

Impact of local variation in coating structure on uniformity in print gloss

GÖRAN STRÖM AND JANET PRESTON

ABSTRACT: Point-to-point variation in the gloss of a print has been reported to be one of the most visually disturbing aspects of a printed paper. This work sought to determine the effect of pigment and binder content on the coating structure, surface properties, and print gloss variations occurring in a printed offset paper. The results from a pilot coating and full-scale sheet-fed offset printing trial are reported, with special emphasis on uniformity in print gloss. The effect of calendering and print impression also was considered. Uniformity in print was analyzed in terms of print gloss variation (PGV) in the heavily inked areas. Calendering and point-to-point variation in coating porosity had a significant effect on PGV. The observed nonuniformity in print is discussed in terms of local variations in coating porosity and local variation in coating micro-roughness. Under the conditions investigated, uniformity in surface porosity decreased with increasing latex content, but increased with clay content.

Application: Results from this study will enable papermakers to design paper that does not suffer from visually disturbing print gloss variations.

The gloss of prints on coated paper is of significant importance for the quality of the printed product, and the factors that control print gloss have been important research topics for more than a half century. The first review article (to our knowledge) on this subject was published in the early 1960s by Fetsko and Zettlemoyer [1]. They discussed the importance of the paper (e.g., smoothness and porosity), ink properties (e.g., pigment load and vehicle viscosity), and printing condition (e.g., ink film thickness).

The topography of the ink film is a determining factor for the final print gloss [2-4], and most likely the most important one, but the refractive index of the ink film also affects print gloss [5]. Most published work has focused on the effect of coating surface structure and that of leveling of ink filaments after ink transfer [2-12]. Both factors have a strong impact on the structure of the ink film, and thus on the print gloss.

When considering the surface structure of the coated paper it is important to divide the structure into a macro-scale level, most often induced by the base paper, and a micro-scale level induced by coating pigment size and agglomeration, as discussed by Oitinen [2]. The ink film follows the topography of the coating, but because of the ability of the ink film to fill out the micro-roughness, the paper becomes smoother on the micro-scale after printing, thus gaining higher gloss [2-4,6,7]. The macro-roughness is difficult to fill out when considering normal ink layer thickness (1-3 μm). Because macro-roughness normally decreases with paper grades that are matt coated, silk coated, or gloss coated, the print gloss for the different grades increases in the same way [3]. Despite the

general role just described, it is possible to produce low-gloss coated papers with high print gloss, if the macro-roughness is kept low and the coating gloss is tailored by a thin and non-continuous layer of particles [13].

Coating absorbency has a negative effect on print gloss, as demonstrated by Lepoutre and coworkers [14]. This phenomenon was later explained to be the result of poor ink vehicle hold out [1] and poor ink leveling [6,8-10]. The ink film transferred to a substrate with high absorption potential will quickly gain in viscosity, which results in poor ink leveling. The frozen filament pattern will make the ink film rough and show a low print gloss. Thus, high surface porosity and ink interactive latex binders are factors that promote ink setting rate, which in turn will give lower print gloss compared to a closed surface with noninteractive latex [3-12]. The effect of ink leveling on print gloss is most pronounced for smooth surfaces [6]; thus, a smooth closed surface is the optimal case for generating a high print gloss.

Solids within the ink film, such as ink pigments and wax particles, also contribute to the smoothness of the ink film when protruding from the binder layer [5]. The ink film also might be disturbed by fiber rising induced by the fountain solution during printing. This phenomenon is most common on uncoated and coated magazine paper [15-18] and seldom seen on fully coated fine paper.

Nonuniformity in print is basically nonuniformity in print density, which is referred to as print mottle, and nonuniformity in print gloss, which often is referred to as gloss mottle. Nonuniformity in an offset print is believed to be the result of local variations in paper properties, particularly surface prop-

erties such as smoothness and porosity. To some extent, it also may be generated or enhanced by the conditions and settings on the printing press. Thus, to some extent, the impact of coating nonuniformity can be minimized by proper settings on the press.

Fetsko and Zettlemoyer [1] also discussed uniformity in print, noting that lack of uniformity in print gloss is the greatest deterrent to any print quality characteristic. Yet, the mechanism behind this phenomenon is not fully understood. Although gloss variation of unprinted and printed coated paper has been shown to increase with calendering nip pressure [18], there appears to be no simple correlation between gloss variation of the coating and that of the print [18,19]. However, direct measurements of the topography of areas with low and high gloss have shown that the areas that show high gloss also are much smoother [20,21]. The open literature also presents various techniques to measure variation in print gloss and correlations between measured values and perceived print gloss variation [19,20,22-25]. In this paper, we show experimentally and discuss the effect of coating nonuniformity on print gloss variation.

Two sets of coated papers were produced at pilot coating and calendering facilities at Vestra in Munich, Germany. The first set contained calcium carbonate only and different amounts of latex. In the other set, part of the calcium carbonate was exchanged for clay in three steps at constant binder content. The coated papers were printed before and after calendering, which divided the printed material into four different groups. The general print quality (e.g., ink setting rate, print gloss, and ink scuff) was evaluated. Special emphasis was placed on print gloss variation occurring in the 400% printed surfaces (i.e., surfaces printed with all process colors in full tone).

EXPERIMENTAL

Pilot coating

The pigments used for the pilot coating trial were a mixture of ground calcium carbonate (Carbital 90) and platy development clay, with an average particle size (d50) of 0.5 µm and shape factor of 27. Both were supplied as dispersions from IMERYS Minerals (Par, England). The binder and thickener were Dow DL 920 (Styron Europe; Horgen, Switzerland) and FinnFix 5 (Metsä Specialty Chemicals; Äänekoski, Finland)

with the addition of 11 pph and 0.5 pph, respectively. Coating solid contents are given in **Table I**. The base paper was composed of a mixture of chemical and mechanical pulps. The grammage was 60 g/m². The Parker Print-Surf (PPS-10) roughness for the base paper was 7.0 µm on the felt side and 5.0 µm on the wire side.

The pilot coating trial was conducted at the VESTRA pilot plant in Munich. The coating was carried out on the felt side in a blade coating unit with a roll applicator, using a stiff blade at a 35° angle. The coating speed was 1000 m/min and target coat weight was 12 g/m². The formulation containing 40 pph clay also was applied to a coat weight of 8 g/m². To reduce two-sidedness, 10 g/m² of the same coating was applied to the opposite side. A target moisture content of 5% was achieved using a combination of infrared heating and air foils for drying. The papers were calendered in an 11-nip supercalender at 300 m/min and a line load of 260 N/m, which gave paper gloss of 53±3%.

Full-scale printing

The paper was printed in a commercial six-color sheet-fed offset printing press (a Heidelberg Speedmaster 74; Heidelberg, Germany). The ink was LithoFlora FTX (manufactured by XSys, now Flint Group Sweden; Trelleborg, Sweden). The fountain solution contained 2% Aqualith Z (Flint Group Sweden) and 8% isopropyl alcohol. The print impression was 0.10, 0.18, and 0.25 mm. The printing order was black (K), cyan (C2), magenta (M), and yellow (Y). The print impression is the deformation of the rubber coated set-off roller resulting from the pressure from the impression cylinder. Thus, a print impression of 0.10 mm means that the rubber blanket of the set-off cylinder becomes deformed by 0.1 mm. A constant print density was used as press setting for all the samples. The density was measured off-line during the printing. Reference values were K 1.90, C2 1.50, M 1.50, and Y 1.40.

Laboratory tests

The laboratory tests included the following:

- Optical properties using a Datacolor Elrepho 3300 (from Datacolor; Lawrenceville, NJ, USA) with d/O° geometry, D65 Illumination, 10° Observer ISO R457, including brightness (TAPPI 525 om-12 “Diffuse brightness of paper, paperboard and pulp”), CIE Whiteness (ISO

Formulation	1	2	3	4	5	6
Carbonate, pph	100	100	100	90	80	60
Clay, pph	0	0	0	10	20	40
Latex, pph	9	11	13	11	11	11
CMC, pph	0.5	0.5	0.5	0.5	0.5	0.5
Solids, %	69.7	70.5	70.5	67.8	66.8	64.5
Coat weight, g/m²	12	12	12	12	12	12 and 8

I. Coating color formulations for the pilot coating trial.



1. Original image (left) and two fast Fourier transform band passed filtered images of coating 1. The original image had a coefficient of variation size class 0-1 mm and had a coefficient of variation of 1.03% while the right image was in the size class 2-3 mm and had a coefficient of variation of 0.33%. In these images, the refractive index of pure black was 1.30 and of pure white was 1.43.

11475:2004 Paper and board – “Determination of CIE whiteness”), and opacity (DIN 53146 “Testing of paper and board - Determination of opacity” and TAPPI 519 om-6 “Diffuse opacity of paper [d/0 paper backing]”).

- Paper and print gloss using TAPPI T 480 “Specular gloss of paper and paperboard at 75 degrees” (print gloss was measured after laboratory printing).
- Surface roughness (PPS) using TAPPI T 555 om-94 “Roughness of paper and paperboard (print-surf method)”; micro- and macro-roughness from imaging reflectometry [26-28].
- Pore structure (mercury porosimetry using a AutoPore IV from Micromeritics (Norcross, GA, USA) and variation in surface porosity (imaging reflectometry) [26-29].
- Characterization of ink setting using an ink surface interaction tester [30]. The ink setting rate is defined as the slope of the ink tack rise and ink setting time is defined as time until the tack decay has reached half the value of the maximum tack force.
- Ink scuff was measured using an in-house technique where the unprinted paper is scuffed against a printed (100% K) paper at a preset pressure in a single scrape sequence. The result is characterized by measuring the print density on the (receiving) unprinted paper. The test was performed 6 months after printing. Thus, the ink film was fully cured [7].

Variation in surface porosity was characterized by measuring the refractive index of small spots having a diameter of 1 mm over a 32×32 mm area of the paper surface using an imaging reflectometer. The step size of the measurement between dots was 0.25 mm. The refractive index reflects the material composition of pigment, latex, and voids. A low refractive index will be obtained for spots with high amounts of voids, since the refractive index is 1.0, 1.50, 1.56, and 1.65, respectively, for voids, latex, clay, and calcium carbonate. The image

shows up as a grey-scale image, which is subjected to fast Fourier transformation to obtain variations in refractive index over the surface and divide those into different size classes (**Fig. 1**). The coefficient of variation in refractive index will then give a measure of the variation in refractive index, which is influenced by the void distribution at the sheet surface.

The instrument used to characterize print gloss variations (PGV) was developed by The Swedish Pulp and Paper Research Institute [20,22]. Images of all four process inks on top of each other (i.e., 400% KCMY) having a size of 13×13 mm were captured in the machine direction. White light was illuminated with a 20° angle from the normal of the surface and the CCD camera was located at a 20° specular angle from the illumination. The exposure time was set to 10 ms for each sample and the black level was set to 101. The mean grey level shows high correlation to Hunter 75° [22] and the grey level of each pixel represents a local gloss value.

The image of the sample was subjected to a two-dimensional frequency analysis using fast Fourier transform to calculate the gloss variations at different size classes. PGV is given as the coefficient of variation of the reflectance for different wavelength classes. The most disturbing PGV to the human eye is found in the spatial wavelength region of 0.5-4 mm [22]. This value is thus the PGV value reported. The higher the PGV value, the larger the print gloss variation. Five specimens and nine areas within each specimen from each printing setup were analyzed and mean values and standard deviations were calculated.

RESULTS AND DISCUSSION

Data on optical properties and smoothness are given in **Table II**. The paper gloss for uncalendered papers were 17.7%, 17.3%, 17.2%, 15.8%, 16.9%, and 17.4% for papers 1 to 6, respectively. The pore coating structure was measured using mercury intrusion porosimetry. Some differences can be observed between samples, for example the pore volume

Paper	Opacity %	D65/10° Brightness	D65 + UV CIE Whiteness	Paper Gloss, %	PPS-10, μm	Micro-roughness, nm	Macro-roughness, μm
1: No clay, 9 pph latex	91.8	86.2	88.1	51.1	0.98	159 $\pm$ 9	2.7 $\pm$ 0.7
2: No clay, 11 pph latex	91.5	86.0	88.0	52.6	1.03	158 $\pm$ 10	2.4 $\pm$ 0.4
3: No clay, 13 pph latex	91.1	85.8	87.9	53.8	1.00	144 $\pm$ 15	2.3 $\pm$ 0.8
4: 10 pph clay, 11 pph latex	91.7	85.2	86.5	54.1	1.04	132 $\pm$ 16	2.6 $\pm$ 0.8
5: 20 pph clay, 11 pph latex	92.0	84.8	85.3	56.2	0.99	127 $\pm$ 10	2.5 $\pm$ 0.8
6: 40 pph clay, 11 pph latex	92.5	83.8	83.3	56.0	1.02	147 $\pm$ 12	2.8 $\pm$ 0.8

II. Optical properties and roughness of the pilot coated and calendered paper.

Paper	Pore Volume (cm ³ /kg)	Pore Diameter (μm)
1: No clay, 9 pph latex	35	0.13
2: No clay, 11 pph latex	36	0.13
3: No clay, 13 pph latex	25	0.12
4: 10 pph clay, 11 pph latex	43	0.13
5: 20 pph clay, 11 pph latex	37	0.12
6: 40 pph clay, 11 pph latex	39	0.11

III. Coating pore volume/kg paper and coating pore diameter of calendered papers as obtained from mercury porosimetry. NB curve fitting was used to extract the data from the coating layer only.

decreased at the highest latex level. The clay content did not significantly affect pore size distribution and pore volume (Table III). The decrease in porosity with increasing latex content can also be inferred from the decrease in opacity.

Local variation in porosity

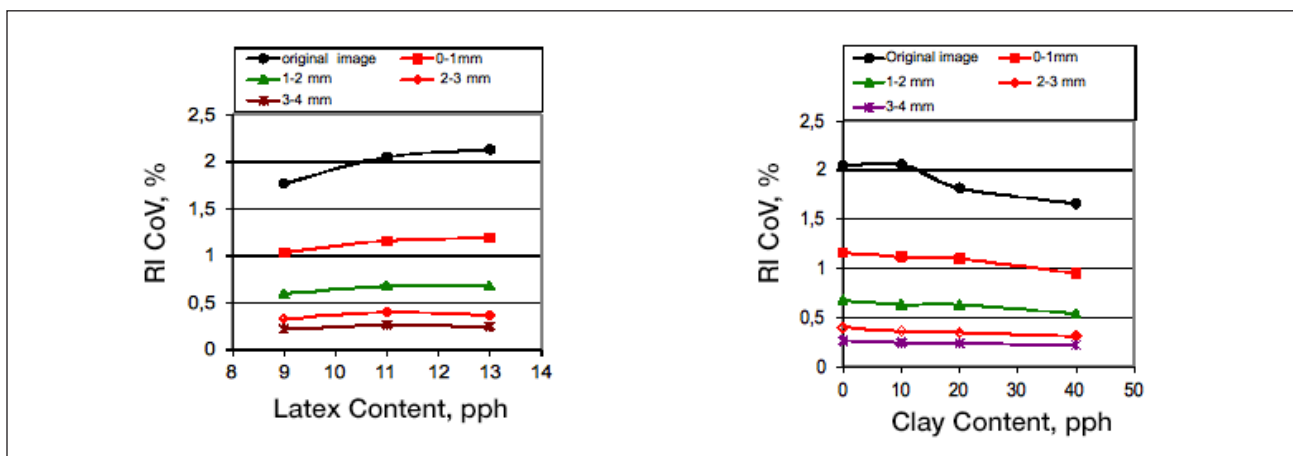
Figure 2 shows the effect of latex content and pigment com-

position of calendered papers on the variation in refractive index. An increase in latex content raised the value of refractive index coefficient of variation, mainly in the small size classes (up to 2 mm), which suggests a decrease in uniformity of porosity. Addition of clay resulted in an improvement in uniformity, when the clay content was 20 pph or 40 pph. Figure 2 also indicates that the greatest degree of variation was occurring at the smallest length scales measured: between 0 and 1 mm.

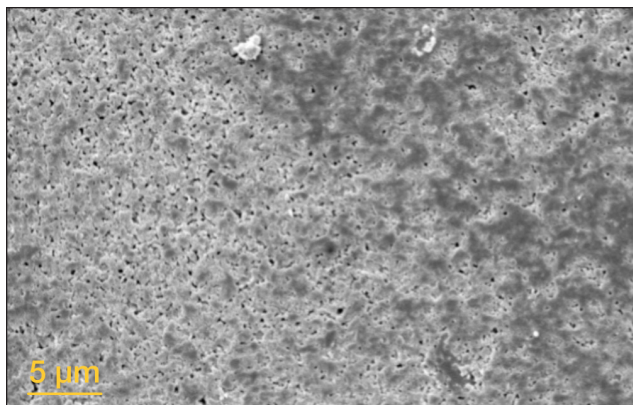
Coating micro-smoothness

Table II shows PPS values and micro- and macro-smoothness data obtained from the imaging reflectometer measurements of the coating surface structure. Unfortunately, these data cannot categorize the coatings with respect to variation in micro-roughness.

Calendering reduces the micro-roughness of the elevated areas more than the depressed areas [31-33]. An example is shown in the scanning electron microscope image displayed in Fig. 3. Micro-smoothness of elevated areas after calendering was discussed by Lepoutre more than 30 years ago [31]. In a more recent publication, Chinga and Helle [32] reported a comprehensive study on coating surface structural variation



2. The content of latex slightly increased the coefficient of variation in refractive index of the coated surface (left), meaning that the uniformity in coating porosity was worsened. The effect decreased with increasing size class. The papers were calendered. When part of the calcium carbonate pigment was exchanged for clay, the uniformity in coating porosity was slightly improved (right). The effect decreased with increasing size class. The papers were calendered.



3. Scanning electron microscope image of a calendered coated paper showing local variation in porosity and smoothness.

and its effect on back-trap mottle. They applied scanning electron microscope and image analysis to characterize closed area in size and distribution (standard deviation). They found good correlation between distribution and back-trap mottle, and the correlation coefficient increased with the size of the closed area. Areas up to 8800 μm^2 were considered.

To gain insights in the micro-roughness of elevated areas of the studied papers, we carried out ink scuff experiments. The test involves scuffing an unprinted paper against a completely dry print (100% black) on the same paper at a certain pressure. The unprinted paper abrades ink from the printed one. The amount of ink transferred to the receiving paper is characterized by measuring print density, and it is referred to as ink scuff. The ink is mainly transferred to the elevated areas; therefore, a small value will indicate low micro-roughness (Fig. 4). However, the value does not only depend on micro-roughness. Other factors (e.g., the size of the elevated areas) will contribute to a measured value.

Previous work [34] supports the thoughts that ink scuff is related to micro-roughness. In this work, ink scuff correlated with micro-roughness measured by atomic force microscopy on small areas (10 $\times$ 10 μm). The micro-roughness and ink scuff decreased with increasing clay content which were 10,

30, and 50 pph. The strongest decrease in micro-roughness was found in the number of peaks that were raised 0.4 μm above the surface. The measured values were 93, 80, and 56, respectively. Also found was a strong decrease in the ratio of the measured actual area to the projected area. This measure may be considered as surface volume. The values were 1.31, 1.26, and 1.18. The root mean squared (rms) values were not very different: 151, 142, and 140 nm, respectively.

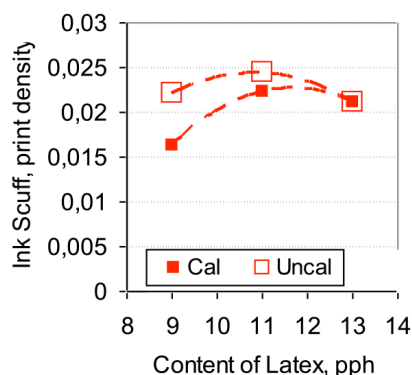
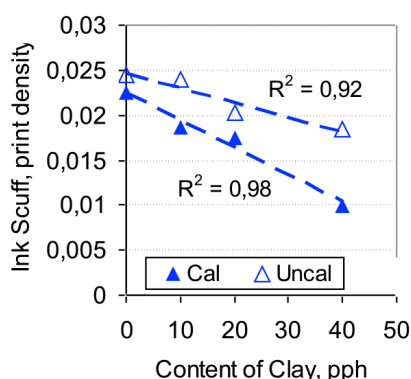
Considering the ink scuff values to be an indication on micro-roughness on elevated areas, we conclude from Fig. 4 that it is decreased by calendering, higher addition of clay, and the combination of low content of latex binder and calendering. This information will be used in the discussion below.

Ink setting rate

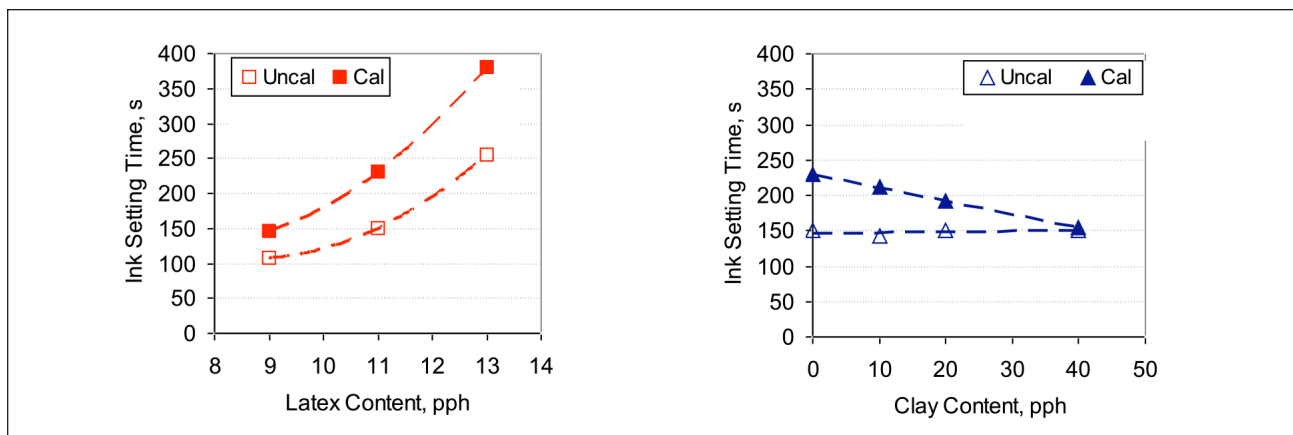
Curves of ink tack development were determined by the ink surface interaction tester [30]. Ink setting trends are similar to those reported earlier [35] (i.e., ink setting becomes slower when the content of latex binder increases, which is the result of decreased porosity). This is shown in Fig. 5 (left). Increased amounts of clay had no effect on the ink setting time of the uncalendered sheets, but had a slight effect on the calendered sheets (Fig. 5, right). The slight change in ink setting with increased clay content might be because of the limited change in porosity and bulk structure which occurred. Variations in surface energy would not be expected to affect the ink setting rate because this experiment did not incorporate fountain solution. The ink setting rate (slope of tack curve) was very similar for all coatings, the highest value being 0.29 N/s and the lowest value 0.23 N/s. Surprisingly, the addition of more latex caused little change in this rate.

Print gloss

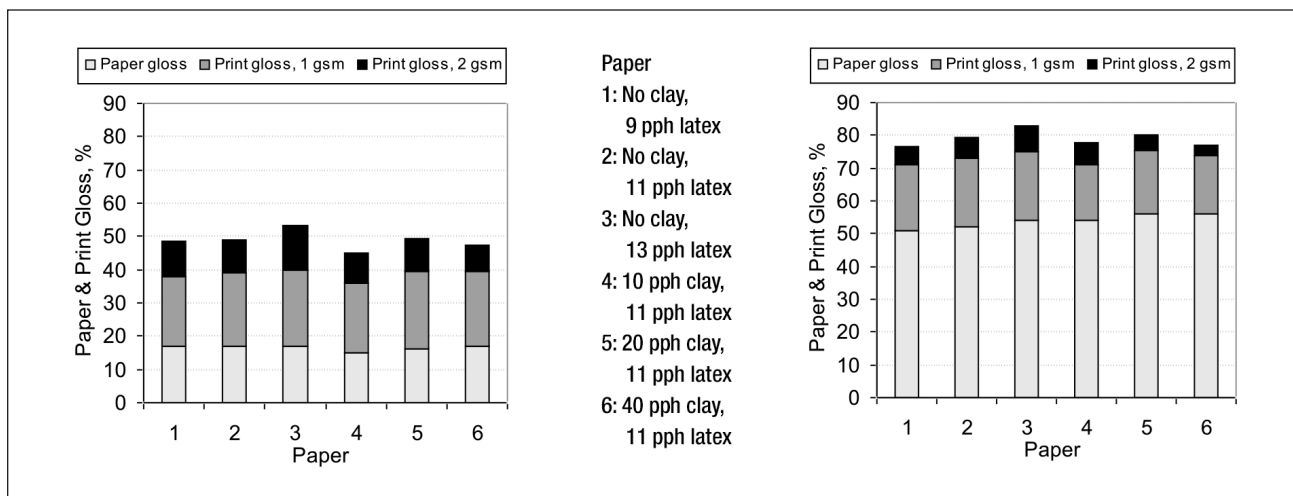
Although the refractive index of an ink layer affects print gloss, the main factor controlling print gloss is the smoothness of the ink layer. This is primarily controlled by the coating smoothness [3,4], ink setting [4,6,8,12], and a micro-roughness in the ink surface caused by protruding ink specimen



4. Impact of latex and clay content on ink scuff of uncalendered and calendered paper. Ink scuff was measured 6 months after printing, which makes the printed surface completely cured.



5. Ink setting time vs. latex content for the coatings that only contained calcium carbonate (left) and vs. clay content for coatings with 11 pph latex (right).



6. Paper and print gloss for uncalendered (left) and calendered (right) papers at 1 and 2 g ink/m² printed on dry paper using a Prüfau laboratory printing press.

such as ink pigments and wax particles [5].

Print gloss was measured after laboratory printing for a range of ink loading levels and interpolated to 1 g/m² and 2 g/m² of ink on the paper (Fig. 6). The results were as expected: thicker ink layers gave higher print gloss and calendered papers showed higher print gloss than uncalendered. An increased print gloss was observed with increasing amount of latex.

The relationship between print gloss and ink setting is observed from the data presented. Figure 7 shows that print gloss increased with ink setting time (i.e., when ink setting was slower). This is in good agreement with the general theory on impact of ink leveling on print gloss which has been extensively studied and discussed by Bousfield and co-workers [6,8]. The increase was observed on both uncalendered and calendered coatings when the ink setting time was increased by an increase in the content of latex in a carbonate coating. The increase in latex content is regarded to have no or very slight impact on coating surface structure.

The clay series did not show the same behavior, most like-

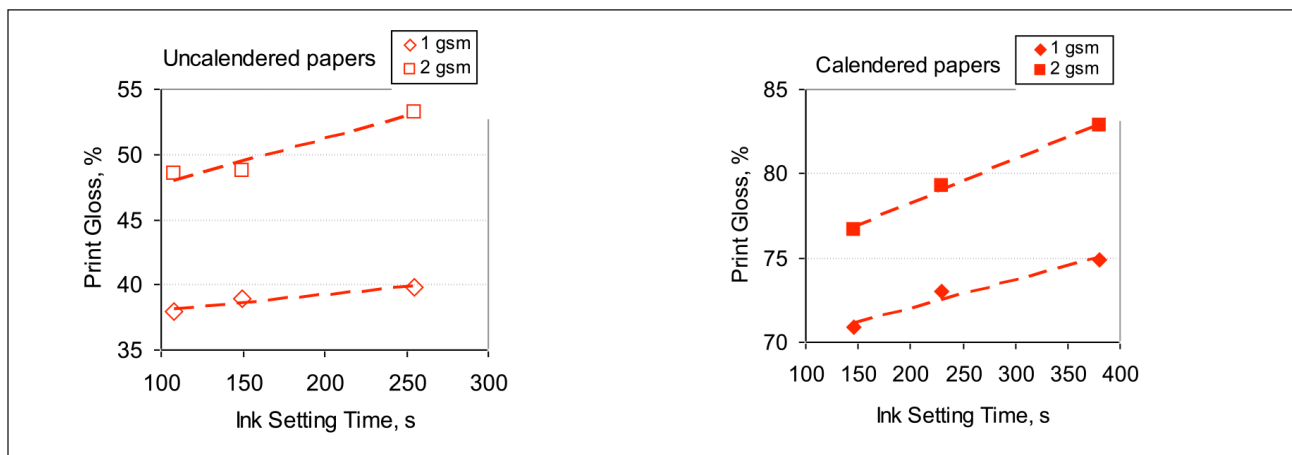
ly because of the small difference in ink setting time between the papers of this series.

PGV and variation in smoothness and porosity

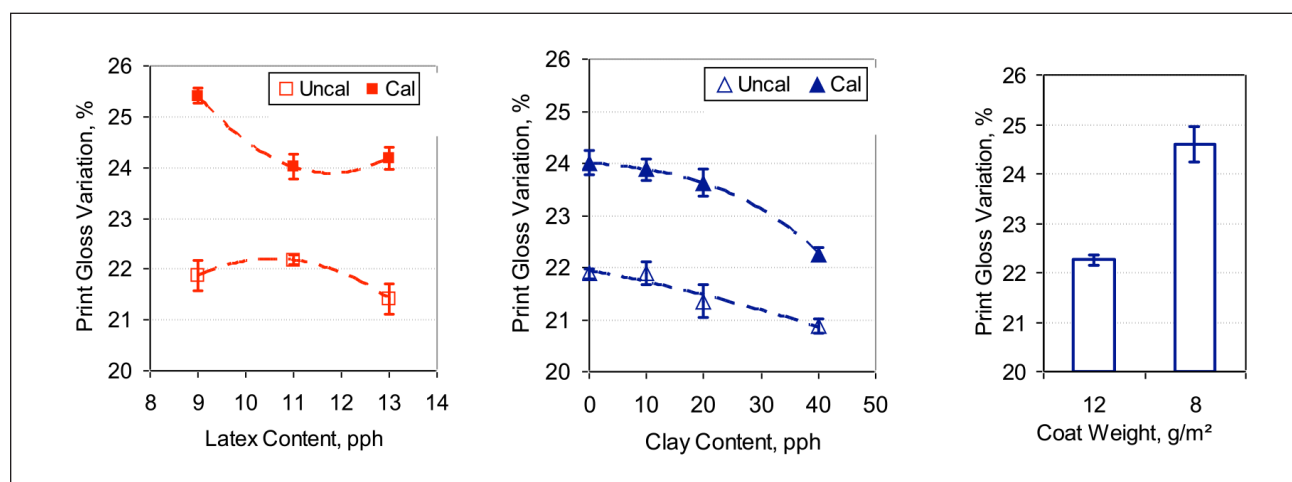
Figure 8 (left and middle) shows that calendering clearly increased PGV. The strongest impact of calendering was observed for the coating containing the lowest amount of latex. Increased PGV upon calendering has been reported earlier [18] in a work where different calendering techniques were evaluated.

This work shows that coating composition and coat weight also affect PGV. A significant decrease in PGV was observed with increasing clay content (Fig. 8, middle) and increasing coat weight (Fig. 8, right). The slight changes occurring with increased binder are probably relevant for the modest changes occurring here. If the binder level was increased further, then poorer print quality would probably result.

The print impression had no significant impact on PGV. The print impressions (i.e., the deformation of the rubber blanket during printing) studied were 0.10, 0.18, and



7. Print gloss vs. ink setting time for uncalendered and calendered papers. Coatings with only calcium carbonate as pigment and increasing amount of latex (papers 1-3).



8. PGV shows a dependence on nonuniformity in coating porosity (original image from Fig. 2) with one exception. The papers were calendered. The values 0.1, 0.18, and 0.25 refer to print impression.

0.25 mm. The fountain solution level had no significant impact on PGV. This was concluded after reducing the fountain feed by 15% when printing calendered paper 6 (40 pph clay). Normal water feed gave $PGV = 22.2 \pm 0.5$, while reduced water feed gave $PGV = 22.0 \pm 0.2$. Because reducing the fountain feed had no significant effect on PGV, we conclude that fiber rising induced by the fountain solution had no effect on PGV in this trial.

The differences in PGV between the different papers were not large, but they were significant. According to our experience, PGV values below 25 represent fairly good gloss uniformity and the just-noticeable difference is in the order of two units or slightly above. The lowest value found in this study was $20.0 \pm 0.4\%$, while the highest was $25.4 \pm 0.2\%$. The lowest value was obtained for the uncalendered coating containing the highest amount of clay (40 pph). The highest PGV was obtained for the calendered coating without clay and the lowest amount of latex binder

It was clearly shown that calendering increased PGV and

that increased coat weight reduced PGV. This is quite reasonable because elevated areas of the coating will be exposed to a higher line load during calendering, and this will induce nonuniformity in coating structure. The elevated areas will be smoothed but also more compact (lower porosity). This structural change has been discussed by Lepoutre [31] and Hunger [33]. A smoother surface will give a higher print gloss [2-4,6,7]. A reduced porosity will reduce ink setting rate, which promotes ink leveling [6,12]. This will also give higher print gloss. Both effects will give higher print gloss on elevated areas compared to depressed areas. In addition, high glossy areas of a print that show PGV are smoother than low glossy areas [20,21]. Because a higher coat weight will reduce macro-roughness, the unevenness in coating structure also will be reduced.

The nonuniformity in coating surface porosity that was established by the refractive index technique correlated with PGV. This is shown in **Fig. 9**, where all calendered coatings are included. The significance of the values is very high, be-

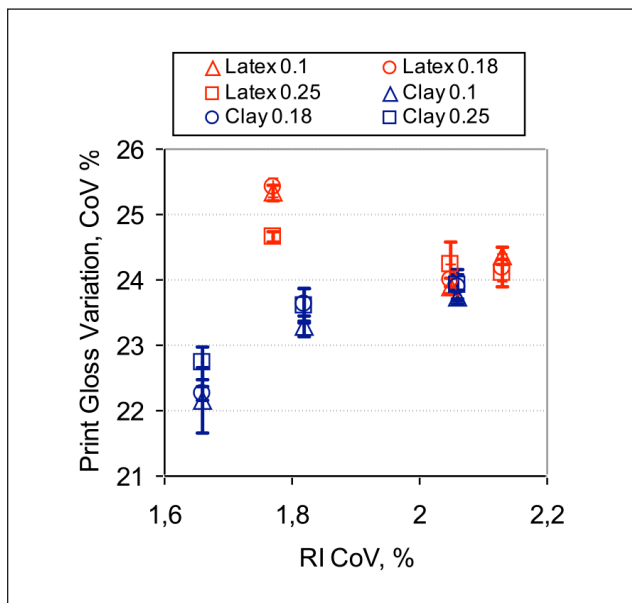
cause the value given for each trial point is the mean value out of 45 measurements.

One coating did not follow the trend. This is the one without clay and only 9 pph latex. It is possible that the low latex content within this coating layer made the coating more sensitive to calendering, meaning that the elevated areas become more micro-smooth. Support for an increased micro-smoothness on elevated areas can be found from the ink scuff data presented in Fig. 4 and discussed previously. This decrease in ink scuff likely reflects an increased micro-smoothness. Thus, nonuniformity in porosity was not very high (as can be seen from the refractive index coefficient of variation value), but nonuniformity in surface smoothness became high upon calendering (smooth elevated areas with rough areas in-between). The print gloss variation for that coating before calendering was in the same range as for the coatings with higher latex content.

Our data thus suggests that PGV results from a combination of nonuniformity in surface smoothness and nonuniformity in surface porosity. The coefficient of variation in RI is a measure of the latter.

CONCLUSIONS

Our experimental data show that print gloss variation under the conditions investigated was made worse by calendering, yet it was reduced by increasing the amount of clay in the coating, which also improved the uniformity in surface porosity. Elevated areas within the macro-roughness of the coating are exposed to a higher line load than depressed areas. Thus, calendering induces local variations in micro-smoothness and porosity. We conclude that PGV is controlled by local variation in two paper properties:



9. PGV shows a dependence on nonuniformity in coating porosity (original image from Fig. 2) with one exception. The papers were calendered.

- Local variation in coating surface porosity, since this gives local variation in ink setting rate and thus alternative areas where leveling of ink filament is poor and good. A slow ink setting and an efficient ink leveling give smooth ink film and high print gloss.
- Local variation in coating surface smoothness. This is mainly generated by calendering in areas found on elevated parts of the coating, parts that also are more compact and therefore get an efficient leveling of ink filament. Both smooth coating and good leveling result in high print gloss.

The hypothesis is that areas in-between the elevated areas after calendering are rough and have a more open structure. Both effects result in lower print gloss. **TJ**

ACKNOWLEDGEMENTS

The authors thank John Husband and Matthew Cheeseman from Imerys, and Mikael Karathanasis, Sandra Madstedt, and Sofie Ström for their contributions in this work. Voith, Stora Enso, M-real, Arctic Paper, AssiDomän Frövi, Korsnäs, Norske Skog, Imerys and Innventia are acknowledged for financial support.

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ABOUT THE AUTHORS

Print gloss variation is one of the most severe offset print quality defects. Much work has been done on print gloss, but very little on the local variation in print gloss, and only a handful of scientific work has been published on print gloss variation. In addition, our studies were done in a full-scale printing trial using coated papers with well-controlled composition and well-characterized structure. Our earlier research has to a large extent been on interaction between ink and coatings, but not often evaluated in full-scale printing trials. Laboratory printing is more frequent.

The most difficult aspect of this study was to document that calendering induced nonuniformity in micro-roughness, thus elevated areas had become more micro-smooth. This was addressed by a literature search of microscopy studies and ink scuff measurements.

One of the most interesting findings was that print gloss variation originates from a combination of local differences in smoothness, porosity, and setting rate.

From this study, mills will get a better understanding on the effect of coating color composition and coating structure on print gloss variation and find strategies to minimize this phenomena.



Ström



Preston

Ström is senior project manager, Innventia AB, Stockholm, Sweden, and Preston is senior scientist, Imerys Minerals Ltd. Par, Cornwall, UK. Email Ström at goran.strom@innventia.com.