HWK & CTMP GRAVURE PRINTABILITY

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Abstract

Uncoated paper for gravure printing can be modified at four key control points during papermaking: fiber selection, stock refining, wet-end additions and supercalendering. The relative impact of each of these variables on the paper's quality can be assessed by a series of laboratory and pilot plant experiments. At a given level of refining, dramatic product quality changes are governed by fiber selection, filler content and supercalendering conditions. As an example of paper design procedure, it is shown that a furnish consisting entirely of hardwood Kraft (HWK) pulp can be used to produce paper for the gravure press. The quality of the paper is approximately the same for either imported eucalyptus or native aspen pulp. An even more economical but poorer performing paper can be achieved by substituting chemithermomechanical (CTMP) hardwood pulp for up to 50% of the HWK pulp. The printer's final specifications for paper are considered for the four control areas in terms of cost, press constraints and image quality.

INTRODUCTION

Never before have the possibilities for designing paper to exactly meet the specifications of the printer been so great. New papermaking raw materials have been developed including fibers from nonwoody cellulosic and synthetic sources, fillers of calcined clay and precipitated calcium carbonate, and a host of wet-end and size-press additives and specialty coating formulations. Process developments have revolutionized both pulping and papermaking from the proliferation of high yield pulping technologies to the increasing refinement of twin-wire formers. Almost matching the rate of technological innovation, the theoretical understanding of materials and process variable interactions has been increasing to explain the structure-property correlations of new paper grades and guide the development of new or improved products.

Despite the complexity of the new systems engendered by this expansion of the raw material base interacting with the more sophisticated process steps, an estimate of the

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papermaker's "degrees of freedom" in meeting any printer's set of paper specifications can be obtained by considering the impact on the desired paper properties of changing the conditions at key control points. For example, for uncoated paper for rotogravure printing (Sunday supplements, catalogs, etc.), four such key control points along the papermaking sequence are fiber selection, stock refining, wet-end additives and supercalendering. The first and third steps are the critical ones in raw materials specification whereas the second and fourth are the dominant process variables affecting product properties.

With paper generally being the most costly single item in printing a job, it is worthwhile for the printer no less than the papermaker to appreciate how the process constraints which the papermaker must operate under influence the cost and quality of a given product. The purpose of this communication is twofold: to demonstrate how the four identified variables can affect product quality and to provide specific information on novel low-cost fibers that are suitable for the production of rotogravure paper.

FIBER SELECTION AND SUPERCALENDERING

Traditional woody fibers for papermaking come from the softwood (gymnosperm) and hardwood (angiosperm) genera of trees. A common furnish for printing papers consists of a blend of about 40% softwood fibers (for strength properties) and 60% hardwood fibers (for optical, formation and smoothness properties). This combination is largely dictated by economics, hardwood pulp usually being less costly than softwood pulp. Since fiber expenses are generally the most costly single item in producing paper, a good starting point for cost reduction is to explore the quality impact on maximizing the use of hardwood in any given grade.

To estimate the effects of fiber species on important printability characteristics of gravure paper, two fiber types of widely different types were chosen. The pulp in both cases is bleached kraft, the difference between the two principally being one of fiber morphology. The southern pine, Pinus taeda, has dimensions of about 4 mm length, 35-50 microns diameter, and a cell wall thickness of 3-8 microns vs. the Brazilian eucalyptus' (Eucalyptus globulus) dimensions of about 1 mm length, 16 microns diameter and cell wall thickness of 3 microns. The pine is clearly a coarser fiber than the eucalyptus and the resulting papers might be expected to exhibit different properties as a result of this difference. Table 1 gives data on the effects of these fiber types and supercalendering conditions on certain properties

Table 1. Supercalendering of Southern Pine (P) and Brazilian Eucalyptus (E) Handsheets, bleached kraft *Pinus taeda* (P) and *Eucalyptus globulus* (E).

		Supercalendering Conditions*		
		0	1	3
Caliper, microns	P	165	98	92
	E	205	96	88
Bulk, cubic cm/g	P	2.19	1.30	1.20
	E	2.66	1.24	1.15
Roughness, microns Parker Print Surf**	P	9.2, 8.2	5.5, 4.8	5.0, 4.3
	E	7.8, 6.6	3.4, 3.0	3.0, 2.6
Helio, mm to 20th Missing Dot	P	18	-	54
	E	111	-	515
Gloss (75 Degree Hunter), % Refl.	P	2.3	9.9	12.6
	E	2.2	10.6	14.4

*Supercalendering conditions:

0 = Uncalendered

1 = 1 x 2,000 pli

3 = 3 x 2,000 pli [The handsheets were passed through the supercalender nip at 2,000 pounds per lineal inch three times].

**Parker Print Surface, Measurement of Rotogravure Printability, (10 kgf/square cm, 20 kgf/square cm).

of gravure paper. No additives were used in the preparation of the handsheets and refining was uniform to 300 mL CSF in a Valley Beater.

The results of Table 1 indicate that with the important exception of the dot-skip test (the Helio test for gravure printability), the effects of supercalendering dominated the development of the measured properties. As expected, caliper, bulk, and roughness (as measured by the Parker Print Surface test) all decreased while gloss and helio increased with increased supercalendering. Interspecies differences were consistently present after supercalendering and were evident in the thicker, bulkier, rougher, less glossy and increased dot-skip properties of the pine handsheets compared to the paper made from the eucalyptus pulp. An additional interspecies difference is notable in the greater property responsiveness of the eucalyptus handsheets to changes in the imposed supercalendering conditions.

The important exception to the dominance of the supercalendering effect in this experiment was the response of the pulps to the Helio test. The difference in the dot-skip for the two furnishes is much greater for the uncalendered or highly calendered sheets than for any change that occurs within the furnish with increased supercalendering. The difference ranges in the extreme case by nearly an order of magnitude, the pine handsheets are nearly ten times less receptive to gravure printing than the eucalyptus handsheets, a difference which would not have been predicted by analogy from measured differences in any of the other properties.

REFINING AND SUPERCALENDERING

Using the superior performing eucalyptus pulp, another experiment was run to estimate the relative importance of the two principal process variables on the development of handsheet properties. The same eucalyptus pulp employed for the handsheets of Table 1 was refined to four different levels in a Valley beater and supercalendered at two different pressures. The data on the resulting handsheets are shown in Table 2. Again, both factors do influence the development of the paper properties. Supercalendering decreases the caliper, bulk, porosity, roughness, tensile strength, brightness and dot-skip of the sheet. Refining similarly affects all of those properties with the exception of the tensile strength, which it increases. Thus far these observations are predicted by theory and experience and are the reasons why both treatments are employed in the manufacture of rotogravure paper. The magnitude of the

Table 2. Refining and Supercalendering of Brazilian Eucalyptus (*E. globulus*) Handsheets.

		Refining by Freeness Level (mL CSF)			
		610	460	345	275
Caliper, microns	0*	145	112	94	104
	1*	69	66	64	64
	2*	64	64	61	61
Bulk, cubic cm/g	0*	2.35	1.82	1.54	1.69
	1*	1.11	1.07	1.04	1.03
	2*	1.03	1.03	1.00	0.99
Roughness, Parker Print Surf**	0*	9.4, 8.8	8.6, 7.8	7.6, 6.3	7.1, 6.0
	1*	3.6, 3.1	3.5, 2.9	2.5, 2.2	2.4, 2.0
	2*	3.2, 2.6	3.0, 2.4	2.8, 2.4	2.2, 1.8
Helio, mm to 20th Missing Dot	0*	30	12	54	220
	1*	40	23	69	220
	2*	41	40	71	220
Brightness, % Refl.	0*	85	83	83	82
	1*	83	80	81	81
	2*	82	80	80	81
Opacity, %	0*	82	78	73	71
	1*	83	79	73	72
	2*	83	79	74	73
Tensile Strength, kg/15 mm	0*	1.2	5.3	6.4	6.4
	1*	0.9	4.6	4.4	4.6
	2*	0.9	3.8	4.0	4.1
Sheffield Porosity, ml/min	0*	400	100	12	10
	1*	110	20	4	1
	2*	135	13	3	1

*Supercalendering conditions:
0 = Uncalendered
1 = 35 psi
2 = 60 psi

**Parker Print Surface, Measurement of Rotogravure Printability, (10 kgf/square cm, 20 kgf/square cm).

property changes (the dependent variables) upon changes of the main effects (the independent variables) must be experimentally determined and such data as presented in Table 2 can serve as a basis for a better understanding of the interaction of these variables. As in the preceding experiment, supercalendering is the dominant variable for caliper, bulk, and roughness (Parker Print Surf), as well as (weakly) for brightness. However, refining is the dominant variable for tensile strength, porosity, dot-skip (Helio test) and opacity. Just as in the preceding experiment, the main effects are interactive in that the property response to one variable is conditioned by the value of the other variable.

FIBER SELECTION AND FILLER CONTENT

Having established the importance of high levels of supercalendering and refining for bleached kraft Brazilian eucalyptus in rotogravure printing, consider the fourth key control point: wet-end additions. The most important item that is added at the wet-end of the papermachine in the production of uncoated gravure paper is filler. In acidic papermaking systems, a high-brightness clay is used as filler whereas calcium carbonate is used in alkaline systems. In gravure paper filler has two functions: upon supercalendering to provide the smooth, bright, compressible surface desired for printing and to substitute inexpensive minerals for expensive fiber. The last experiment presented here has its focus on material costs: to test the feasibility of using inexpensive hardwood fibers and high filler loading to manufacture a good quality gravure paper.

The fibers selected were bleached kraft eucalyptus (due to its proven importance in Brazilian and European papermaking), bleached kraft aspen (a North American fiber of similar morphology to the eucalyptus), and chemithermomechanical (CTMP) aspen pulp (the same fiber produced by a less costly, high yield chemimechanical pulping process). The paper was manufactured on a 24-inch wide Fourdrinier pilot plant machine after refining the kraft pulp to 400 CSF on a Claflin refiner (the lignocellulosic CTMP pulp was refined to 230 CSF). A high brightness calcium carbonate was used as filler (0.4 micron discrete particle size, 97% dry brightness and 2.71 g/cc density). The paper was made under alkaline papermaking conditions (headbox pH 6.5-9.8) with a cellulose-reactive size and the "Compozil" system of anionic silica and cationic potato starch to aid filler retention [Batelsson & Kurt, 1985]. The paper was supercalendered at

Table 3. Physical Properties of Papermachine HWK and HWK/CTMP Papers*.

		Ak	Ek	Ek/Ac	Ac/Ak
Basis Weight, g/square meter	1	57.9	56.3	56.9	58.5
	2	52.7	61.0	59.4	57.9
	3	60.6	57.3	64.5	66.4
	4	57.4	58.3	58.3	58.1
	5	61.5	57.7	60.6	72.3
Density, g/cubic cm	1	1.01	0.99	0.79	0.88
	2	1.01	1.04	0.75	0.94
	3	1.06	1.03	0.81	1.05
	4	1.02	1.08	0.80	0.98
	5	1.08	1.09	0.86	1.08
Ash Content of Paper, % [CaCO3]	1	0.7	1.1	0.8	0.8
	2	1.0	1.8	1.0	1.4
	3	8.7	11.3	10.8	17.4
	4	9.6	14.1	14.5	18.7
	5	13.3	17.0	16.5	19.3
Tensile Index, Machine Direction and Cross-Machine Direction, Newton m/g		49.1, 27.1;	47.4, 29.1;	36.6, 21.7;	36.8, 18.2
		59.9, 34.6;	68.8, 35.2;	48.2, 24.4;	51.4, 29.1
		38.6, 19.6;	- , 19.1;	27.4, 14.7;	23.6, 11.4
		36.4, 18.6;	- , 14.9;	26.9, 13.1;	17.8, 10.6
		26.6, 14.5;	- , 13.4;	17.5, 11.4;	23.0, 10.8
Tear Index, Machine Direction and Cross-Machine Direction, mN square m/g		3.0, 5.7;	2.8, 7.6;	2.2, 4.0;	2.2, 3.9
		3.6, 4.8;	4.1, 6.7;	2.9, 5.3;	3.1, 4.5
		2.3, 4.0;	1.1, 4.4;	1.6, 3.5;	1.4, 3.0
		2.2, 4.3;	0.9, 4.6;	1.6, 3.2;	1.1, 2.8
		1.6, 3.8;	0.8, 3.7;	1.0, 2.7;	1.4, 2.7

*Hardwood Kraft (HWK) and Chemithermomechanical (CTMP) papers:
Ak = paper made from bleached North American Aspen kraft pulp
Ek = paper made from bleached Brazilian Eucalyptus kraft pulp
Ek/Ac = paper made from a 50:50 mix of Eucalyptus kraft and Aspen chemithermomechanical pulp
Ac/Ak = paper made from a 50:50 mix of Aspen chemithermomechanical and Aspen kraft pulp

Species: Aspen (A), *Populus tremuloides* and eucalyptus (E), *Eucalyptus globulus*.

Table 4. Optical and Printability Properties of Papermachine HWK and HWK/CTMP Papers*.

		Ak	Ek	Ek/Ac	Ac/Ak
Brightness, % (Percent Reflectance)	1	87	87	82	83
	2	84	84	82	79
	3	89	89	86	88
	4	89	90	87	88
	5	90	90	87	88
Opacity, % (TAPPI Opacity)	1	69	71	78	76
	2	69	75	81	75
	3	80	80	87	87
	4	79	82	87	85
	5	83	83	87	88
Gloss, % (75 Degree Hunter Gloss), Percent Reflectance	1	32	26	16	22
	2	28	30	16	26
	3	28	28	16	25
	4	28	28	17	26
	5	28	27	15	26
Roughness, Parker Print Surf**, microns	1	2.6, 2.1;	2.6, 2.2;	3.1, 2.5;	3.0, 2.5
	2	2.9, 2.4;	2.4, 2.0;	3.4, 2.8;	2.6, 2.2
	3	2.5, 2.0;	2.4, 2.0;	3.2, 2.5;	2.6, 2.1
	4	2.4, 1.9;	2.3, 1.9;	3.1, 2.5;	2.4, 1.9
	5	2.4, 2.0;	2.3, 1.9;	3.0, 2.4;	2.5, 2.0
Helio, Missing Dots in 440 mm	1	16	24	16	20
	2	16	12	18	22
	3	10	10	12	14
	4	8	6	12	13
	5	8	6	12	14

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Ek = paper made from bleached Brazilian Eucalyptus kraft pulp
Ek/Ac = paper made from a 50:50 mix of Eucalyptus kraft and Aspen chemithermomechanical pulp
Ac/Ak = paper made from a 50:50 mix of Aspen chemithermomechanical and Aspen kraft pulp

Species: *Populus tremuloides* (A) and *Eucalyptus globulus* (E).

**Parker Print Surface, Measurement of Rotogravure Printability, (10 kgf/square cm, 20 kgf/square cm)

100 fpm, 1700 pli through 9 nips with the heated rolls at 160 F (225 F steam).

The results of this experiment are given in Tables 3 and 4 with the properties of two commercial grades given in Table 5. The 5 runs conducted correspond to different levels of filler addition. Runs 1 and 2 contained no filler, Run 1 having nothing but the fiber and water present and Run 2 having the wet-end chemicals (size and "Compozil"). The same level of wet-end chemicals initiated in Run 2 were maintained through Runs 3-5 with increasing amounts of calcium carbonate (20%, 25%, and 30% addition levels). The total amount of filler retained is indicated by the ash content of the sheet. All reported properties were determined by TAPPI standard methods.

The data presented in Tables 3 and 4 show that as in the previous experiments both independent variables affect the sheet properties, in this case, both filler content and furnish. Filler content, measured as percent ash content, correlated positively with density and opacity and negatively with tensile & tear strength and dot-skip. However, the correlation of filler content to brightness and roughness is weak relative to the dominance of furnish. The gloss is entirely dependent on the furnish and is not influenced by the filler content at all. Overall, the largest differences are noted when comparing the values of the properties of the runs without filler (No. 1 & 2) to those with filler (No. 3-5) and the kraft pulps to the CTMP furnishes.

The paper made from furnishes containing 50% (by weight) of CTMP aspen had higher dot-skip and opacity and lower brightness, gloss, density, smoothness, and strength (both tensile and tear) than the 100% kraft furnish papers. Qualitatively, such effects would be expected from the introduction of the stiff, high yield, lignocellulosic pulp fibers into the kraft fiber network. It will be of interest to see if the quantitative magnitude of effects is followed in other well-defined systems. For instance, cutting the kraft pulp content of the furnish by 50% resulted in only a 25% drop in strength properties whereas a 100% CTMP furnish did not have enough intrinsic cohesive strength to be manufactured on the pilot plant machine. Although the values of some properties are currently predictable given the properties of papers starting from their constituent fibers, such as the brightness [Bobalek and Chaturvedi, 1989], other values still need to be empirically determined. A case in point is the surprising bulk and roughness of the Ek/Ac mix relative to the Ak/Ac mix, especially in view of the near identity of these values in the 100% kraft papers.

Table 5. Properties of Two Commercially Manufactured Rotogravure Papers*.

	Company No. 1	Company No. 2
Basis Weight, g/square meter	59.2	58.5
Density, g/cubic cm	1.03	1.00
% Ash Content of Paper, [CaCO3]	27.1	27.3
Tensile Index, MD & CD, Nm/g	31.4, 16.0	31.8, 14.1
Tear Index, MD & CD, mNsq.m/g	1.9, 4.4	1.9, 5.3
Brightness, %	64	66
Opacity, %	94	90
Gloss, % (75 Degree Hunter)	31	44
Roughness, PPS**, microns	2.0, 1.4	1.7, 1.2
Helio, Missing Dots in 440 mm	3	5

*Sold as SCB (Supercalender Grade B) papers. The paper from Company No. 1 consisted of 100% softwood fibers. The paper from Company No. 2 was a mix of 75% softwood and 25% hardwood fibers.

**Parker Print Surface, Measurement of Rotogravure Printability, (10 kgf/square cm, 20 kgf/square cm)

The trial paper properties of Tables 4 & 5 compare favorably with those of the commercial papers of Table 6, particularly when the limitations of the pilot plant supercalender and the non-softwood furnishes are considered. However, even with more severe supercalendering, the CTMP containing paper would be unlikely to show dramatic improvements in surface smoothness and dot-skip reduction and its strength would further decrease. Thus any advocacy of the use of chemithermomechancal hardwood pulp for the manufacture of uncoated rotogravure paper will probably have to be based on cost-cutting rather than quality considerations.

SUMMARY

Of the four control points considered in this study, both those concerned with materials (fiber type, as specified by species origin and subsequent pulping treatment, and filler content) and with process (refining and supercalendering) are critical to control in the intelligent manufacture of uncoated rotogravure paper. Although qualitative trends can be used to estimate the structure-property correlations of the resultant paper, the exact relationships must still be determined empirically for uncoated just as for coated gravure paper [Von der Heyde, 1982]. Even such widely accepted generalizations as that of the correlation of smoothness and gravure printability [Voas, 1989] must be accepted with reservations, as the Table 5 data for the Ac/Ak and kraft furnishes indicate.

Compromise will probably continue to be the determining factor in meeting the printer's specifications of cost, quality and press constraints. This study has indicated one such example of the compromise process: in the USA less expensive kraft aspen could be used to produce an uncoated gravure paper with as low dot-skip as can be made from Brazilian eucalyptus, but the tendency for press breaks would probably be greater than for conventional softwood-containing furnishes. Further cost reductions could be affected by substituting a portion of the kraft aspen with chemithermomechanical aspen pulp, but with a probable increase in dot-skip and press-breaks. Certainly, as new raw materials and process refinements are introduced, it is reasonable for the printer to expect improved paper. A better understanding of the process and constraints limiting the development of the paper can only help the printer to accelerate progress towards the exact specification of the paper necessary for a given press to produce a perfectly printed job.

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