. FFT band passed images of the PCC coating burnout. The other coatings had similar scales of variation.

ations in the water absorption of the coating layer. In the black halftone area, absorption of water is not an issue, as this is the first color applied.

The mottle features observed in the fulltone (cyan) prints and in the halftone prints probably arise from different origins related to the different printing mechanisms: in the case of the halftone, data suggests that point-to-point variations in surface porosity across the coated sheet are important, affecting either dot spread or ink transfer; in the case of the fulltone prints, gross differences in the water absorbency of the coated sheets produce a water interference mottle, which is less strongly correlated to surface porosity variations.

These results were also corroborated by the point to point variation in water absorbency as determined by the Micro-DAT water drop application system. The COV of water absorption into these coated papers showed the greatest variability with the PCC. A good correlation was observed between the DOMAS print mottle of the cyan printed area and the COV water absorbency as shown in **Fig. 9**. There was a poor correlation between the water absorbency and the grey halftone mottle.

Scales of mottle

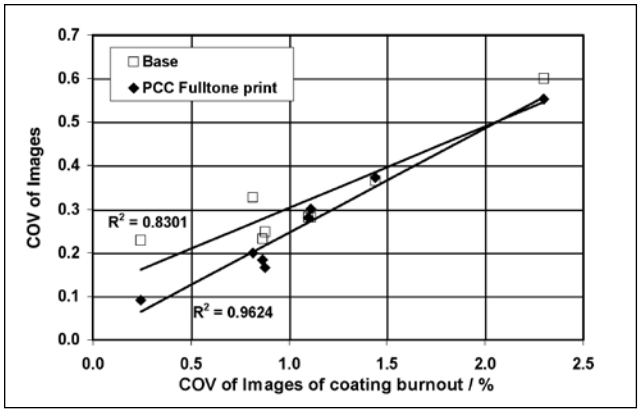
A comparison of the scale of variation in the basepaper (optical reflectance), coating layer (burn-out) and prints (optical reflectance) was made by comparing the COV at each length scale. The images for the basepaper are shown in **Fig. 10**, and the burnout in **Fig. 11**.

The basepaper images showed that the greatest degree of variation was occurring in the smallest length scales measured, up to 0.4 mm in size. This variation was reproduced in the subsequent coating burnout analysis and also in the variations in the final printed sample.

Figure 12 shows the correlation between the variations in the burn-out images, the base paper reflection images, and the print mottle for the PCC coated paper. A good correlation is shown to exist between them.

SUMMARY AND CONCLUSIONS

The coated papers were characterized in terms of their rough-



12. A correlation exists between the scale of variations occurring in the basepaper and the coating layer (burn-out), and the coating layer and the print, shown for the PCC coating.

ness and coating structure. They were similar in gloss and smoothness, but very different in porosity. The PCC coating had the highest pore volume and the largest pores, and this resulted in superior optical properties, with a higher brightness, whiteness and opacity.

A good correlation was found between the visual and DOMAS assessment of print mottle. In the halftone area, the PCC had the worst mottle followed by the GCC paper and the kaolin coating had the least mottle. The 100% cyan full tone prints all had less mottle than in the halftone area. In this case, the PCC coating was clearly the worst and there was little difference between the kaolin and GCC coatings.

One objective of this work was to examine how novel techniques such as the imaging reflectometer could be used to gain improved understanding of how a coated paper influences print mottle. Refractive index is a useful measure of surface composition. Mapping RI over a surface allows spatial variations in surface porosity (for coated sheets) or ink distribution (for printed sheets) to be assessed. These data have been compared with various mottle analyses using DOMAS and spatially filtered images. For the halftone prints, the scale and distribution of visual mottle features appears to correlate with RI 'mottle' in the coated paper surface, and it is suggested that spatial variations in surface porosity lead to variations in ink transfer or dot spread leading to observed mottle features. The corresponding correlation was found to be weak for the fulltone prints. However, water absorbency tests and further laboratory printing trials indicate that the mottle in the fulltone prints is determined by water interference. This appears less influenced by spatial variations in surface porosity in the coated paper.

When looking at the scale of the print mottle, it could be seen that the scale of variation was similar for the basepaper formation and the coating coverage as determined by the burnout test.

This work has highlighted the need for pigment engineering in order to achieve optimum print and paper properties. The coating porosity variations need to be minimized by good coverage of the basepaper by the coating, in order to reduce print mottle. The coating surface absorption characteristics also need to be optimized in order to prevent short timescale rejection of the ink and water interference mottle.

Further work would be useful to examine in greater detail the precise relationship between visual mottle features in the printed paper and the 'invisible' RI mottle in the coated paper before printing. **TJ**

ACKNOWLEDGEMENTS

Sincere thanks are expressed to Dr. Sanna Rousu and Mr. Jan Gustaffson from Stora Enso, for allowing use of samples and printing results from our recent project.

Received: November 16, 2006
Accepted: July 10, 2007

LITERATURE CITED

1. Jordan B., Aspler, J., O'Neill, M., Chasle, J., 1998 *Pan Pacific and Int. Printing and Graphic Arts Conf.*, Quebec Oct., PAPTAC, CANOPY, Toronto, ISBN 1-896742-39-4, 13(1998).
2. Field, G.G., *Proc TAGA 1985*, Rochester, p.382.
3. Purfeerst, R.D., Van Gilder, R.L., *Proc. TAPPI Coating Conf*, 1991.
4. Kolseth, P. (2004): Paper presented at "New Concepts in Paper Surface Treatment", Stockholm, October 19-20, 2004.
5. Zang, Y.H., Aspler, J.S., *J Pulp & Paper Sci.*, 24 (5) 141(1998).
6. Van Gilder, R, *TAPPI J.*, 3 (1), 2004.
7. Kim-Habermehl, L., Wittbrodt, E., Mccoy, B., Langolf, M., Pollock, M., Roper, J., Stolarz, J., Rolf, M., 1998 *Pan Pacific and Int Printing and Graphic Arts Conf*, Quebec Oct., PAPTAC, CANOPY, Toronto, ISBN 1-896742-39-4, 71(1998).
8. Chinga, G. and Helle, T. JPPS 29:6, 179(2003).
9. Gane P.A.C Proc. 2001 Tappi Coating Conf. (2001).
10. Ridgway C.J. and Gane P.A.C., Paper presented at the PITA Coating Conference, Edinburgh, March 4-5 61(2003).
11. Waech T.G.,Pan Pacific and Int. Printing and Graphic Arts Conf., Quebec Oct. 1998, PAPTAC, CANOPY, Toronto, ISBN 1-896742-39-4, 57(1998).
12. Johansson P-A., Lundby H., Lindberg S., Nystrom S., In J. Anthont Bristow (Ed), Advances in Colour Reproduction. Proc 28th Res. Conf of the Int. Assoc of Research Institutes for the Printing Information and Communication Industries. GATF, Pittsburg, PA, USA.
13. Shen Y., Vyorykka J., Bousfield. D.W., Van Heiningen A., Donigan D., Proc 2004 Int. Printing and Graphic Arts Conf., Vancouver, 71(2004).
14. Lindberg S., PhD Thesis "Perceptual Determinants of Print Quality", Department of Psychology Stockholm University, (2004).
15. Matias Daun PhD thesis, 2006 Darmstdat University.
16. Svanholm, E "Printability and ink-coating interactions in inkjet printing" Dissertation, Karlstad University, Faculty of Technology and Science, Chemical Engineering, ISBN 91-7063-104-2, (2007).
17. www.surfoptic.com

18. Gate, L.F., Leaity, K., Proc. TAPPI Coating Conf, 1991, Tappi Press, Atlanta, 473(1991).
19. Elton, N.J. & Preston, J.S. Proceedings of 2005 Tappi Coating Conference, Toronto, April (2005).
20. Rousu S., Gustafsson J., Preston J.S.,Heard P.J., Proc. Tappi / TAGA joint day Toronto, April (2005).
21. Gretag Macbeth densitometer (D186 Zurich),Unpolarized light 2856K ANSI,Filter 47/U ANSI Status.
22. Gane P.A.C., Seyler E.N, Tappi Coating Conf. San Diego, Tappi Press, Atlanta, GA, 243(1994).
23. Full version of this paper, which is to be found in Proc 2006 Tappi Coating Proc. Atlanta, GA April (2006).
24. Desjumaux D.M., Bousfield D.W., Donigan D., Proc. of 1996 Coating Conf. Symposium, (1997).
25. Donigan D.W., Ishley J.N., Wise K.J., TAPPI J.,vol. 80, No 5, May (1997).
26. Preston J.S., Nutbeem C., Parsons D.J., Jones A., Paper Technol., Vol. 42, No. 2, March (2001).
27. Schoelkopf J., Gane P.A.C., Ridgway C., Matthews G.P., Nordic Pulp & Paper Res. J., 15, (5), 422(2000).

INSIGHTS FROM THE AUTHORS

A mottled print is often considered unacceptable to a printer or publisher and can be noticeable to a reader. Mottle is influenced by many different paper, ink, and press variables and there is still plenty of room to further understand it.

The imaging reflectometer is a relatively new instrument that is capable of mapping the paper or print in terms of its effective refractive index. Much in the literature supports uneven point-to-point surface porosity on the substrate as a reason for print mottle. We wanted to see if we could capture this uneven surface porosity using a refractive index map and relate it to occurrence of print mottle.

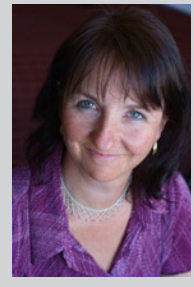
We also wanted to see if the scale of variations occurring in the basepaper carried through into the coating distribution and finally into the scale of variations occurring in the final print.

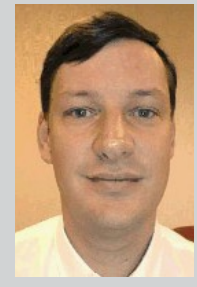
We found a good correlation between porosity and print mottle for the black halftone print, but not for the solid cyan print. We needed to conduct further analyses of the coatings to determine that the areas had different water absorption properties that also caused mottle to occur.

An interesting finding was that mottle from the black first color station and cyan prints from the second were caused by different mechanisms.

If the causes of mottle were understood, paper mills could design base and coating layers that would reduce point-to-point variations that lead to visually disturbing print mottle. Further work would be useful in examining the precise relationship between visual mottle features in the printed paper and the refractive index mottle in the coated paper before printing.

Preston is senior printing scientist and Hiorns is senior scientist, Imerys Minerals Ltd., Cornwall, United Kingdom. Elton is managing director, Surfoptic Ltd., Cornwall, United Kingdom. Ström is research manager, STFI-Packforsk AB, Stockholm, Sweden; email Preston at janet.preston@imerys.com.


Preston


Hiorns


Elton


Ström



» *Standards and TIPs Online. On Demand.*

Our *Standards and TIPs Online* subscription gives you point-and-click access to the most current TAPPI Test Methods and Technical Information Papers (TIPs) from anywhere in the world. You will enjoy the convenience of online access – all you need is a username and password. Simply log in and you're ready to go. Visit **www.tappi.org/standardsonline** or call TAPPI PRESS at 1 800-332-8686 (U.S.), 1 800-446-9431 (Canada) or +1 770-446-1400 to subscribe.