

ABSTRACT

Metered film press (MFP) coating is commonly applied to wood-containing grades. This study examines the possibility of improving MFP paper and print quality by optimizing the base sheet. MFP coating trials were carried out on a pilot coater running at 1800 m/min using a wood-containing base paper produced on a commercial paper machine. The results showed that two base-paper properties—smoothness (attained by precalendering) and filler content—had a major influence on paper and print quality. While precalendering did not improve surface roughness or gloss significantly, it did improve the coat weight distribution, which resulted in better print quality. Coat weight distribution also was improved by increasing the sheet's filler content. Precalendering also minimized fiber roughening of printed sheets. Increasing the level of filler content reduced surface roughness and print mottle while improving coated-paper gloss and print gloss. The results suggest that with optimized coating colors and base sheets (precalendered, higher filler levels), MFP coated paper can compete with standard lightweight coated (LWC) as an offset grade.

Application:

Pilot results show that if the base paper is optimized, MFP coated paper can compete with LWC.

METERED FILM PRESS (MFP) coating has become a common way of up-grading newsprint and supercalendered grades. Since the introduction of MFP coated grades on the European market in 1992, the process has developed rapidly (1) and is today a very cost-efficient way of producing coated wood-containing paper.

Influence of base-paper filler content and precalendering on metered film press coating—paper and print quality

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The MFP coating technique has many advantages. The mechanical stress applied on the web is less than in blade coating, which increases production efficiency by 3–5% because of fewer web breaks at the coating station. It also allows the use of weaker and less expensive furnish with higher filler contents. Moreover, the MFP produces a contourlike coating that provides superior fiber coverage. It has also been reported that MFP coated paper shows less fiber roughening during heat-set web offset printing (1, 2). On the other hand, surface roughness is generally higher on these grades, which makes them unsuitable for roto gravure printing (1, 2).

Today's modern production techniques have made it possible for wood-containing MFP coated grades to compete with blade-coated LWC. Extensive efforts to optimize coating color formulations and machine parameters have helped in overcoming such problems as color misting at the nip outlet and "orange peel" pattern on the coated surface (3). Increasing the filler content in the base paper also improves the surface properties of MFP coated paper (1). With a higher filler content in the base paper, there is less fiber-to-fiber contact, which reduces hygroexpansion and swelling pressure within the fiber matrix during water contact (4, 5).

Precalendering does not always have the expected beneficial effects on surface roughness and printability. During coating, water can cause the fibers to swell, relaxing the stress built up within the sheet during pre-

calendering. Mechanical fibers are more prone to such effects than chemical fibers (6–8). The result can be a reduction in gloss and an increase in surface roughness. Moreover, expansion of fiber flocs can disrupt the even distribution of coating mass, with a consequent reduction in print quality (9). According to one study, the tendency for fibers to rise during coating was greater for sheets that were precalendered using a steel-to-steel nip compared with a soft nip (10).

If the quality of MFP coated wood-containing paper is to be improved, a better understanding of how the base paper influences paper and print quality is required. The influence of base-paper properties on paper and print quality is, of course, an important consideration for all coated grades. Indeed, the effects of precalendering and filler content have been studied for blade coating. Nevertheless, a separate study of these effects on MFP coating is justified because the prevailing dewatering conditions and the nature of the MFP coating layer are significantly different from blade coating (11). This report presents the results of a study into the effects of precalendering and filler content on the quality of MFP coated paper.

EXPERIMENTAL

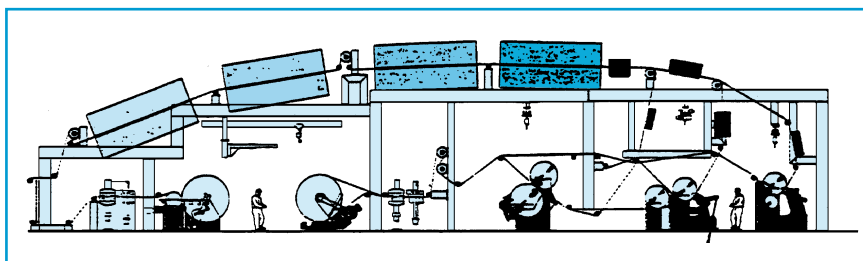
Extensive pilot trials on a MFP unit were carried out to study both runnability and paper/print quality. This report presents the results for paper/print quality. Results for runnability are presented in a sepa-

Base paper	Filler content, %	Opacity, %	Density, kg/m ³	Tensile stiffness (MD), kN/m	Tensile strength (MD), kN/m
Uncalendered	10	94.2	1015	457	3.7
Precalendered	10	94.6	980	460	3.7
Uncalendered	15	94.0	1044	451	3.4
Precalendered	15	94.4	999	458	3.5
Uncalendered	20	94.4	1030	446	3.3
Precalendered	20	94.4	1040	441	3.3

II. Base-paper properties of precalendered and uncalendered papers at three levels of filler content

Content	Trial 1	Trial 2
Clay, pph (SPS, English China Clay Intl., Cornwall, England)	100	...
Calcium carbonate, pph (HydroCarb 90, Omya, Switzerland)	...	70
Clay, pph (Amazon 88, CADAM, Brazil/Kaolin Intl. BW, Netherlands)	...	30
S/B latex, pph (Styronal FD-516, Raisio Chemicals Oy, Raisio, Finland)	12	12
CMC, pph (FinnFix 5, Metsa Specialty Chemicals Oy, Äänekoski)	0.3	0.3
Optical brightener, pph (Blankophor P, Bayer AG, Germany)	0.8	0.8
Solids content, %	57	63
Brookfield viscosity at 100 rpm, mPa·s	400	800

III. Coating color compositions for Trials 1 and 2



I. MFP pilot coater

rate report (12). For a more detailed description of the trials, refer to Part 1 of this report (12).

Testing

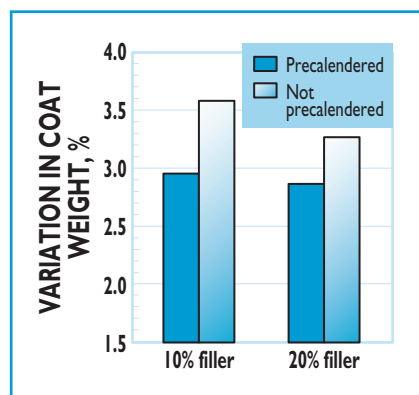
Conventional paper testing. The following paper properties were measured according to standard testing methods: grammage (SCAN P 5:63); ash content (SCAN P 5:63); gloss measured at 75° (TAPPI T 480); and surface roughness (SCAN P 76:95) at PPS-S5 and PPS-S10, i.e.,

with clamp pressures of 0.5 and 1.0 MPa, respectively.

Coat weight variation. Coat weight variation was evaluated using a standard method (Stora) involving image analysis of ashed samples. Coated sheets were ashed, and the coefficient of variation of reflectance of the ashed sample was measured. The area analyzed was 90.3 mm × 34.9 mm, and the reported values are within the floc size range 1–8 mm.

Number of tracks	20
Length of track, mm	58
Distance between tracks, mm	3
Vertical range, μm	2.5
Sampling distance, μm	20
Probe speed, mm/s	0.5

I. Operational details of the laser probe



2. Variation in MFP coat weight distribution (wavelength = 1–8 mm) for precalendered and uncalendered base papers at two levels of filler content

Surface topography. The surface topography of the coated paper was analyzed using a laser probe (Perthometer C5D, Mahr GmbH, Göttingen, Germany). The results are presented as a variance spectrum of the surface topography. Operational details of the laser probe are presented in Table I.

Print mottle. Print mottle was measured on a 40% black halftone area in accordance with a standard method (Stora) based on image analysis. Variation in print density was measured and divided into different floc sizes with a band-pass filter. The best correlation with visual appearance was within a floc size range of 1–8 mm.

Fiber roughening. Fiber roughening is the increase in surface roughness of the sheet during heat-set web offset printing. In this paper, fiber roughening is defined as the difference between the surface roughness of printed and unprinted sheets. (Roughness was determined using a Parker print-surf device with a clamp pressure of 0.5 MPa, i.e., PPS-

S5.) Printed surface roughness was measured on an area consisting of two full tones printed on top of each other (200% solid print) (13).

Pilot trials

Base paper. The base papers used in the trials were produced on a commercial paper machine at three levels of filler content (10%, 15%, and 20%). The furnish was based on pressurized groundwood (PGW) and kraft pulp. Sheet basis weight was 45 g/m² with a starch content of 0.7%. **Table II** lists the properties of the three base papers before and after precalendering. For further details, see Part I of this report (12).

Coating color composition. Two separate coating trials were run. In Trial 1, a standard kaolin formulation was used; in Trial 2, the coating color formulation was improved to attain a paper quality comparable with commercial LWC grades. **Table III** shows the coating color compositions for Trials 1 and 2.

Coater. The paper was coated on a pilot coater with a metered film press unit (SymCoat, Valmet Corp.) at the Valmet Finishing Technology Center (Järvenpää, Finland) (12). The machine speed was 1800 m/min. The pilot coater is shown in **Fig. 1**.

Precalender. Precalendering was done with one hard nip (steel to steel) at a linear load of 50 kN/m to reach a smoothness (Bendtsen) target of 400 mL/min. Machine speed was 1800 m/min.

Conventional supercalender. Supercalendering was carried out on a conventional stack with 11 nips and a double finisher in the 6/7-nip position (Valmet Finishing Technology Center). The speed was 700 m/min with a linear load of 310 kN/m. Cotton-wool rolls (85 Shore D hardness) were used as soft rolls. The temperatures of the steel rolls were 60°C, 80°C, and 100°C.

Printing press. Printing was performed on a heat-set web offset printing press (Albert-Frankenthal) at the Finnish Pulp and Paper Re-

search Institute in Espoo, Finland. Printing speed was 6.1 m/s (366 m/min). The order of color application was black, cyan, magenta, and yellow. The dampening water contained 10% isopropanol. Negative printing plates were used (Osasol N71). All inks were obtained from commercial vendors [black ink (Challenge) from Sun Chemicals; colored inks: cyan (2054-6790K), magenta (2054-5090K), and yellow (2054-2390K) from Sicpa].

RESULTS AND DISCUSSION

The effects of precalendering and filler content on paper and print properties were studied during Trial 1. In Trial 2, the coating color formulation was further optimized to improve both paper and print quality. The papers coated during Trial 2 were compared with a standard LWC paper from the European market.

Trial 1: Effect of base-paper filler content and precalendering

Paper properties. The MFP provides good physical fiber coverage, which is important both for print quality and fiber roughening (2). This brings up the question of whether coverage can be further improved by improving the base paper. **Figure 2** shows that variation in coat weight distribution can indeed be reduced significantly by precalendering and by increasing the base paper's filler content.

There is a clear need to reduce surface roughness on MFP coated grades, which are widely perceived to be rougher than blade-coated surfaces. However, the results in **Fig. 3** indicate that precalendering did not reduce surface roughness on this type of coated paper. A possible explanation is that fiber roughening occurred when the paper was coated. Surface roughness declined slightly with increasing filler content for the precalendered base papers.

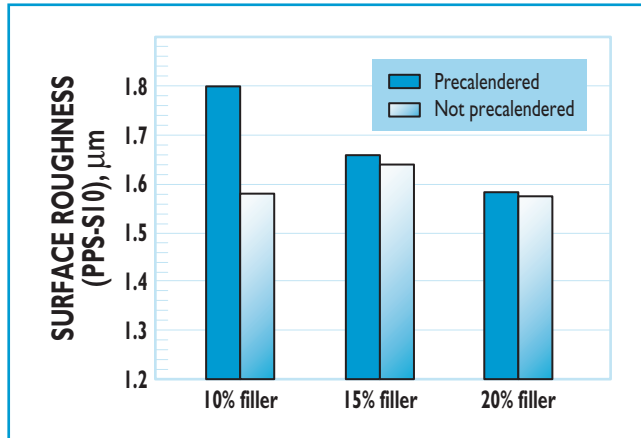
Figure 4 shows that coated-paper gloss increased with increasing filler content for the precalendered base papers. On the other hand, precalendering did not increase gloss.

The surface topography of the coated paper was analyzed with a laser probe (Perthometer), which gives a variance spectrum of the surface topography. The trends observed in surface roughness of the coated papers (**Fig. 3**, PPS-S10 values) are also apparent in the curves depicted in **Figs. 5 and 6**. A higher filler content level reduced the topography variations in the wavelength up to 1 mm, as seen in **Fig. 5**. Precalendering had no effect on topography variations at the filler content level of 20%, as seen in **Fig. 6**.

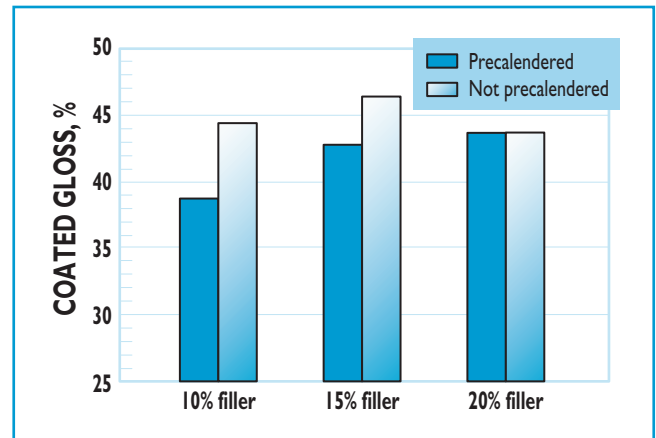
The increase in filler content reduced sheet tensile strength and stiffness (**Table II**), as expected. However, there were no runnability problems in the printing press resulting from insufficient strength properties. The effect of precalendering on strength properties was negligible.

Print quality. Precalendering slightly reduced print mottle in 40% black halftone areas for the two lower filler contents, as shown in **Fig. 7**. Increasing the filler content also reduced print mottle in 40% halftone areas for the paper that was not precalendered. A difference in print mottle of 0.1 units is visible to the eye on these samples, where a lower value indicates a better result. The effect of precalendering and filler content on print gloss is shown in **Fig. 8**. Print gloss increased slightly with a higher filler content, but precalendering had no impact on the print gloss.

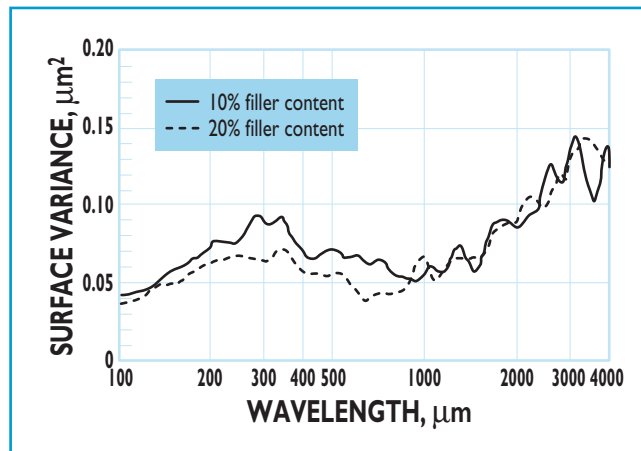
Fiber roughening, which is the increase in surface roughness of the sheet during printing, is an important quality parameter on heat-set web offset-printed LWC paper. This fiber roughening can be expressed as the difference between the surface roughness of a printed area (200% solid print) and an unprinted sheet. Of course, the measurement of surface roughness on the printed image is also an important quality characteristic. The water in the printing process is one of the reasons for roughening of the sheet (13). Results presented in **Fig. 9** show that



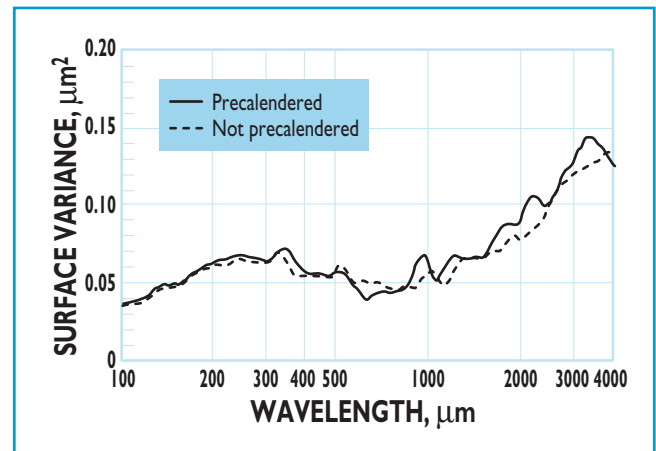
3. Surface roughness for MFP coated precalendered and uncalendered base papers at three levels of filler content



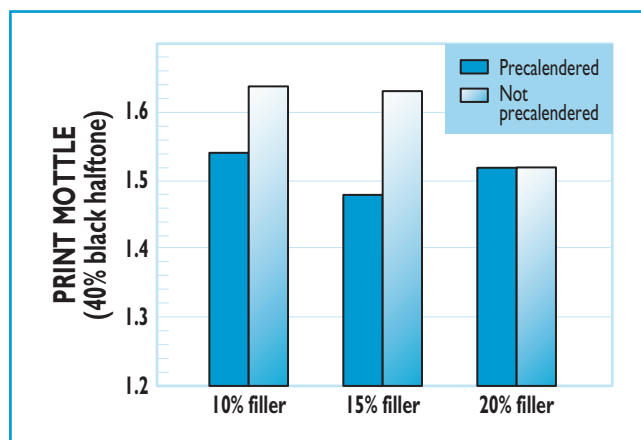
4. MFP coated-paper gloss for precalendered and uncalendered base papers at three levels of filler content



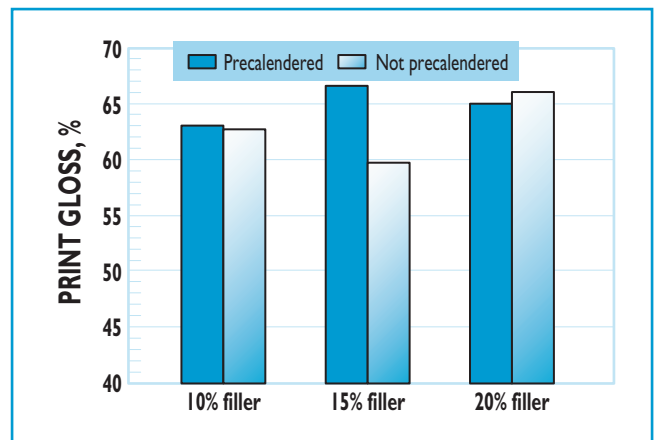
5. Surface variance for MFP coated precalendered base papers with filler contents of 10% and 20%



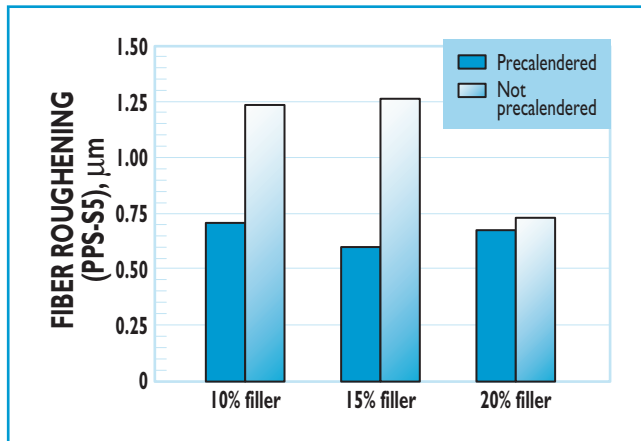
6. Surface variance for MFP coated precalendered and uncalendered base papers at a filler content of 20%



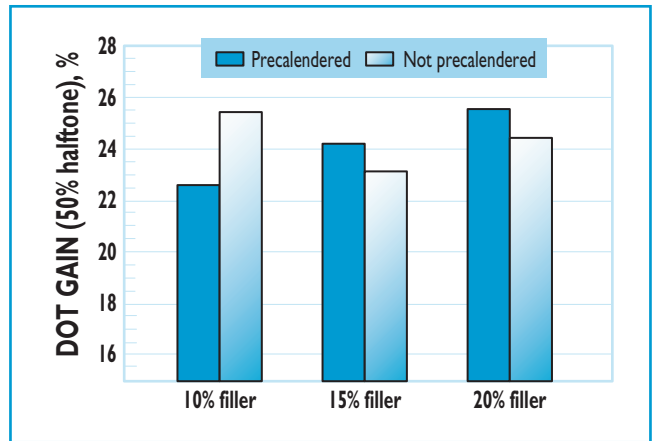
7. Print mottle (in 40% black halftone area) for MFP coated precalendered and uncalendered base papers with different filler contents



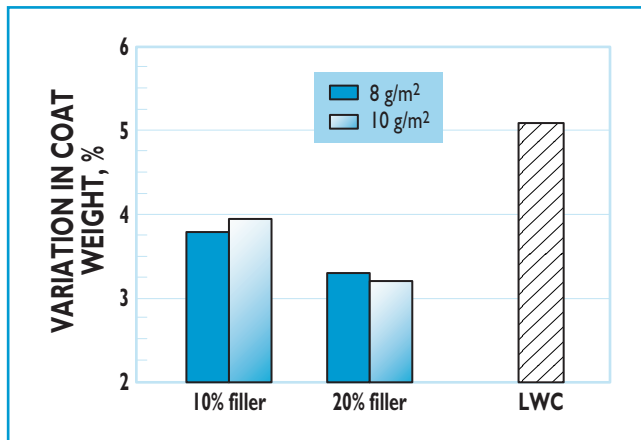
8. Print gloss for MFP coated precalendered and uncalendered base papers with different filler contents



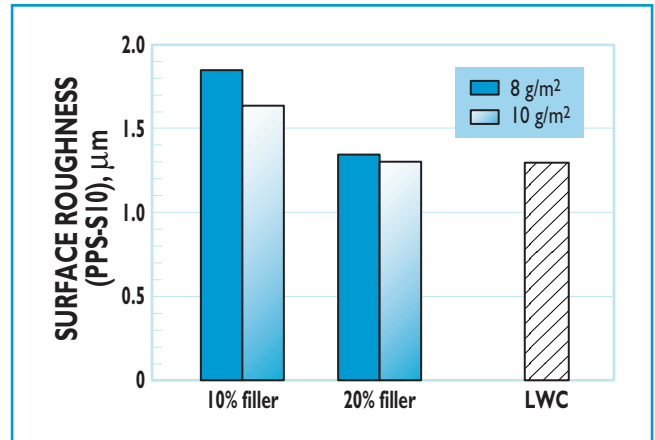
9. Fiber roughening for MFP coated precalendered and uncalendered base papers with different filler contents



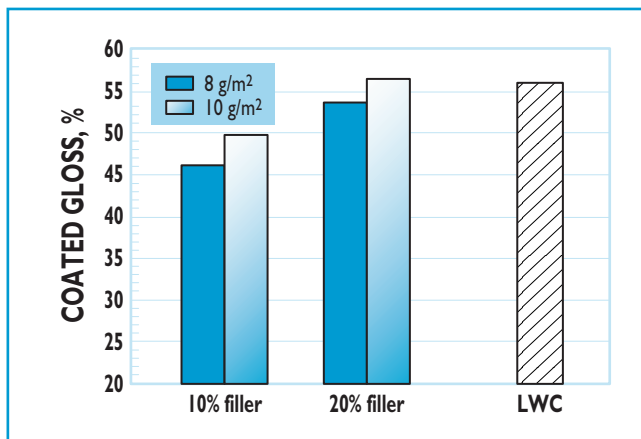
10. Dot gain for printed MFP coated precalendered and uncalendered base papers with different filler contents



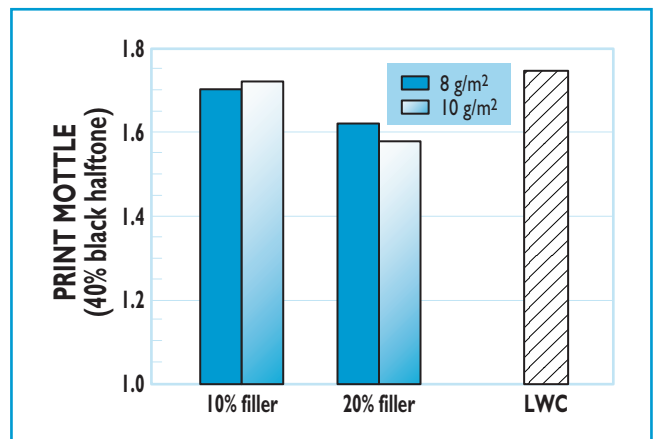
11. Variation in coat weight distribution (wavelength = 1–8 mm) for MFP coated precalendered base papers (10% and 20% filler contents, 8- and 10-g/m² coat weights) and for the blade-coated LWC reference sample (10-g/m² coat weight)



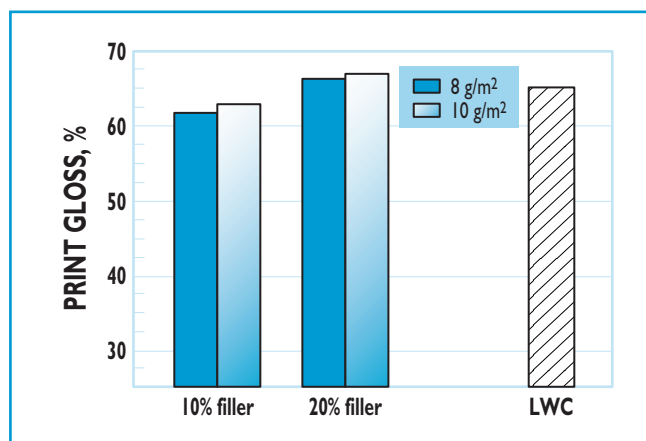
12. Surface roughness for MFP coated precalendered base papers (10% and 20% filler contents, 8- and 10-g/m² coat weights) and for the blade-coated LWC reference sample (10-g/m² coat weight)



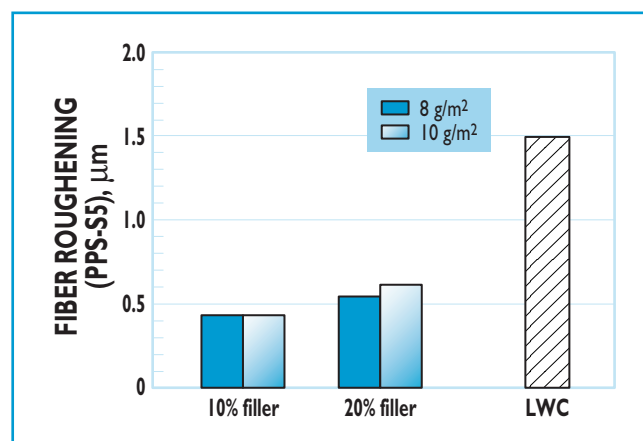
13. MFP coated-paper gloss for precalendered base papers (10% and 20% filler contents, 8- and 10-g/m² coat weights) and for the blade-coated LWC reference sample (10-g/m² coat weight)



14. Print mottle (in 40% black halftone area) for MFP coated precalendered base papers (10% and 20% filler contents, 8- and 10-g/m² coat weights) and for the blade-coated LWC reference sample (10-g/m² coat weight)



15. Print gloss for MFP coated precalendered base papers (10% and 20% filler contents, 8- and 10-g/m² coat weights) and for the blade-coated LWC reference sample (10-g/m² coat weight)



16. Fiber roughening for MFP coated precalendered base papers (10% and 20% filler contents, 8- and 10-g/m² coat weights) and for the blade-coated LWC reference sample (10-g/m² coat weight)

precanceling reduced fiber roughening for the sheets with low filler contents. At the higher filler content, fiber roughening was reduced for the paper that was not precancelled.

Figure 10 shows the dot gain for the printed papers. (A lower dot-gain indicates a better result because it improves tone rendering.) Precanceling did not have any significant effect on dot gain except for the sheet with a filler level of 10%, where precanceling reduced the dot gain. The slight increase in dot gain with increasing filler levels for the precancelled papers is difficult to explain.

Summary. Surface roughness and gloss were not improved by precanceling the three base papers used in the trials. However, precanceling did reduce the variation in coat-weight distribution, with a consequent reduction in print mottle. Regarding print properties, precanceling had no impact on print gloss. However, the results showed that fiber roughening during heat-set web offset printing can be minimized by precanceling, although this effect decreased with increasing filler content.

Surface roughness decreased slightly with increasing filler content levels. Increasing filler content also gave higher gloss for precancelled papers, whereas filler content had no

effect on gloss for the nonprecancelled papers. Coat weight variations and fiber roughening during printing diminished with increasing filler content. Based on these results, precanceling and 20% filler content levels are recommended.

Trial 2: Quality optimization

For Trial 2, the coating color formulation was optimized (composition and solids content) for use with a precancelled base paper. Details of the formulation are presented in Table III. The results obtained during Trial 2 were compared with a blade-coated LWC paper with a coat weight of 10 g/m².

Paper quality. The results in Fig. 11 show an improvement in coat weight distribution with increasing filler content. The MFP coated papers had a more even coat weight distribution than the blade-coated LWC paper. This result was expected, since the MFP gives a more contourlike coating.

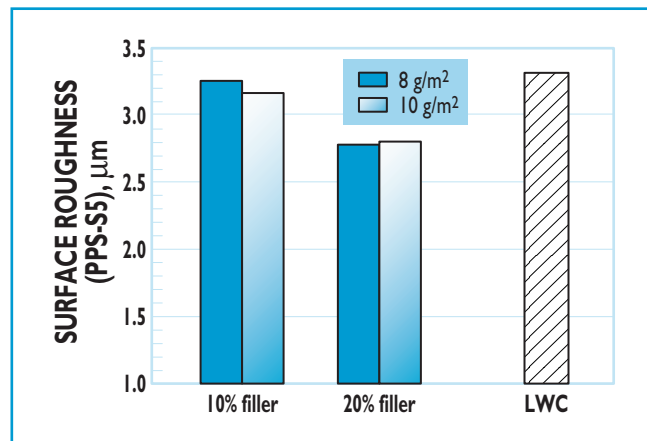
The surfaces of MFP coated grades are widely perceived to be rougher than blade-coated surfaces. However, Fig. 12 shows that the pilot-coated paper with the higher filler content achieved a roughness that rivals that of a typical blade-coated LWC offset grade. These results confirm that a higher filler content reduces the surface roughness.

The MFP coated paper with the higher filler content achieved the same coat gloss as the LWC reference paper, as seen in Fig. 13. However, gloss can be optimized by adjusting coating color composition and is less relevant in this kind of comparison. Nevertheless, these results confirm the results of Trial 1, which showed that gloss increased with increasing filler content.

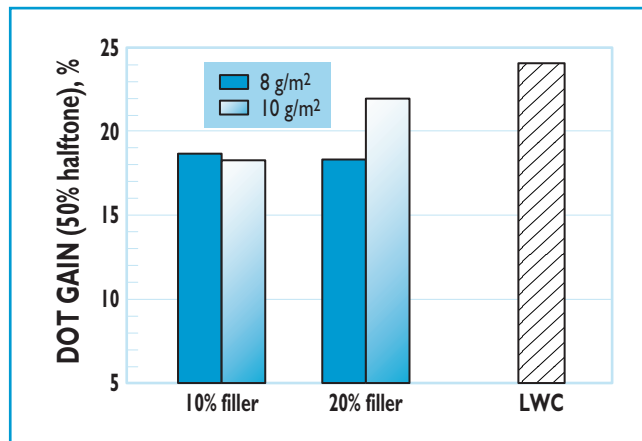
Print quality. Print quality for the MFP coated paper was slightly better than for the blade-coated LWC reference sample, as seen in Fig. 14. The slightly lower degree of mottle for the heat-set web offset-printed MFP coated sheets could be explained by the more evenly distributed coating. Mottle decreased slightly with increasing filler content in the base paper.

Print gloss in Fig. 15 follows the same trend as coated gloss (Fig. 13). The sheet with a higher filler content gave a slightly higher print gloss that reached the level of the LWC reference paper.

Figure 16 shows the results for fiber roughening, defined as the difference in roughness values (PPS-S5) between the printed and the unprinted samples. The blade-coated LWC showed a higher degree of fiber roughening than the MFP coated paper.



17. Printed surface roughness (PPS-S5) of a 200% solid print for MFP coated precalendered base papers (10% and 20% filler contents, 8- and 10-g/m² coat weights) and for the blade-coated LWC reference sample (10-g/m² coat weight)



18. Dot gain for printed MFP coated precalendered base papers (10% and 20% filler contents, 8- and 10-g/m² coat weights) and for the blade-coated LWC reference sample (10-g/m² coat weight)

The results in Fig. 16 might appear to suggest that the sheet with the lower filler content had a smoother surface after printing, but this is not the case. Figure 17 shows the surface roughness measured on a 200% solid print. Surface roughness was lowest for the sheets with the higher filler content.

Figure 18 shows the results for dot gain. The LWC reference suffered a higher level of dot gain than the MFP coated paper. Filler content of the MFP coated sheets did not have a significant impact on dot gain.

Summary. Trial 2 confirmed the beneficial effects of increasing base-paper filler levels. Surface roughness and gloss improved slightly with increasing filler content levels. The higher filler level also gave a better coat weight distribution, which led to less print mottle.

A typical blade-coated LWC paper served as a reference during Trial 2. The coat weight of the MFP coated sheets was more evenly distributed than the LWC sheet. For the MFP coated sheets with a higher filler content (20% filler), the print mottle and dot gain were lower than for the blade-coated LWC sheet, while PPS roughness, coated gloss, and print gloss were comparable with LWC.

CONCLUSIONS

The study shows that two base-paper properties—filler content and smoothness (attained by precalendering)—have a major influence on paper and print quality for MFP coated paper. Precalendering did not significantly improve the surface roughness or gloss of the solely wood-containing base paper used in the trials. However, the coat weight distribution was improved by both precalendering and higher filler contents, which improved print quality.

Precalendering also minimized fiber roughening during printing for MFP coated paper. Increasing the base-paper filler content reduced surface roughness while improving print gloss and coated-paper gloss, thus reducing print mottle.

The results of this study demonstrate that—with optimized coating colors and base sheets (precalendered, 20% filler)—MFP coated paper can compete with standard offset LWC grades. **TJ**

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