FACTORS INFLUENCING THE SURFACE STRENGTH OF COATED PAPERS

Peter Dahlvik, Guillermo Bluvol, Karl-Heinz Kagerer and Manfred Arnold
Omya International AG, CH-4665 Oftringen, Switzerland
peter.dahlvik@omya.com; guillermo.bluvol@omya.com; karlheinz.kagerer@omya.com;
manfred.arnold@omya.com

Dan Varney
Omya Inc., 39 Main Street, Proctor, VT 05765
dan.varney@omya.com

ABSTRACT

This paper focuses on the influence of different coating color parameters on the surface strength of pilot coated paper as determined in full-scale sheet-fed offset printing. A tailor-made printing method using a special printing plate and high-tack inks was developed with the objective to evaluate the impact of different coating parameters on surface strength, mainly in terms of edge picking. Evaluated parameters included the solids content of the coating color, the type, fineness and particle size distribution of the pigment, the binder level, and calendering.

The developed printing test method provided clear differentiation relative to the investigated parameters and it was possible to correlate these results with lab test data on ink-coating interaction and mercury intrusion porosimetry. It was shown that by maximizing the solids content of the formulation, the binder level could be optimized for cost savings while maintaining sufficient pick resistance. In addition, clear differences related to the type of pigment were detected. Other lab tests showed poor correlation with the observed degree of edge picking.

INTRODUCTION

Coated wood-free (WF) papers are normally printed in sheet-fed offset (SFO) or heat-set web offset (HSWO) printing presses. Both processes involve the use of high-tack inks, with the tack of the HSWO inks in general being lower than the tack of SFO inks. In contrast to the HSWO process, where the web goes through a drying section, SFO printing is performed without externally applied heat. Ink drying in SFO takes place in two phases: first, ink is set off to the paper and then follows the oxidative drying phase. The drying is strongly influenced by the pore structure of the coating layer, which in turn is determined mainly by the pigment properties as well as the binder type and amount.

SFO is normally referred to as the most demanding printing process. Printing takes place at very high speeds with multiple consecutive ink and fountain solution applications. The coating must withstand the splitting forces of the tacky inks several times in the presence of the aqueous fountain solution. Too low surface strength may lead to picking of the coating layer and subsequent contamination and runnability limitations in the print press, or print quality claims from the customer. In some cases, even delamination of the paper may occur due to very high splitting forces. Variations in solids content, pigment and binder type or binder level may greatly influence the surface strength as a result of changed pore structure and ink setting behavior.

Cost reduction is currently the top priority of many producers of coated WF paper. In the coating process, pigments and binders must be chosen to obtain the optimal relation between cost and quality. The latex binder is normally the most expensive component per unit in the coating formulation and optimizing the binder level to a minimum therefore provides a substantial opportunity for cost savings.

In the last 5-10 years, we have observed a clear reduction in the level of latex binder used in coating formulations. Still, there is a high interest to further decrease binder levels, without compromising printing press runnability or risking a higher degree of claims from the market. Obviously the binder level not only affects the surface strength in SFO printing, but it is also crucial for print quality and other important properties like fold cracking and glueability.

Ink setting characteristics of the coated surface influence the tack development of the printing ink and therefore determine the demand for surface strength. The ink setting process is generally explained by assuming that the mechanism behind oil absorption can be described via the pore structure and chemistry of the coating. The theory of capillary forces controlling the loss of ink vehicle is broadly accepted. It says that a high number of small interparticle voids (pores) in the coating results in a structure exhibiting a high capillary force, especially in the case of isometric particles, due to the multi-interconnectivity of the pores and their low aspect ratio promoting inertial wetting at the absorption front (1-7).

This kind of coating structure is typically produced by ultra fine pigments, mainly blocky in shape, such as GCC and fine US glossing clay, with high specific surface area. Large pores in the coating consequently create a lower capillary pressure, meaning low initial ink setting rates and slow tack build-up of the printing ink. Larger pores also encourage penetration of the ink due to increased permeability. In general, a coating layer with fine pigments will result in a higher number of fine pores and faster ink setting, whereas coarse pigments will lead to a lower number of larger pores and slower ink setting (8). The relations between pore structure, ink setting, ink tack development and print gloss have been reported in several studies (9-16).

EXPERIMENTAL

Pilot Coating

Pilot coater trials were performed with the objective to produce double coated papers with a range of different surface characteristics, thus providing a varying degree of edge picking in the SFO print trials. A summary of the trial points (TP) is given in Table 1. Four commercially available ground calcium carbonate (GCC) pigments, including one with Narrow Particle Size Distribution (NPSD), and one high gloss clay were included in the trial program. The particle size distribution curves of the pigments are depicted in Figure 1, as determined by the Sedigraph.

Table 1 Trial program (mill blade precoated base paper)

	1	2	3	4	5	6	7	8	9	10	11
GCC 95 (80 % < 1 µm)	100	100	100	100	100	100	50				
Clay (high glossing)							50	100			
NPSD GCC (75 % < 1 µm)									100		
GCC 60 (60 % < 2 µm)										100	
GCC 90 (90 % < 2 µm)											100
Latex SBR	7.5	7.5	7.5	5.0	5.0	5.0	7.5	7.5	7.5	7.5	7.5
Synthetic thickener	0.10	0.15	0.20	0.10	0.15	0.20	0.25	0.15	0.15	0.30	0.20
Solids content	71	68	65	71	68	65	65	65	68	68	68

Two binder levels were evaluated, using standard styrene-butadiene latex with a particle size of 140 nm and a minimum film-forming temperature of approximately 10 ºC. The fairly low binder level of 7.5 parts was chosen to reflect the ambitious targets of coated paper producers today in optimizing the cost-performance relationship of their formulations. Reducing the amount of latex to 5 parts provided the means to effectively evaluate the impact of the binder on the surface strength in commercial printing and on the associated surface properties given in lab testing. Synthetic thickener was added to obtain similar Brookfield viscosity (about 1000 mPas at 100 rpm) in all trial points.

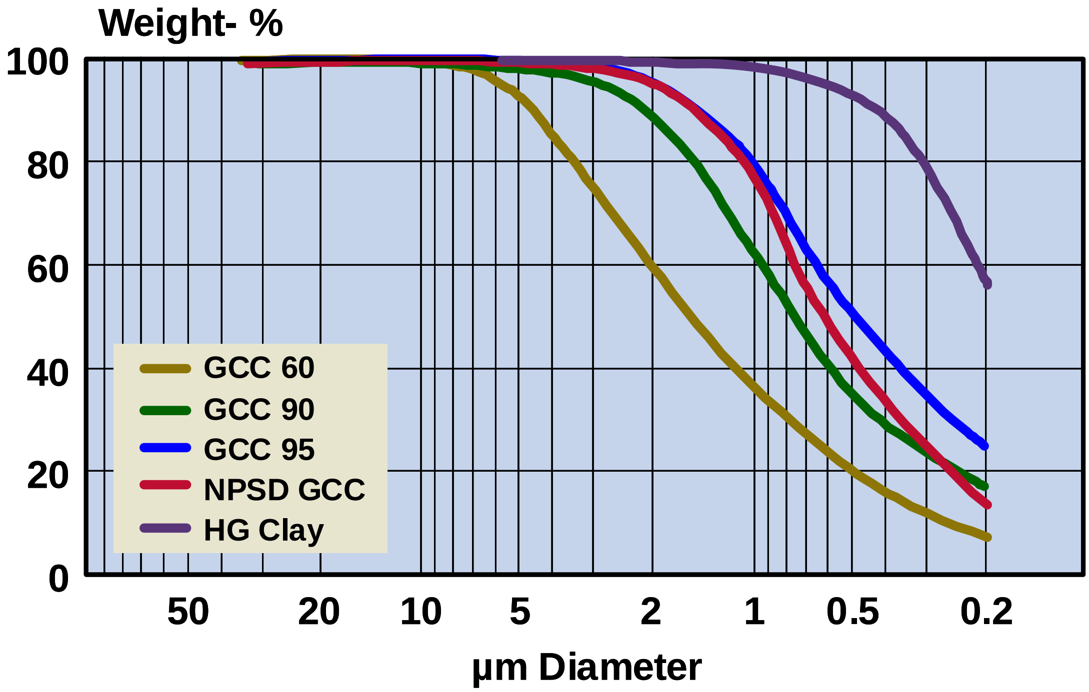

Figure 1 Particle size distribution of the pigments (the data do not represent product specifications)

The pilot coating conditions used and the evaluated parameters are summarized below.

Pilot coating conditions

- Mill blade-precoated[1] base paper 78 gsm
- Machine speed 1200 m/min
- Jet application, stiff blade
- Brookfield viscosity (100 rpm) 1000 mPas
- Coat weight 12 gsm/side
- Supercalendering (11 nips, 300 m/min, 80°C, 120 kN/m)

Evaluated parameters

- Pigment type (GCC/clay)
- Pigment fineness (GCC)
- Pigment particle size distribution (GCC)
- Binder level
- Solids content
- Calendered vs. uncalendered

Calendering conditions were adjusted to obtain a sheet gloss of 75% for trial point 1. The same calender parameters were used for the remaining trial conditions.

Commercial Printing Trial Method

A special method for analyzing the surface strength of coated paper on a commercial offset press was developed based on a standard test form normally used for commercial printing trials. The layout of the new test form (Figure 2) was designed with the aim to provoke edge picking; a printing defect that typically occurs at the interface of printed and unprinted areas. An example of edge picking is shown in Figure 3. A commercial market paper (glossy double coated 115 gsm paper from the same paper mill) was identified as a suitable reference paper. The initial printing conditions were adjusted in such a way that the reference paper showed slight edge picking.

Pre-trials were carried out to obtain the desired printing conditions. The commercial printing trials took place on a Man Roland R706 LTTLV[2] printing press at a speed of 8,000 sheets per hour, using six printing units (K, C#1, M, Y, C#2 and Blue[3]) and one varnishing unit. The first four inks were of especially high tack[4], applied to further provoke differences between trial points in terms of edge picking. After the six printing units, the sheets were run through the varnishing unit (without varnish) to put an additional stress on the printed surface (Figure 4).

[1] 100% GCC, starch-latex binder system
[2] L = varnish, T = drying section, V = stretched delivery section
[3] Special blue shade (Omya blue)
[4] Ink tack values: standard = 7.5 – 10; high = 9.5 – 10.8

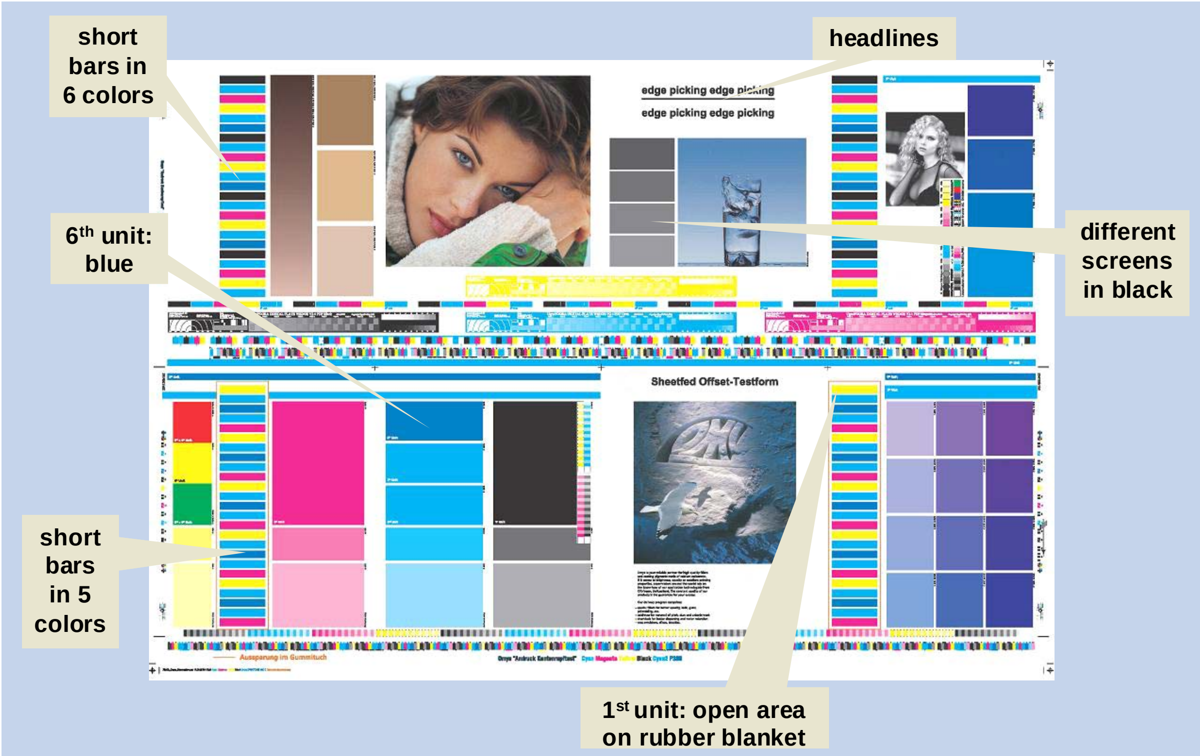

Figure 2 Layout developed for evaluation of edge picking in commercial offset printing trials

The surface strength was evaluated visually by examining the degree of edge picking of the printed image and by sweeping the rubber blanket at each printing unit by hand to estimate the level of blanket contamination. Based on this information, the degree of edge picking for the different trial points was divided into five categories within a scale between 0 and 100. The above mentioned market paper was used as a reference in the print trials. The printing conditions were adjusted so that the market paper showed a medium level of edge picking (around 50 on the scale).

The five categories in the scale were defined according to the following:

- I: picking on sheet visible to the naked eye; picking on more rubber blankets – clearly visible and well detectable by hand ⇨ unacceptable situation, paper replacement imperative
- II: picking on sheet visible to expert eye or with a magnifying glass; picking on more rubber blankets – clearly visible and well detectable by hand ⇨ extra cleaning intervals and therefore longer make-ready time and less production time
- III: picking on sheet visible with a magnifying glass; slight picking on more than one rubber blanket – visible and detectable by hand ⇨ extra cleaning intervals and therefore longer make-ready time
- IV: no picking on sheet visible; minor picking on any rubber blanket – hardly visible, but detectable by hand ⇨ potentially problem to achieve print runs of high quantity
- V: no picking on sheet visible; picking on rubber blankets neither visible nor detectable by hand ⇨ no problem for the printer

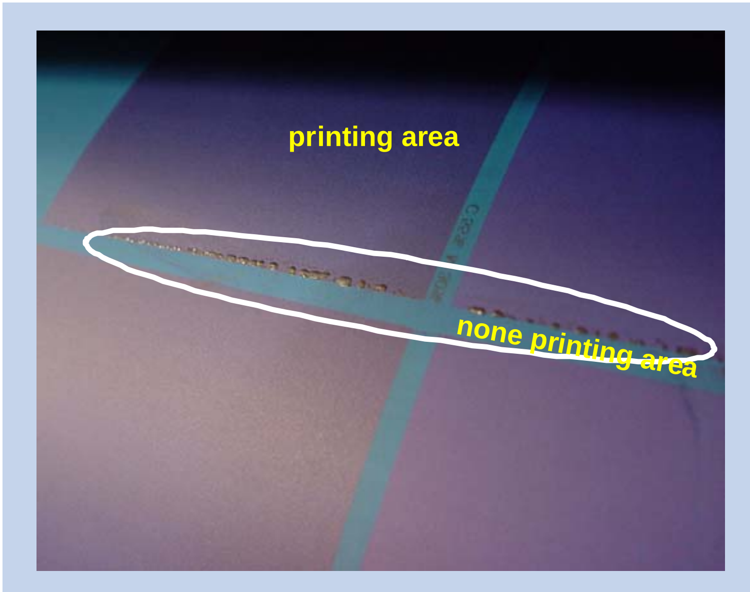

Figure 3 Typical edge picking (example)

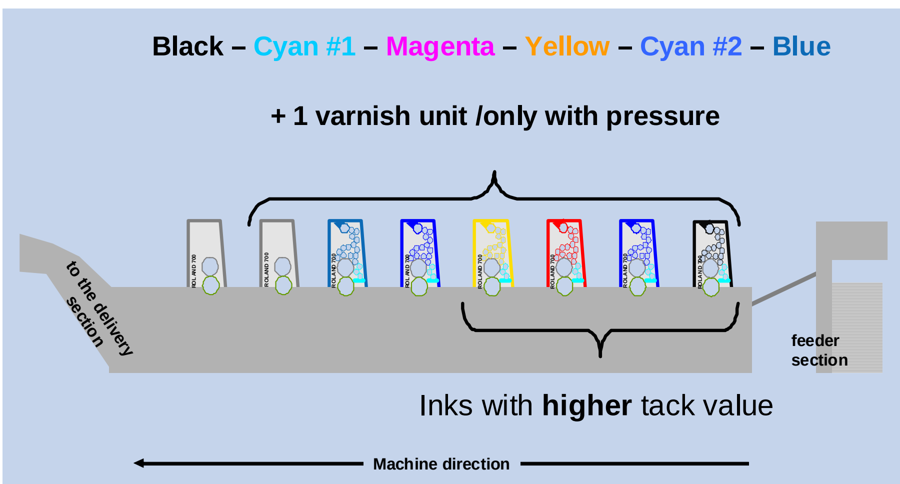

Figure 4 Setup of the sheet-fed offset printing press

Laboratory Testing

The coated samples were evaluated by standard lab test methods commonly used in the industry. The following tests were performed:

- Dry pick and wet pick (Prüfbau)
- Print gloss (Prüfbau)
- Ink set-off (IGT, optical density at 60 s)
- Ink set-off (RI-Test, visual assessment: 0 slowest, 6 fastest)
- Ink tack slope and passes to failure (NPA Paper and Ink Stability Test, i.e., P&I Test)
- Mercury intrusion porosimetry

RESULTS AND DISCUSSION

Edge Picking in Commercial Printing

Figure 5 shows the ranking of the trial points within the five categories based on the degree of edge picking, where "0" represents the worst result and "100" the best.

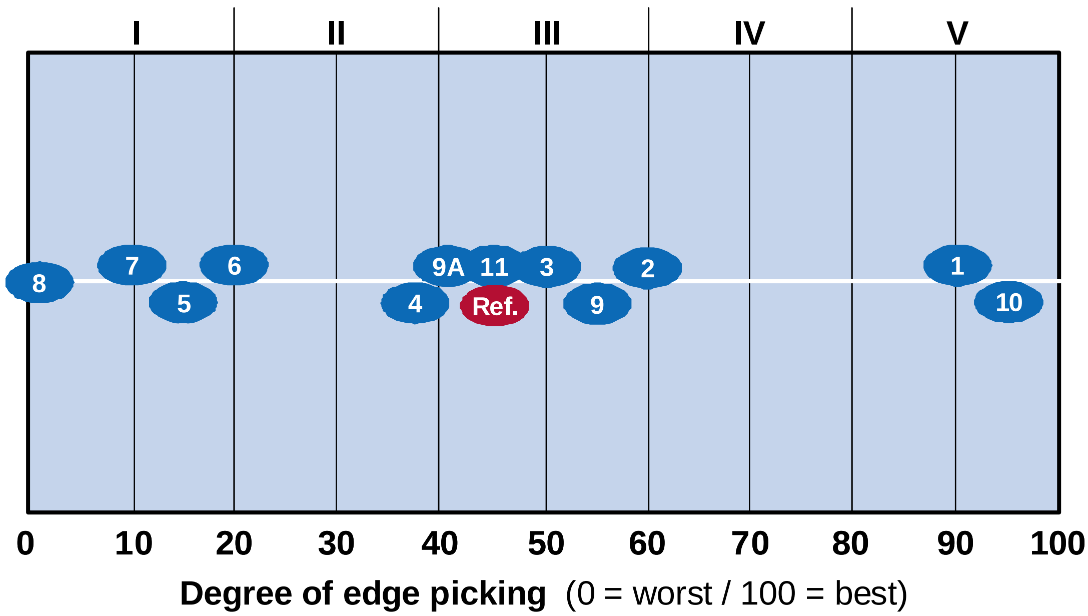

Figure 5 Ranking according to the degree of edge picking

The GCC 95 (fine GCC) with 7.5 parts latex and maximum solids (TP 1) and the coarsest GCC 60 (TP 10) clearly differentiated from the rest by showing the lowest degree of edge picking, whereas the 100 % clay formulation (TP 8) gave the worst results. The second-highest degree of edge picking was observed with the 50/50 GCC/clay formulation (TP 7). Reducing the binder to 5 parts combined with a reduction of the solids content also gave rise to a fair amount of edge picking (TP 5 and TP 6). The rest of the trial points formed an intermediate group of which the GCC 95 with 7.5 parts latex and medium solids (TP 2) and the NPSD GCC (TP 9) gave the best results. TP 9A is the uncalendered version of TP 9.

Pore Size Distribution

The coating pore size distribution curves of the samples are given in Figure 6. The results confirm that coating pore structure largely is a function of pigment fineness; the finer the pigment particles, the smaller the pores. Similar results have been reported by Rousu (15). With 100 parts fine clay (TP 8) a bimodal pore structure was observed, with peaks at 0.06 µm and 0.14 µm. The clay/GCC 95 blend (TP 7) gave a major peak at 0.09 µm. While the distribution for the clay/GCC blend was almost mono modal, a light step was still noticeable at 0.14 µm.

The GCC 95 conditions (TP 1 - TP 6) gave peaks around 0.12 µm. The minor differences when comparing TP 1 - TP 3 and TP 4 - TP 6 indicate that the overall pore structure was largely independent of variations in the solids content or the binder level. Ström and Karathanasis (16) reported clear reductions in pore size with increasing amounts of latex, albeit, at higher levels of binder addition. When calculating the mean pore radius (R_{50}), they observed a reduction only when the latex content reached 14 parts and higher. At the low binder levels of 5 and 7.5 parts used in the current study, the sealing effect of the binder is probably not sufficient to be reflected in the pore size distribution. The results of Larsson et al. (17) support this assumption, implying that the reduction in pore volume at these very low latex levels would be virtually negligible.

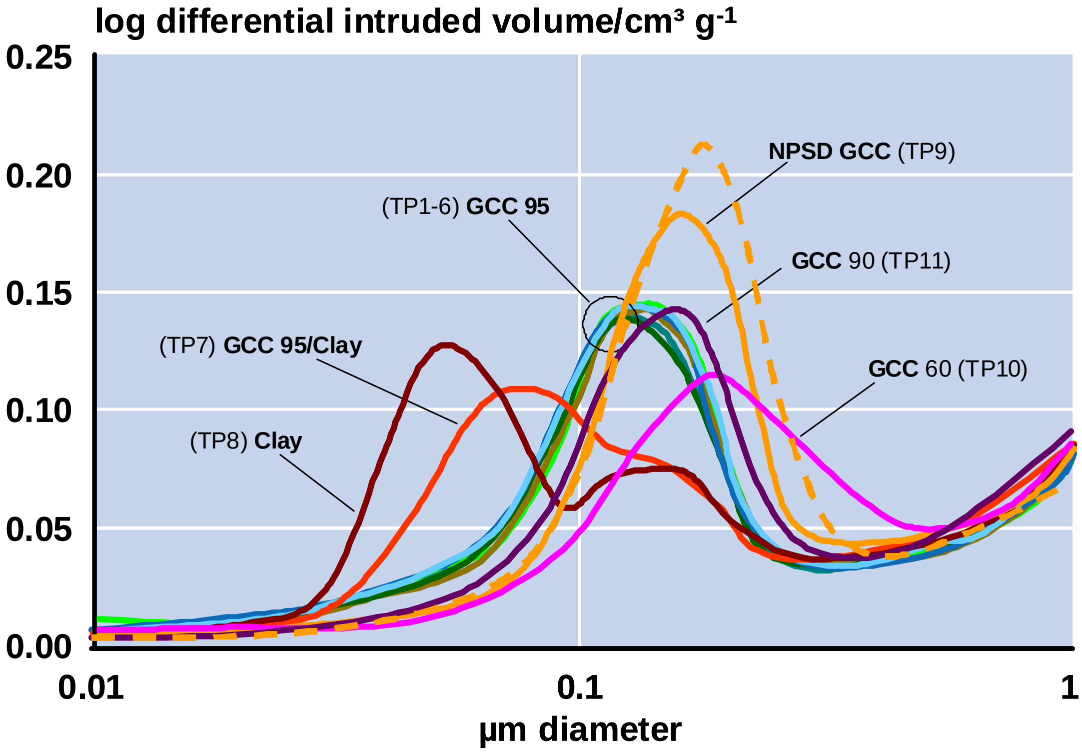

Figure 6 Pore size distribution, calendered (including TP 9A uncalendered – dashed line)

For TP 9 and TP 11, the NPSD GCC and the GCC 90 respectively, the peaks fall above 0.14 µm. The NPSD GCC, which is known to produce a coating with high bulk, accordingly gave a narrow distribution with a large volume contribution. The coarsest pigment, GCC 60 (TP 10), resulted in a very broad distribution with a fairly low peak at 0.20 µm.

The effect of calendering on pore size distribution for TP 7 - TP 11 is shown in the Figure 7 (and in Figure 6 for TP 9 vs. TP 9A). (The calendered conditions are represented by the solid lines and their uncalendered counterparts are represented by the dashed lines of the same color.) Calendering as such primarily makes the surface smoother by aligning the pigment particles, thereby also resulting in a densification of the coating layer and a smaller pore volume. Even though the results show that calendering shifted the pore size distribution towards smaller values, this effect was relatively small compared to the influence of pigment fineness/type. Furthermore, a somewhat larger effect on the pore size distribution was seen for the clay-containing coatings than for the pure GCC coatings.

Suontausta (18) found that the pure pressure applied in the calendering process reduced the porosity when the coating was based on platy clay particles, while the porosity of GCC-based coatings (having 12 parts latex) was affected only when high-temperature calendering was applied. The reduction in porosity as a result of high-temperature calendering can mainly be related to deformation of the latex binder within the coating matrix (17, 18).

With only 7.5 parts latex, it can be speculated that the temperature effect is rather limited and that the effect of calendering mainly results in a re-arrangement of the particles. The resulting higher smoothness distributes the tack forces over a larger area and thus can be expected to show better pick resistance than a rougher uncalendered surface in which the load concentrates over a smaller area (TP 9 vs. TP 9A in Figure 5).

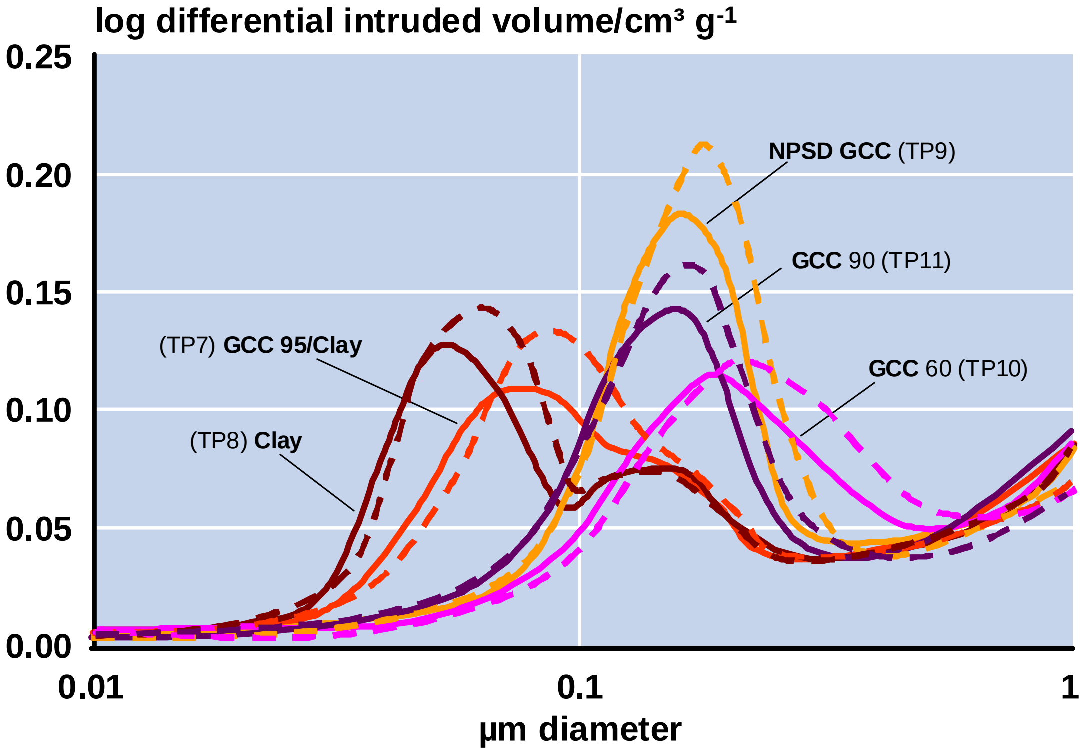

Figure 7 Pore size distribution, uncalendered (dashed lines) vs. calendered (solid lines) samples (TP 7 - TP 11)

Ink Setting

Figures 8 and 9 illustrate the ink setting behavior as determined using the two different lab test methods. The results from both tests show approximately the same trends, with the following factors resulting in slower ink setting:

- Using GCC instead of high glossing clay
- Coarser pigments
- Higher solids content
- Higher amount of latex

The narrow particle size distribution (NPSD) GCC had a limited affect on edge picking or ink setting. The lack of fines in this GCC could be expected to impact the pore structure in such a way that ink setting would become slower compared to GCC 95 (12). However, except for the very finest particles, the particle size distribution of the GCC 95 and the NPSD GCC are almost identical (Figure 1), which would support the similar ink-coating interactions of these two pigments.

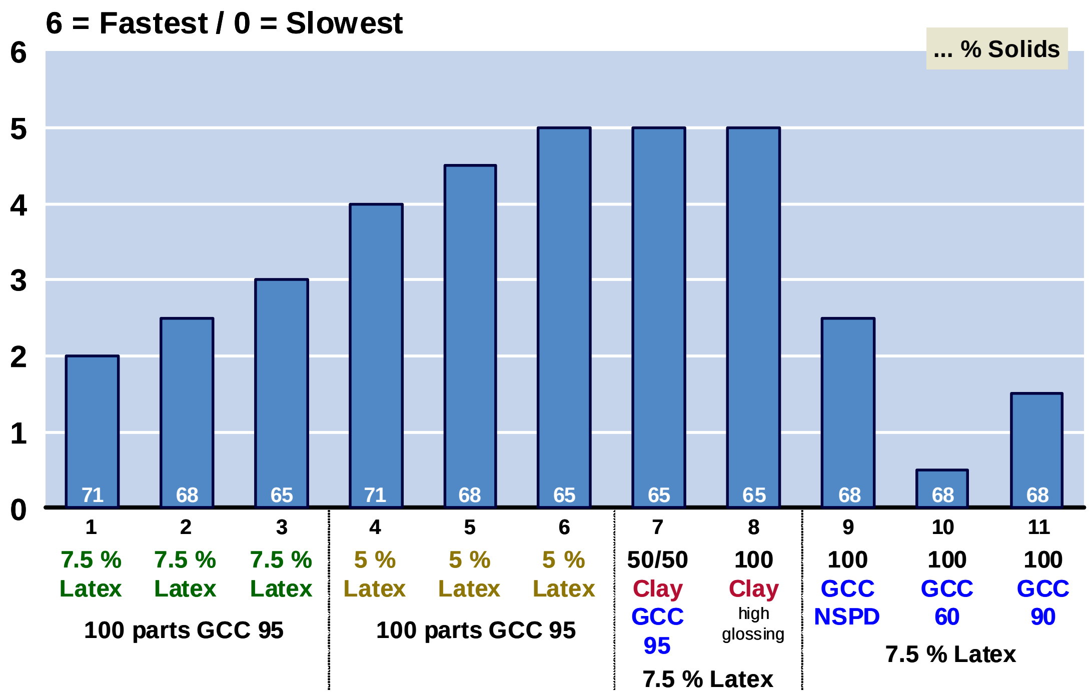

Figure 8 Visual assessment of ink setting (RI Test set-off)

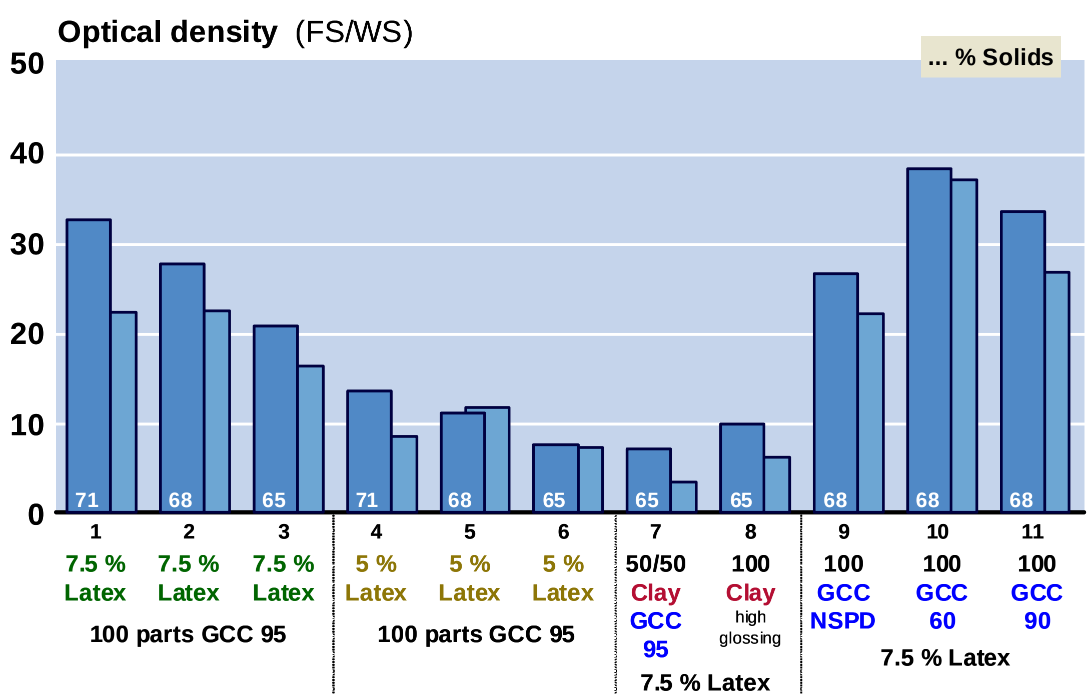

Figure 9 Optical density (IGT set-off at 60 s)

Ink Tack

Surface strength in the sheet-fed offset process is primarily related to the "ink-coating interaction", or how rapidly the ink tack build-up takes place when the sheet passes through the print units. In addition to performing ink setting measurements as shown in Figures 8 and 9, the ink-coating interaction was determined via ink tack tests, where the ink tack build-up was recorded as a function of time. From the resulting curve, the slope of the ink tack build-up was obtained. The number of passes until coating failure is normally determined by visual inspection of the test strips. The level and rate of ink tack development are directly related to the composition of the coating formulation, with the pigments and binders constituting the most influential components (19-21).

Figure 10 shows the slope or rate of ink tack build-up. A steeper slope (higher number), indicating fast ink tack build-up, was obtained with finer pigments, reduced binder level and lower solids. Similar findings have been reported in several previous studies (9-16). The evaluation of the number of passes to failure (Figure 11) in the same test correlates well with the slope; a lower slope is associated with a larger number of passes to failure. In other words, a low degree of interaction between the ink and the coating results in a high number of passes to failure and a less steep slope.

Somewhat faster ink tack build-up was observed for the NPSD GCC (TP 9) compared to GCC 95 (TP 2) at similar solids (68%) and latex level (7.5 parts), which was not reflected in the ink setting results. This result may be attributed to the more open surface with the NPSD GCC as indicated by the mercury intrusion measurements.

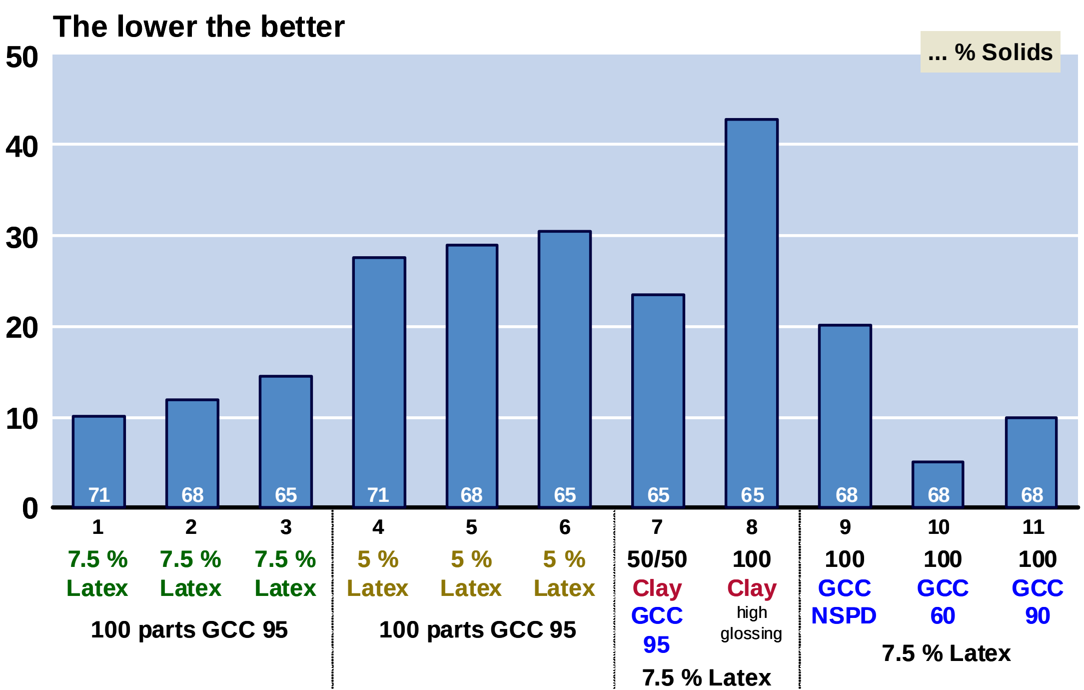

Figure 10 Ink tack slope (P&I Test)

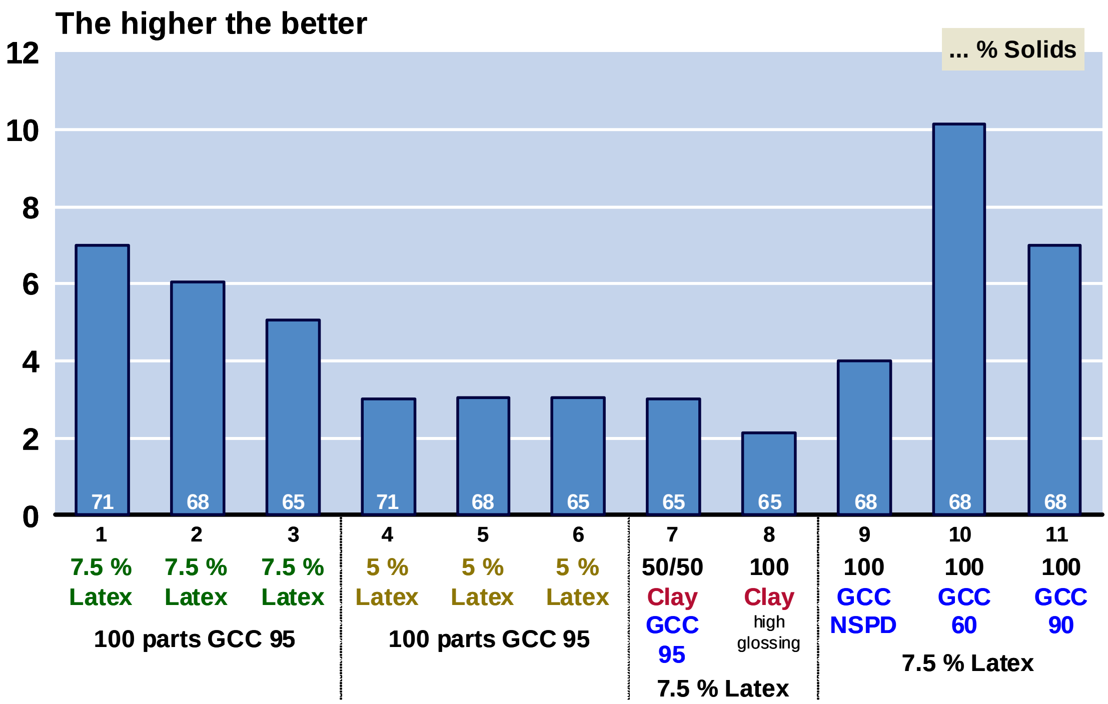

Figure 11 Passes to failure (P&I Test)

Lab Test Results vs. Edge Picking

As depicted in Figures 12 and 13, the ink setting as determined by both test methods (IGT and RI test) correlated well with the degree of edge picking in the commercial printing test. Only a few trial points deviated from the curve. Results from ink tack measurements also provided a fairly good correlation (Figures 14 and 15). Other properties tested in the lab, such as dry pick (Figure 16) or wet pick (Figure 17), showed poorer correlation with the degree of edge picking.

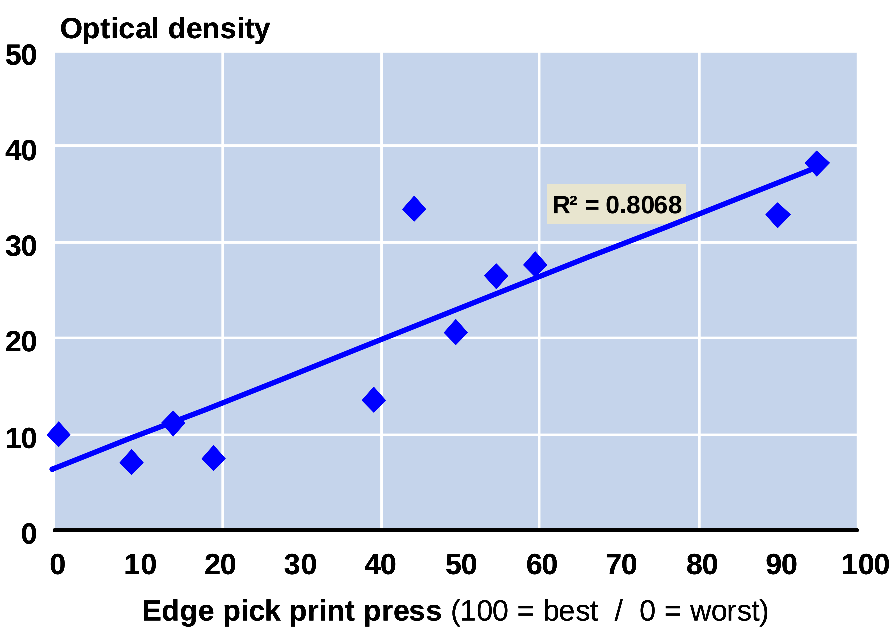

Figure 12 IGT Optical density vs. edge picking (commercial printed papers)

The results indicate that quantifying the interaction between the ink and the coated surface *as a function of time* is required for a sensible lab-scale simulation of the “surface strength” of a coated paper in multicolor sheet-fed offset printing. The surface strength can be defined as the rate of ink tack build-up when the ink diluent absorbs into the coating. A coating layer that creates slow ink tack build-up and low tack forces shows a low degree of (edge) picking and is regarded as having a high surface strength. Ink tack development is related to the rate of ink setting, which consequently makes this a good indication of surface strength.

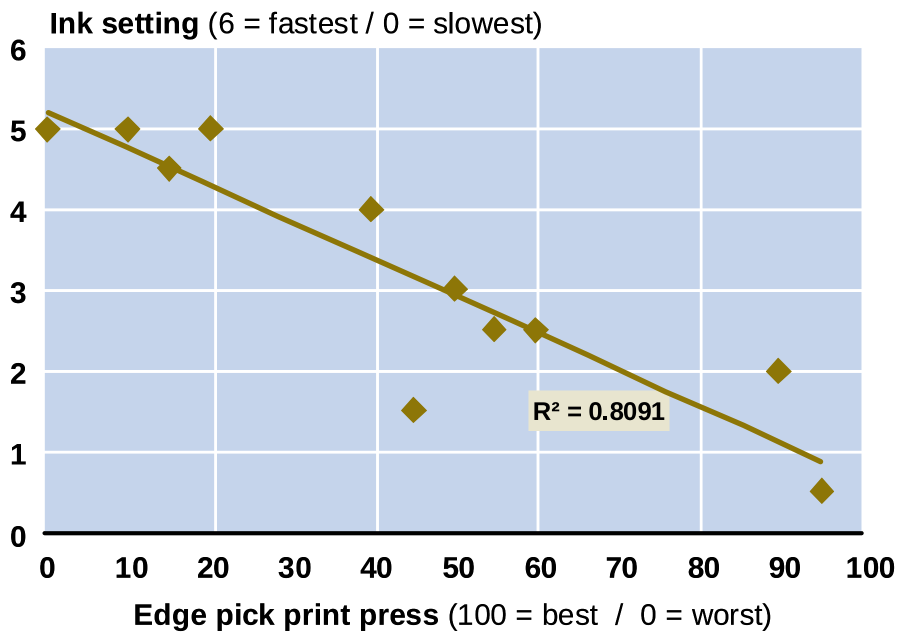

Figure 13 RI Test Ink setting (visual assessment) vs. edge picking (commercial printed papers)

The ink setting and ink tack results make clear that the developed pore structure of the coating layer, and thereby the pigment fineness, is crucial for the degree of edge picking. Fine pigments create a coating layer with a large number of very small pores (high micro-porosity), which generates high capillary pressure and fast ink setting. Higher micro-porosity (finer pigments) also may lead to insufficient ink leveling before ink setting is completed and, thus, reduced print gloss (9, 10, 14). The clay-containing formulations gave the highest degree of edge picking. This finding is most likely related to the very fast ink setting combined with the large surface area (high binder demand) and hydrophilic character of the clay.

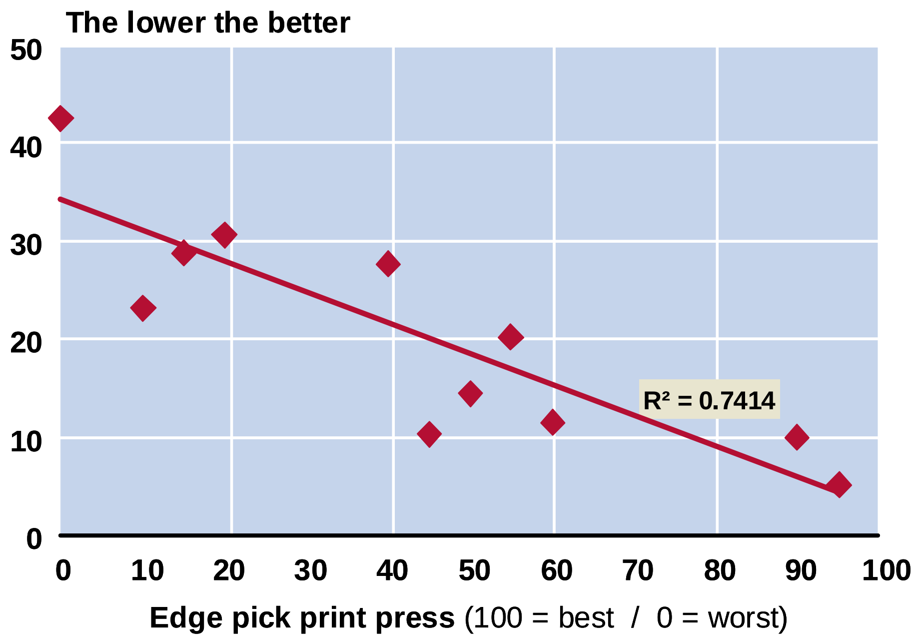

Figure 14 P&I ink tack slope vs. edge picking (commercial printed papers)

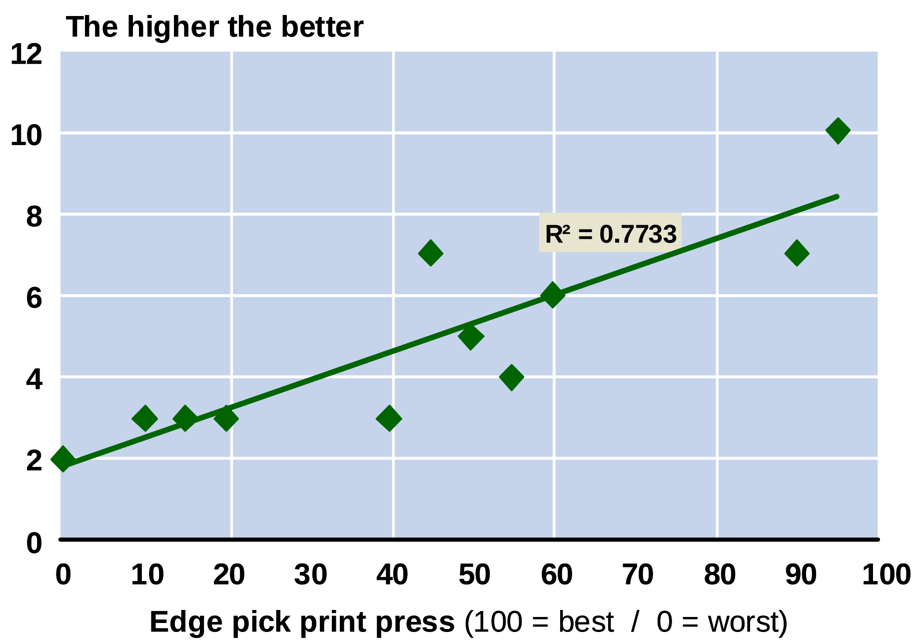

Figure 15 P&I passes to failure vs. edge picking (commercial printed papers)

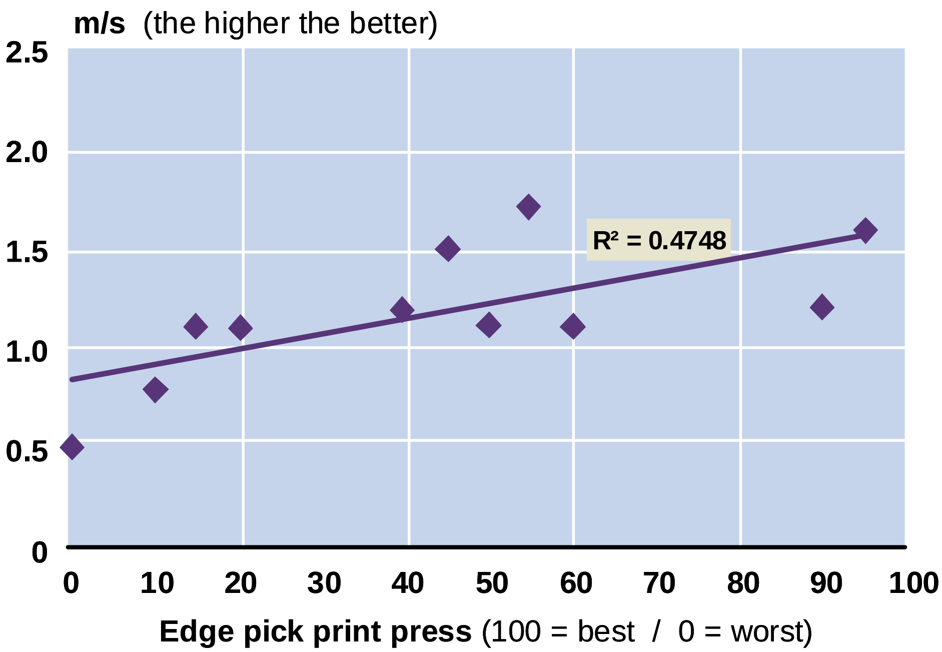

Figure 16 Dry pick vs. edge picking (commercial printed papers)

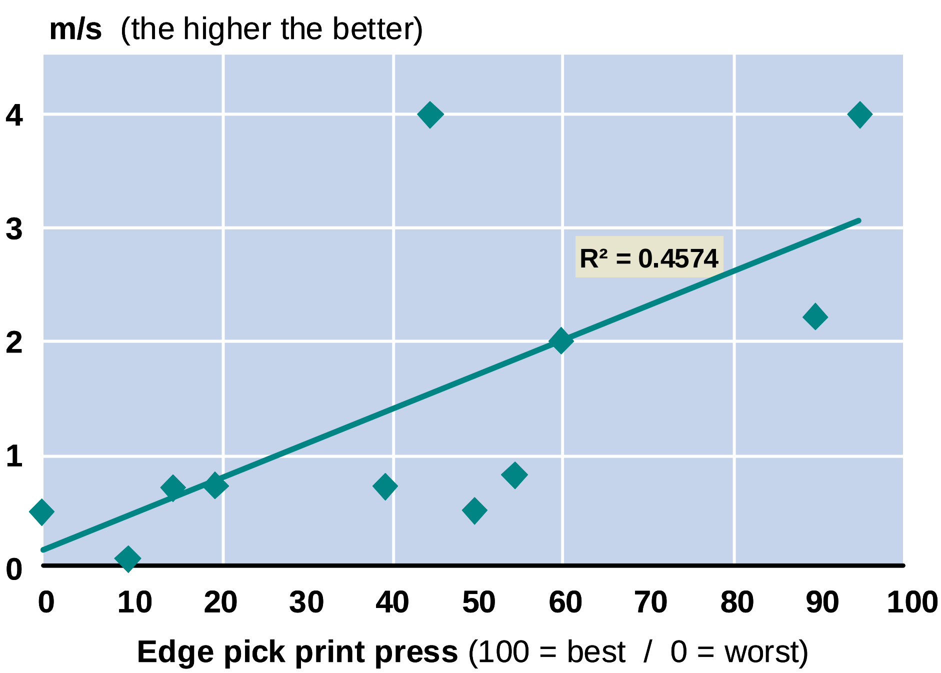

Figure 17 Wet pick vs. edge picking (commercial printed papers)

Sheet Gloss and Print Gloss

Coating at high solids content promotes sheet gloss and print gloss development as a result of improved fiber coverage (11, 22). Particle modeling studies by Toivakka et al. (23, 24) showed that the pigment particles stay more evenly distributed within the coating layer at higher initial solids content, which improves coverage and reduces final surface roughness. The results illustrated in Figure 18 clearly confirm the previous findings that higher coating color solids content promotes sheet gloss development.

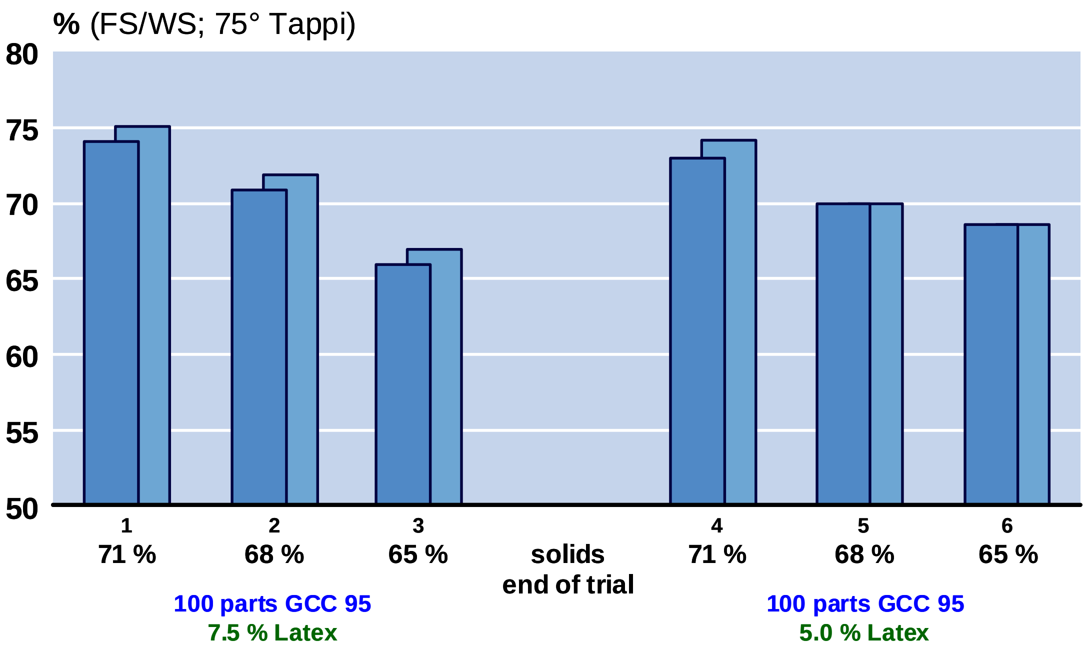

Figure 18 Sheet gloss (calendered)

The print gloss of the test samples followed to a great extent the theoretical expectations based on pigment type, pigment particle size and size distribution, solids content, and binder level. Figure 19 shows the print gloss of the commercially printed samples and Figure 20 shows the lab-evaluated print gloss. In addition to emphasizing the benefits of maximizing solids content for optimal sheet gloss and print gloss, these results also highlight the implications of solids variations. In the industrial coating process it is crucial to continuously control the solids during operation; dilution from cleaning water or up-concentration due to excessive dewatering may cause undesired fluctuations in the solids content with significant quality variations as a result.

We assume that the more rapid consolidation of the coating at higher solids contents prevents excessive binder migration downwards and keeps the latex particles more homogeneously distributed within the coating layer, possibly with a fair portion of the latex concentrated at the very surface. This assumption would support the mechanism proposed by Ranger (25), stating that the top surface of the coating immediately after application contains a high, uniform binder concentration. With a rapid immobilization of the coating (at high solids), more binder stays at the outermost surface, thus slowing down ink setting and favoring ink density and print gloss development. It is well known that a similar effect on print gloss is given from increasing the binder level (12, 14, 16, 26), whereas sheet gloss normally will show the opposite behavior (12, 14, 26, 27).

At the low binder levels used in this study, the detrimental effect of higher latex level on sheet gloss was observed only for the lowest solids content (TP 3 vs. TP 6 in Figure 18), although to lesser extent. The amount of latex was most likely not high enough to create film forming to such a degree that the gloss development upon drying would be disturbed by pronounced shrinkage. At higher solids contents, the faster immobilization promotes instant drying. This may have prevented shrinkage from occurring at the solids contents of 68% and 71% (TP 1 vs. TP 4 and TP 2 vs. TP 5).

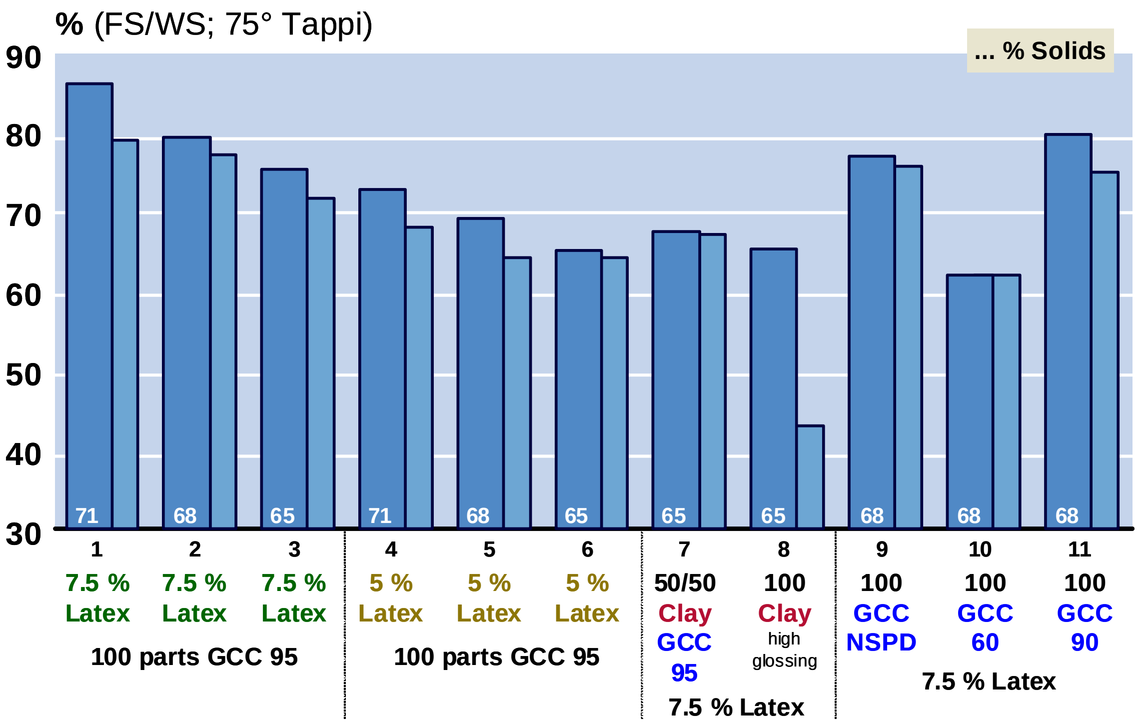

Figure 19 Print gloss (black, commercial printed papers)

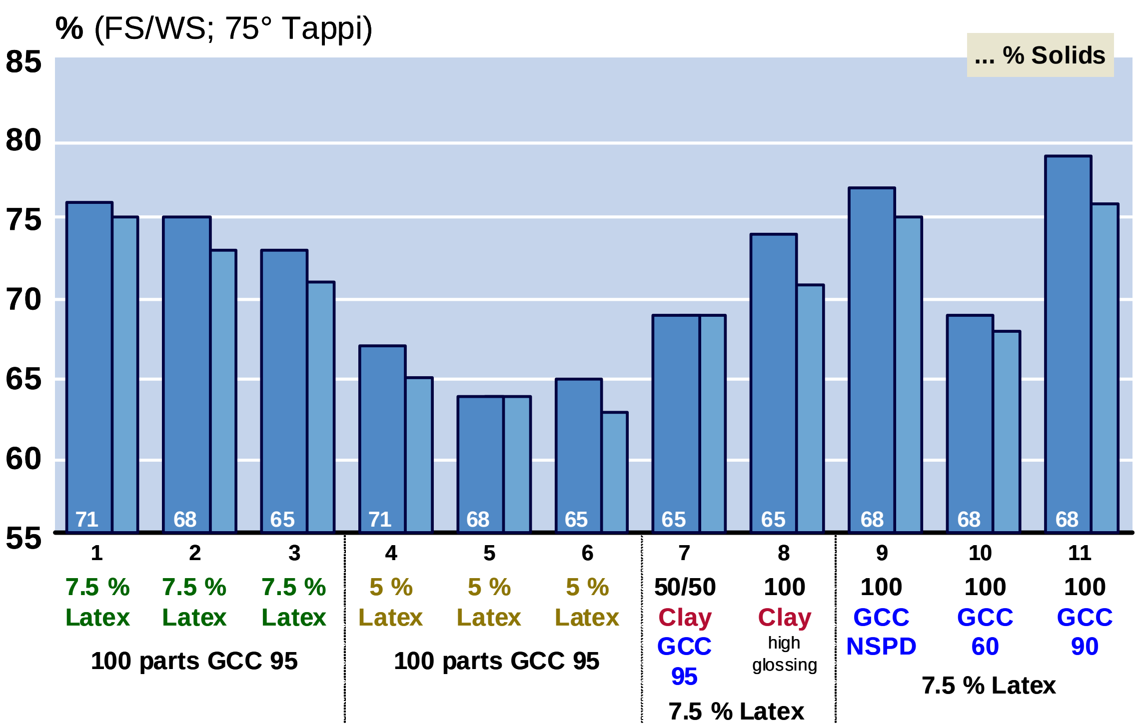

Figure 20 Print gloss (black, lab)

Based on the results from the commercial print trials, the pure clay coating (TP 8) resulted in very low print gloss values, especially on the wire side (Figure 19). This can be explained by the poor surface strength of this trial point, as shown in the previous sections of this study. In the printing trials, the felt side was printed first and then the wire side, without stopping the printing press (note – only one side of each sheet was printed). As the printing proceeded, contamination from the coating significantly disturbed the runnability and ultimately the print quality in the form of low print density and uneven printed appearance (white stripes on the printed image). Print gloss as measured in the lab does not take into account that differences in surface strength may impact surface quality, thus indicating fairly good gloss development for both felt side and wire side of TP 8 (Figure 20).

Ink-Coating Interaction – Pore Size, Solids Content and Binder Level

Mercury intrusion measurements provide information on the pore size distribution of the entire coating layer. The overall pore size seemed to be related mainly to the pigment fineness. Coating color solids and binder level indeed influenced ink-coating interaction, with the conclusion that the variation of these parameters primarily affected the outermost surface of the coating while the general structure of the coating remained fairly unaffected by the latex binder. SEM results by Pöhler et al. (28) suggest that the latex area fraction at the surface of GCC coatings would increase from about 10% to 15% when increasing the latex from 5 to 7.5 parts, while hardly being detectable in the bulk (cross section) of the coating.

It is also possible that the effect of the latex on ink-coating interaction at these low addition levels (5.0 and 7.5 parts) primarily is of chemical nature (polarity) rather than from introducing a significant physical barrier towards ink penetration. A number of studies have reported on the effect of latex modification on ink-coating interaction (11-15, 20, 21). Increasing the binder level above 10 parts has been shown to influence the total coating structure by sealing intrinsic pores to a greater extent, with reduced pore size and slower ink setting as a result (16).

CONCLUSIONS

This study showed that the choice of pigment impacts not only the optical properties of the coated paper, but also the surface strength and, therefore, the binder demand. Commercial SFO printing using a tailor-made printing method provided differentiation of samples with regard to edge picking on a scale of 0 (worst) to 100 (best).

The pigment comparison showed overall best results for GCC 95 at maximum solids and for GCC 60, whereas, as expected, 100 parts of high glossing clay showed the worst results. The low surface strength produced by high levels of high glossing clay can be explained by the very fast ink setting, high surface area, and probably the hydrophilic character of clay compared to GCC. The narrow particle size distribution (NPSD) GCC was less detrimental to surface strength than expected. The uncalendered version of the NPSD GCC showed a slightly higher degree of edge picking than the calendered one.

Maximizing the coating solids can compensate for the loss in pick strength when reducing the binder level, thus giving commercially acceptable printing performance. In addition to the clear improvement in surface strength, increasing the solids content was significantly beneficial for both sheet and print gloss development.

Results from mercury intrusion porosimetry showed that the pore structure of the coated surface, and thereby the ink-coating interaction, is primarily determined by the pigment fineness.

Very good correlation was observed between the degree of edge picking and ink setting. Also the data from ink tack measurements correlated well with the edge picking results. These findings indicate that quantifying the interaction between the ink and the coated surface *as a function of time* provides the most sensible lab-scale simulation of the "surface strength" of a coated paper in multicolor sheet-fed offset printing.

Future trials will further assess the impact of coarser clays and coating PCC.

REFERENCES

1. Gane, P. A. C., Schoelkopf, J., Spielmann, D. C., Matthews, G. P. and Ridgway, C. J., *Fluid Transport into Porous Coating Structures: Some Novel Findings*, Tappi Journal, 83, 5 (2000).

2. Schoelkopf, J., Gane, P. A. C., Ridgway, C. J. and Matthews, G. P., *Influence of Inertia on Liquid Absorption into Paper Coating Structures*, Nordic Pulp and Paper Research Journal, 15, 5 (2000).

3. Gane, P. A. C., Schoelkopf, J. and Matthews, G. P., *Coating Imbibition Rate Studies of Offset Inks. A Novel Determination of Ink-on-Paper Viscosity and Solids Concentration Using the Ink Tack Force-Time Integral*, Tappi International Printing and Graphic Arts Conference Proceedings, 2000.

4. Ridgway, C. J, Gane, P. A. C. and Schoelkopf, J., *Effect of Capillary Element Aspect Ratio on the Dynamic Imbibition in Porous Networks*, Journal of Colloid and Interface Science, 252 (2002).

5. Ridgway, C. J. and Gane, P. A. C., *Dynamic Absorption into Simulated Porous Structures*, Colloids and Surfaces, A: Physiochem. and Eng. Asp., 206, 1-3 (2002).

6. Schoelkopf, J., Gane, P. A. C., Ridgway, C. J., Spielmann, D. C. and Matthews, G. P., *Rate of Vehicle Removal from Offset inks: A Gravimetric Determination of the Imbibition Behaviour of Pigmented Coating Structures*, Tappi Advanced Coating Fundamentals Symposium Proceedings, 2001.

7. Schoelkopf, J., Gane, P. A. C. and Ridgway, C. J., *Pigment Coating Permeability: Measurement and Correlation with Wetting Front Penetration*, Tappi Advanced Coating Fundamentals Symposium Proceedings, 2003.

8. Preston, J. S., Parsons, J., Nutbeem, C. and Husband, J. C., *Ink Gloss Development Mechanisms After Printing - Part 2*, Tappi Advanced Coating Fundamentals Symposium Proceedings, 2003.

9. Carne, T. , Karathanasis, M., Dahlvik, P., Haugwitz, B. and Ström, G., *Importance of Coating Structure for Sheet-fed Offset Print Quality*, PTS Coating Symposium Proceedings, 1999.

10. Donigian, D. W., Ishley, J. N. and Wise, K. J., *Coating Pore Structure and Offset Printed Gloss*, Tappi Journal 80, 5 (1997).

11. Bluvol, G., Dahlvik, P., Hipp, A., Salminen, P. and Welsch, G., *Cost Saving Concept for Production of High Quality Double Coated Papers – Part 2: Blade-Blade Coating Systems,* Tappi Coating Conference Proceedings, 2008.

12. Bluvol, G. and Carlsson, R., *Optimising Ink Setting Properties on Double Coated Wood-Free Papers*, PTS Coating Symposium Proceedings, 2003.

13. Xiang, Y. and Bousfield, D. W., *Influence of Coating Structure on Ink Tack Dynamics*, Journal of Pulp and Paper Science 26, 6 (2000).

14. Karathanasis, M., Fogden, A. and Dahlvik, P., *The Concept of Critical Ink Setting Time and Its Relation to Print Gloss – Influence of Latex Binder,* Nordic Pulp and Paper Research Journal 19, 2 (2003).

15. Rousu, S., *Differential Absorption of Offset Ink Constituents on Coated Paper*, Doctoral Thesis, 2002.

16. Ström, G. and Karathanasis, M., *Ink Setting on Coated Media – Importance of Pore Structure and Latex Content*, 2nd International Papermaking & Environment Conference Proceedings, Tianjin, China, 2008.

17. Larsson, M., Engström, G., Vidal, D. and Zou, X., *Compression of Coating Structures During Calendering*, 9th Tappi Advanced Coating Fundamentals Symposium, 2006.

18. Suontausta, O., *Coating and Calendering – Means of Improving Surface of Coated Paper for Printing*, Doctoral Thesis, 2002

19. Gane, P.A.C. and Seyler, E.N., Tack Development: *An Analysis of Ink/Paper Interaction in Offset Printing*, Tappi Coating Conference Proceedings, 1994.

20. Van Gilder, R. L. and Purfeerst, R. D., *Latex Binder Modification to Reduce Coating Pick on Six-Color Offset Presses*, Tappi Journal 77, 5 (1994)

21. Van Gilder, R. L. and Smith, D. A., *Development of a High Polarity Latex Polymer for Waterless Sheetfed Paper Coatings*, PITA Coating Conference Proceedings, 1999.

22. Van Gilder, R. L. and Purfeerst, R. D., *The Effect of Coating Color Solids on Properties and Surface Uniformity*, Tappi Journal 68, 5 (1986).

23. Toivakka, M., Salminen, P., Chonde, Y. and Bousfield, D., *Consolidation of Particulate Suspension – Model Study with Plastic Pigments*, Tappi Coating Fundamentals Symposium Proceedings, 1997.

24. Toivakka, M., Eklund, D. and Bousfield, D., *Simulation of Pigment Motion During Drying*, Tappi Coating Conference, 1992.

25. Ranger, A. E., Binder Migration during Drying of Pigment Coatings, Paper Technology, December, 1994.

26. Zang, Y.-H. and Aspler, J. S., *The Effect of Surface Binder Content on Print Density and Ink Receptivity of Coated Paper,* TAPPI Advanced Coating Fundamentals Symposium Proceedings, 1997.

27. Lee, D. I., *A Fundamental Study on Coating Gloss*, Tappi Coating Conference Proceedings, 1974.

28. Pöhler, T., Juvonen, K. and Sneck, A., *Coating Layer Microstructure and Location of Binder – Results from SEM Analysis*, 9th Tappi Advanced Coating Fundamentals Symposium, 2006.