Effect of papermaking and coating variables on offset-print quality

Part 2—Coating and calendering variables

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ABSTRACT: Studies were carried out to explore the potential of improving offset-print quality on coated, wood-free publication-grade papers. Part 1 of the study (published in the October issue) examined the effects of fiber source and press configuration on the physical properties and print quality of coated/calendered sheets. Part 2 focuses on the effects of coat weight, finishing technique (thermofinishing vs. supercalendering), and the practice of precoating/precalendering the basestock before applying a top coat. Part 2 shows that both surface smoothness and print quality improved with increasing coat weight at the same sheet gloss. Thermofinishing gave a smoother and glossier surface than conventional supercalendering. Application of a low-solids precoat with precalendering diminished the final smoothness of coated/calendered sheets.

KEYWORDS: Blade coating, coating weight, finishing, offset papers, paper stock, print quality, smoothness, supercalendering, two side coating.

The coated-paper market has become increasingly competitive in recent years, compelling papermakers to strive for greater production efficiency and higher quality standards. The higher quality standards are driven largely by the demands of printers and converters who want to increase their own productivity. Generally, an increase in production rates for these customers imposes higher quality demands on the coated paper.

This article presents the results of studies that were carried out to explore ways of improving the offset-print quality of coated wood-free publication-grade papers. In part 1 of this report, we discussed the effects of fiber source and press configuration on the offset-print quality of coated/calendered papers *(1)*. In part 2, we examine the effects of coating and calendering variables on offset-print quality.

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A search of the literature revealed little work on the relationship between coating and calendering variables and the offset-print quality of coated paper. Therefore, we concentrated on improving the offset-print quality of coated publication-grade papers by optimizing coating coverage and calendering. Because the basestock imposes limitations to achievable finished properties, we also examined the possibility of improving basestock quality through pigmented precoating and precalendering.

Experimental

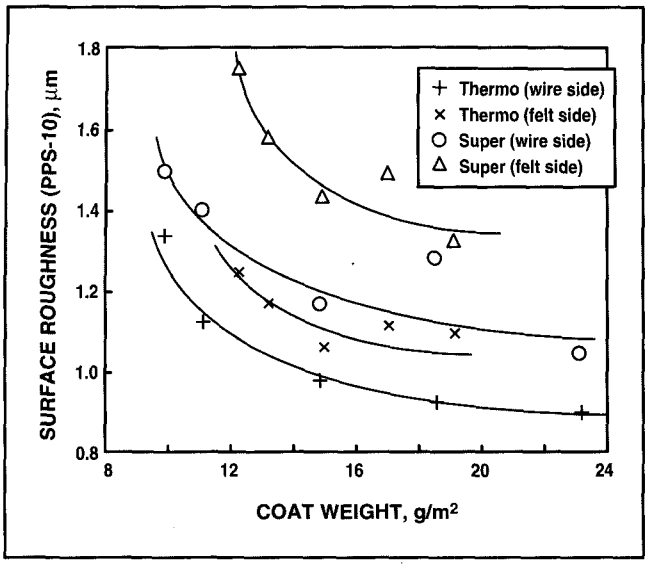
Coating, calendering, and testing

The coating basestock used here was manufactured using northern fiber on a production paper machine equipped with a fourdrinier and a Tri-Nip press. The physical properties of the fiber furnish (Furnish A) and the basestock were described in part 1 of this report *(1)*. General information on the coating, calendering, and testing conditions was also described in part 1. A detailed description of the individual trial conditions is presented under the "Results and discussion" heading.

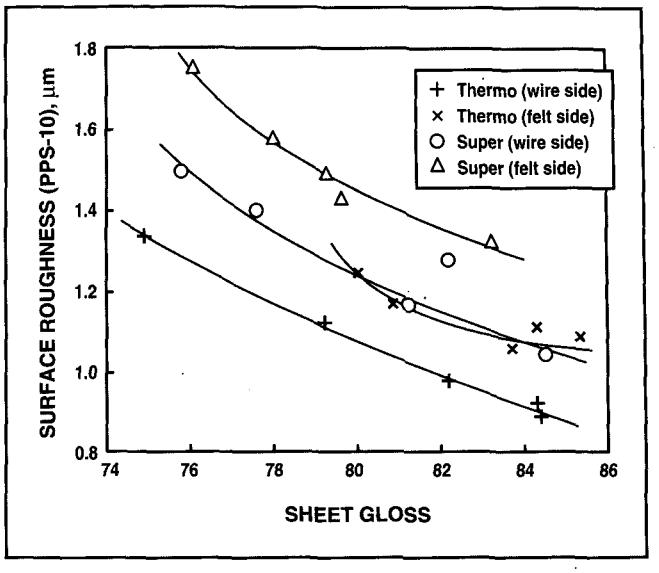
Offset printing

The coated/calendered paper was printed using a commercial-scale, five-color, Heidelberg sheet-fed offset press at 6000 impressions per hour. The press was set up using a production paper to achieve specific ink-density targets. All of the trial papers

1. Parker print–surf roughness (PPS-10) as a function of coat weight for thermofinished or supercalendered sheets



2. Parker print–surf roughness (PPS-10) as a function of sheet gloss for thermofinished or supercalendered sheets



were then printed under constant press conditions. The printed paper was evaluated for printability, including picking and piling. A panel of judges evaluated print quality on a full-color test image using the Rangefinder technique *(2)*. Print gloss and ink density were measured on 100% and 400% ink coverage (black solid targets).

Results and discussion

Effect of coat weight

Good coverage of the basestock fibers with coating is essential to the quality of a coated sheet. Exposed fibers disrupt the uniformity of surface gloss and smoothness, and disturb ink lay, resulting in a nonuniform printed surface.

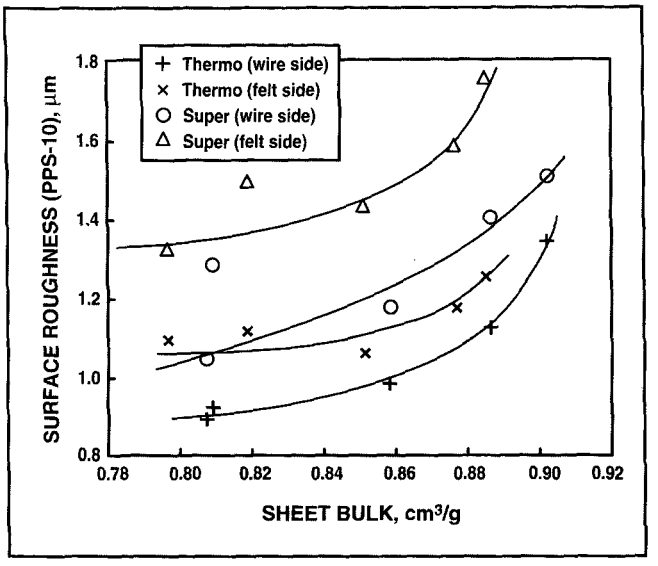
Coating coverage is directly affected by the amount of coating applied, the coating formulation, and the method of coating application. Increasing the coat weight is a simple approach to improve coating coverage. Choice of clays also can affect the degree of coverage in, for example, lightweight-coated grades. Coating coverage is also influenced by basestock roughness and by the fines and filler contents at the sheet surface. Refining, forming, wet pressing, and surface sizing also influence the coating coverage.

I. Effect of coat weight and finishing method on sheet-fed offset-print quality[a]

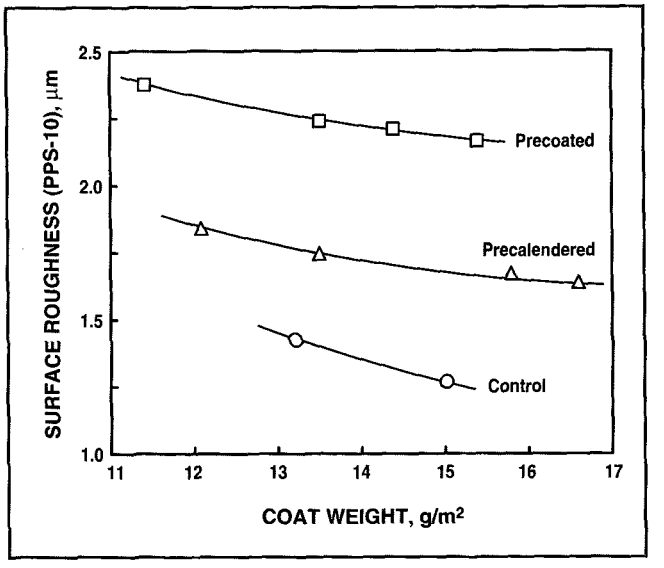
Print rank[b]	*Coat weight, g/m²*	*Finishing method*[c]	*Sheet side*
Category A (best)	23.1	Thermo	Felt
Category B	19.1	Thermo	Wire
	17.0	Super	Wire
	14.9	Super	Wire
Category C	18.5	Thermo	Felt
	14.9	Thermo	Wire
	14.8	Thermo	Felt
	11.1	Thermo	Felt
	9.9	Thermo	Felt
	13.2	Super	Wire
	11.8	Super	Felt
Category D	17.0	Thermo	Wire
	12.3	Thermo	Wire
	13.2	Thermo	Wire
	11.8	Thermo	Felt
	11.1	Thermo	Wire
	18.5	Super	Felt
	12.3	Super	Wire
	11.1	Super	Felt
	9.9	Super	Felt
Category E	14.8	Super	Felt
	11.8	Super	Felt
Category F (worst)	11.1	Super	Wire

[a]Printed using a five-color Heidelberg sheet-fed offset press
[b]Print quality is ranked on solid black images using Rangefinder method.
[c]Thermo = thermofinished; Super = supercalendered

3. Parker print–surf roughness (PPS-10) as a function of sheet bulk for thermofinished or supercalendered sheets



4. Parker print–surf roughness (PPS-10) of coated/calendered sheets as a function of coat weight for precoated, precoated/precalendered, and control sheets (felt side)



Coating basestock manufactured with the northern fibers was obtained from a fourdrinier paper machine with a Tri-Nip press. The basestock was coated at 600 m/min in a pilot coater. Coated basestock was calendered at 600 m/min under both supercalendering (80°C, four nips, one pass) and thermofinishing (170°C, two nips, two passes) simulation conditions in a pilot compact calender. The felt side of the coated rolls was calendered first to the steel roll to minimize the roughness two-sidedness.

Figure 1 shows the effect of coat weight on Parker print–surf roughness values (PPS-10). For both the supercalendered and thermofinished sheets, roughness decreased sharply with increasing coat weight up to about 15 g/m², decreasing very slowly thereafter. This suggests that a coat weight of about 15 g/m² per side represents an optimum level for the final smoothness. Visual observation of the surface confirmed that good fiber coverage was achieved on this basestock with 15 g/m² coating. The slower roughness reduction at coat weights beyond 15 g/m² probably reflects a limitation to the amount of coating that can be applied effectively with a single coating application.

The roughness two-sidedness of the finished sheet did not diminish with increasing coat weight applied to both sides of the sheet. As seen in Fig. 1, the wire side was consistently smoother (0.1–0.2 μm) than the felt side. This two-sidedness echoes the basestock two-sidedness, which is induced by the asymmetrical fourdrinier forming and Tri-Nip pressing. The basestock two-sidedness can be counterbalanced by applying a heavier coating and more intensive calendering to the rougher felt side.

The calendered samples were printed using a sheet-fed offset press. The print quality was ranked into six categories from A (best) to F (worst), as shown in **Table I**. In general, samples with higher coat weights ranked better than those with lower coat weights. Print-quality differences from sheet two-sidedness were small, even though the felt side was rougher. The greater density of the felt side—the result of basestock forming and wet pressing—probably compensated for the smoothness deficiency and helped to improve print quality.

Effect of thermofinishing

The comparative effects of supercalendering and thermofinishing on roughness reduction are illustrated in Fig. 1. Because of the higher temperature of the steel roll during thermofinishing (170°C, compared with 80°C for supercalendering), the mean nip load needed to develop 75° Hunter sheet gloss was 200 kN/m, compared with 356 kN/m for supercalendering. At equal sheet gloss, thermofinishing provided a smoother surface than supercalendering, as seen in **Fig. 2**. The superior smoothness of the thermofinished sheets is also apparent in **Fig. 3**, which compares the surface roughness of thermofinished and supercalendered papers at equivalent sheet bulk. Clearly, thermofinishing offers bulk, gloss, and surface smoothness advantages over conventional supercalendering.

Despite the consistently superior smoothness of the thermofinished papers apparent in Fig. 1, the difference in print-quality rankings between supercalendered and thermofinished sheets was marginal, as shown in Table I. This suggests that measurement of Parker print–surf roughness is not the sole determinant of offset-print quality, at least within the range tested here.

The control coating formulation *(1)* used in the thermofinishing trial had been designed for conventional supercalendering. During the thermofin-

ishing trial, we experienced picking problems at higher nip loads and higher temperatures. The picking almost certainly prevented us from achieving further surface smoothness improvement with the thermofinishing. If this is the case, it demonstrates that the coating formulation, or at least the binder system, must be optimized if thermofinishing is to achieve its full potential.

Effect of basestock precoating and precalendering

The two-sidedness of a coating basestock has a great impact on the final quality of the finished sheet *(3)*. The wire side of a web formed on a fourdrinier retains less fines and fillers than the felt side, thus reducing the print quality of the finished sheet. The felt side contains more fines and fillers, but the Tri-Nip pressing imparts a roughness to this side of the sheet *(1)*. Short of reconstructing the paper machine, there are few options to alleviate this two-sidedness.

Precoating in combination with proper machine calendering is believed to have a potential to reduce surface roughness, minimize the basestock surface roughening, and increase coating holdout. A low coat weight can be applied using a size press or a newer, pre-metered film size press *(4, 5)*. We conducted a precoating/precalendering trial to study the achievable quality improvement on the finished sheet.

Blade metering was used on a pilot coater to apply about 4.5 g/m² of coating to each side of the sheet, thus simulating a pigmented size press. The precoating formulation was 50% styrene/butadiene latex and 50% coarse coating-grade calcium carbonate. The coating color was made down at 20% solids to achieve the target coat weight with a light blade pressure. The basestock used in the precoating trials was manufactured with the northern fibers (Furnish A) on a fourdrinier paper machine with a Tri-Nip press. One roll of the basestock was precoated, and another was precoated and precal-

II. Effect of precoating and precalendering on basestock properties

	Basestock		Precoated[a]		Pre-calendered[b]	
	No. 1	No. 2	No. 1	No. 2	(No. 1)	Control[d]
Basis weight, g/m²	51.1	50.9	56.6	57.2	56.6	51.8
Ash content (550°C), %	7.4	7.3	8.2	9.1	8.2	6.8
Caliper, µm	71.9	71.1	72.1	75.7	60.7	74.7
Bulk, cm³/g	1.407	1.396	1.275	1.324	1.073	1.441
Opacity, %	83.5	84.3	82.0	84.3	82.5	81.2
Coat weight, g/m²						
Wire side	...	...	3.7	3.5	3.7	...
Felt side	...	...	4.0	4.9	4.0	...
Gloss						
Wire side	7.4	5.9	6.8	5.7	19.0	6.9
Felt side	6.2	4.7	6.2	4.6	18.5	5.7
Roughness (PPS-10)[c], µm						
Wire side	7.47	7.61	7.47	8.49	3.83	7.27
Felt side	8.81	9.29	9.43	9.88	4.28	9.53
Smoothness (Sheffield), cm³/min						
Wire side	184	166	142	162	57	174
Felt side	186	179	195	210	65	204

[a]Basestock precoated with 20% solids $CaCO_3$/latex formulation
[b]Precoated basestock precalendered at 50 kN/m
[c]PPS-10: Parker print–surf roughness measured at 980 kPa
[d]Basestock without precoating and precalendering

III. Effect of precoating and precalendering on properties of top-coated and top-coated/calendered sheets

	Top coated			Top coated/calendered		
	Pre-coated[a] (No. 2)	Pre-calendered[b] (No. 1)	Control[c]	Pre-coated[a] (No. 2)	Pre-calendered[b] (No. 1)	Control[c]
Basis weight, g/m²	80.1	77.6	79.5	80.1	77.6	79.5
Caliper, µm	82.3	72.6	85.3	66.3	66.3	68.3
Bulk, cm³/g	1.027	0.936	1.073	0.827	0.854	0.845
Opacity, %	93.1	92.1	94.4	89.8	89.1	90.8
Coat weight, g/m²						
Wire side	14.4	14.1	15.0	14.4	14.1	14.8
Felt side	15.4	15.8	14.8	15.4	15.8	15.0
Gloss						
Wire side	33.0	42.1	38.2	83.0	84.9	81.2
Felt side	27.7	35.7	35.3	77.5	79.1	85.0
Roughness (PPS-10)[d], µm						
Wire side	4.56	2.67	3.58	1.50	1.33	1.37
Felt side	7.11	3.55	4.37	2.17	1.67	1.27
Smoothness (Sheffield), cm³/min						
Wire side	59	22	60	18	30	26
Felt side	100	27	79	25	21	18

[a]Basestock precoated with 20% solids $CaCO_3$/latex formulation
[b]Precoated basestock precalendered at 50 kN/m
[c]Basestock without precoating and precalendering (i.e., single coated)
[d]PPS-10: Parker print–surf roughness measured at 980 kPa

endered to simulate the size press and machine calendering on a paper machine. Both rolls were then top coated with the control coating formulation and calendered under supercalendering simulation conditions.

Application of the low-solids precoating increased the basestock roughness, as seen in **Table II**. Precalendering after the precoating greatly reduced the surface roughness and the sheet bulk, as expected. The roughening effect with the precoating is due to rewetting of the fibers during the coating application. Under the blade pressure, the water in the coating penetrates into inter- and intrafiber networks (depending on the sizing level of the basestock), resulting in breakage of fiber bonds, stress relaxation, and fiber swelling *(6)*.

The degree of roughening is related to the level of fiber bonding and stresses embedded within the sheet. We speculate that processes that increase fiber bonding (refining and wet pressing) tend to reduce surface roughening, while processes that build stress within the sheet (machine calendering of the basestock) may have the opposite effect.

The precoated and precoated/precalendered rolls were top-coated to a total coat weight of about 14.5 g/m^2. As seen in **Table III**, the precoated/precalendered basestock gave a coated/uncalendered roughness of 3.6 μm (PPS-10), compared with 7.1 μm roughness for the basestock that was only precoated. In comparison, the control basestock single-coated to the same target coat weight had a roughness of 4.4 μm. Precoating without precalendering clearly increased the roughness of the coated/uncalendered sheets, while precoating combined with precalendering reduced roughness of the coated/uncalendered sheets.

After calendering at a constant nip load, the control became the smoothest, and the precoated-only roll became the roughest. The precoated/precalendered roll exhibited in-between smoothness, as seen in Table III and illustrated in **Fig. 4**. Low-solids precoating/precalendering did not provide any benefits in reducing the final roughness of the coated/calendered sheet. We speculate that the unexpected increase in surface roughness with precoating was related to the low-solids, low-viscosity precoating formulation and the coating application, which enabled the basestock to absorb more water than a conventional size press. The observed lack of smoothness for the precoated sheets was probably a result of excessive surface roughening, which outweighed the voids-filling effect of the pigments.

In addition, it appears that precalendering to reduce the surface roughness of the precoated basestock (at the expense of sheet bulk) did not contribute to the final surface smoothness of the coated/calendered sheet. This is probably because the precalendered basestock is more dense and less compressible as it enters the final calendering stage, where a certain degree of bulk reduction is needed for development of final sheet smoothness.

Consequently, we believe that an ideal coating basestock for developing finished sheet smoothness should be bulky, smooth, and resistant to roughening upon coating application. Roughening can be minimized by using an internally sized and surface-sized basestock, with the precoating conducted at a higher solids. Also, basestock smoothness should not be achieved through calendering but, rather, through improvements in fiber furnish, refining, forming, and wet-pressing. Calendering produces excessive bulk reduction, debonding, and built-in stresses.

Conclusion

The print quality and physical properties of coated wood-free publication-grade papers were evaluated in relation to coating weight, finishing technique, and the practice of precoating and precalendering the basestock.

The results demonstrate that a sufficient coating coverage on the basestock is critical for development of a uniformly smooth surface and good offset-print quality on a coated/calendered sheet.

Thermofinishing at elevated temperature provides greater gloss, smoothness, and bulk than conventional supercalendering. However, thermofinishing did not greatly improve offset-print quality within the range of parameters tested.

Low-solids, low-viscosity precoating did not improve the smoothness of the finished sheet. Apparently, the roughening of the basestock upon rewetting outweighed the voids-filling effect of the precoating. Calendering after the precoating reduced sheet roughness. However, calendering of the pretreated sheet after application of a top coat produced a finished sheet that was slightly rougher than the coated/calendered control sheet.

The results suggest that an ideal coating basestock should be smooth, bulky, and resist roughening upon rewetting. ▮

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