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The Effect of Post Consumer Waste on Flexographic and Rotogravure Printing Operations

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THE EFFECT OF POST CONSUMER WASTE ON FLEXOGRAPHIC AND ROTOGRAVURE PRINTING OPERATIONS

by

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Abstract

The impact of deinked post-consumer secondary fiber (PCW) on the printability and runnability of an uncoated recycled sheet through printing operations was studied. The PCW was substituted into the base stock (50/50 HW/SW) at levels of 25%, 50%, and 100%; and printed on web fed flexographic and rotogravure printing presses. Tensile strength, brightness, and Δ gloss decreased with the addition of secondary fiber, while opacity, roughness, and bond strength increased. Stretch, tensile energy absorption, and tonal response remained relatively unchanged as the percentage of post-consumer waste increased.

Acknowledgements

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Introduction

The objective of this project is to study the effect of post-consumer deinked secondary fiber content on the printability and runnability of an uncoated recycled sheet through the flexographic and rotogravure printing processes.

Background Discussion

Studying the effects of increased amounts of secondary fiber in papermaking is becoming increasingly important as legislation mandates the collection and recycling of wastepaper. Printing is one of the most common converting operations and the impact that secondary fibers will have on the printing processes is largely unknown. Some work has been done concerning the printability and runnability of deinked groundwood pulp (2), but not those made with chemical pulps.

Forecasts predict gravure and flexography printing methods to increase their share of the market at the expense of offset and letterpress (3)(see Table 1). Will the introduction of large amounts of secondary fiber shadow the expected outlook for flexography and gravure? Davis (2) found that increased recycled fiber content had negligible impact on runnability and printability of newsprint. Major effects included a decrease in tensile and caliper, while delamination and ash content increased.

Table 1. Forecast from *American Printer*(3)

	1983	1988	1995
Offset Lithography, %	44	46	35
Gravure, %	18	20	26
Flexography, %	15	18	26
Letterpress, %	17	9	4
Screen and Other, %	6	7	9

Sheet properties important to flexography include: formation, to minimize print mottle; high delamination strength, to reduce linting and plate contamination; and uniform caliper, to provide good ink transfer (2). Fine gravure papers have been typically made from thin-walled, slow growing fibers that provide a well-formed, smooth surface when collapsed during drying (3). Secondary fibers tend to be more brittle and therefore susceptible to damage during the mechanical processes used to separate the fibers. This deterioration of the fibers may lower sheet uniformity which may adversely affect several of the properties above, specifically caliper. However, the damaged fibers may exhibit increased surface area. This should increase bond strength, reducing delamination and increasing conformability.

The increased use of water-based inks in flexo and gravure require paper that does not curl or cockle when wetted and will print well with thinner ink films (7). Secondary fibers, having been previously dried, swell less and should be less susceptible to curl or cockle.(8)

To quantify runnability, the tensile strength of the sheet was measured. Since the web is under tension as it is pulled through the printing press, a lower tensile strength may indicate a higher frequency of web breaks. This would cause more down time and lower productivity. Stretch and tensile energy absorption were also investigated to see if secondary fibers have an adverse effect on these sheet properties. McKee found that tensile strength decreased markedly while stretch and TEA also decreased with repulping.(8)

Internal bond strength was measured to see if the sheets containing deinked post-consumer secondary fiber would have lower resistance to

delamination. Printing papers with low bond strength have a greater tendency to delaminate from the combination of shear and tacky inks. Delamination could lead to linting, dusting, and possibly web breaks. McKee reported that transverse bonding strength decreased drastically (8), while Davis found delamination strength to increase 8%.(2)

Density was studied since flexographic printability is a function of sheet density. At constant basis weight, any changes is density reflect in an increase or decrease in caliper. Flexography transfers ink from a raised printing surface directly to the sheet (9)(see Figure 1). Any changes in caliper would cause differences in ink transfer and thus reduce the print quality. McKee illustrated that density decreases with kraft pulp and increases with groundwood.(8) Davis reinforced McKee's work by finding that density increased with the addition of flotation deinked newsprint.(2)

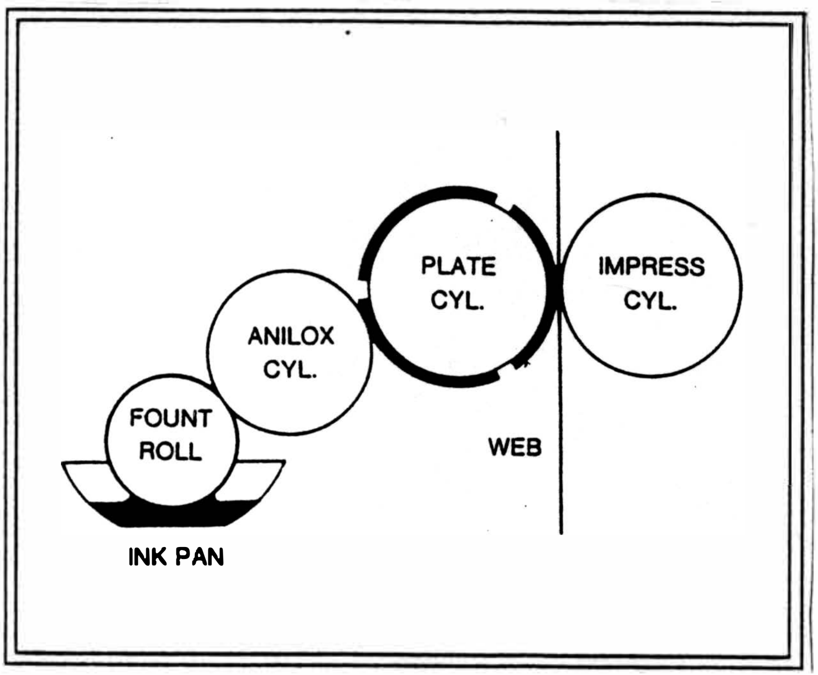

Figure 1. Flexographic Printing (10)

Brightness and opacity were used to quantify the optical properties of the sheet. Brightness measures the ability of the sheet to reflect light in the blue range. With the addition of deinked stock to a base sheet containing virgin pulp, the brightness was expected to decrease as ink particles are dispersed over the secondary fibers. Opacity is a measure of the sheet's ability to scatter light and hide printing on the back side of the sheet. As more rigid secondary fibers are added to the furnish, the light scattering ability of the sheet should increase, thus improving opacity.

Roughness, which is the inverse of smoothness, was also used as an indicator of print quality. Rotogravure printing transfers the image to the sheet via an etched metal cylinder (5)(see Figure 2). Decreases in smoothness would result in less ink transfered from the recessed cells to the paper. This would cause missing dots and skips, resulting in poorer print quality.

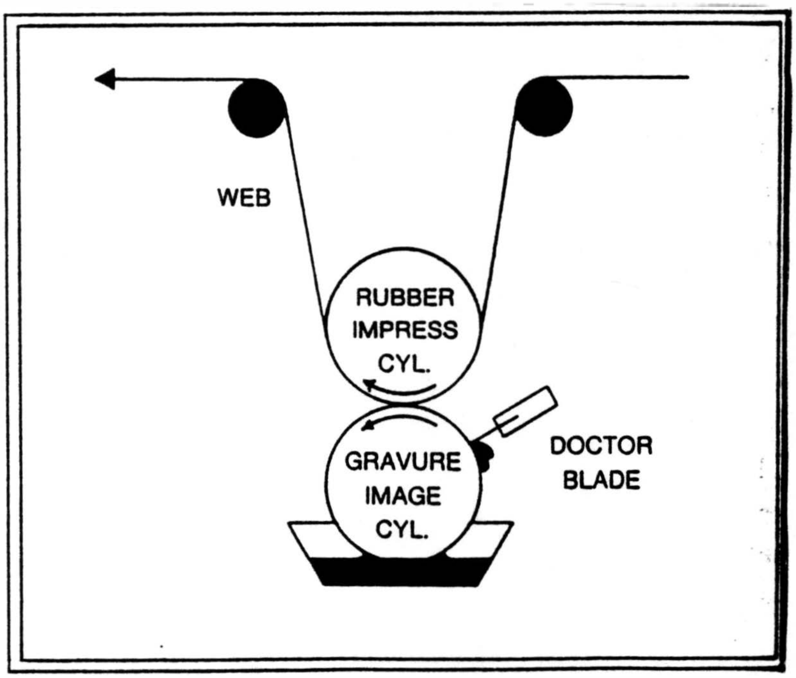

Figure 2. Rotogravure Printing (10)

The difference in 60° Gardner gloss from an unprinted area relative to the gloss of a printed region is known as Δ gloss. This number gives an indication of as to how well the ink was held out on the surface of the sheet. Gloss measures the specular reflectance of the surface of the sheet at the micro-topagraphical level.(6) A low Δ gloss represents high ink holdout or low ink penetration into the sheet. The ink particles conform to the surface of the sheet and do not change the surface topography. Expected results include lower Δ gloss for papers printed with solvent based inks, relative to water based inks and a lower Δ gloss with increasing secondary fiber content. These expectations are based on the presumption that fiber swelling decreases the specular reflectance and increases the loss in gloss. Data McKee presented stated that secondary fibers swell less(8), and Ginman showed that solvent-based inks distort the paper less than water-based inks.(4)

Tonal response was used to measure the print quality. It was represented by plotting the sheets containing post-consumer secondary fiber against the control sheet. The points on the graph represent the ink density measured at each graduation of the print wedge. A 45° line would indicate equal ink density between the control sheet and those containing secondary fiber. Any points above the 45° line represent higher ink density on the secondary fiber containing sheets and vice versa.

Experimental Procedure

Materials. The post-consumer deinked pulp was obtained from Mississippi River Company. It consisted of coated book, non-laser CPO, and lightly printed SBS.(1) Internal size (Hercon 76) was obtained obtained from Hercules, Inc. Virgin pulp used in the base sheet consisted

of Burgess hardwood and Dryden DCX softwood. The inks and printing supplies used in the trial were obtained from the printing pilot plant at Western Michigan University.

Equipment. The paper used for this study was produced on the pilot scale fourdrinier papermachine at Western Michigan University. The pilot scale printing presses used were a Cerutti rotogravure press and a Mark Andy flexographic press located at Western Michigan University. Fiber length distribution was characterized using the Kajaani Fiber Length Analyzer. The paper was tested for physical, optical, and printing qualities using test equipment and procedures listed in Table 2.

Table 2. Testing Equipment and Method

Test	Method
Density	TAPPI T220
Tensile	TAPPI T494
Stretch	TAPPI T494
Tensile Energy Absorption	TAPPI T494
Internal Bond Strength	Scott Bond
Brightness	TAPPI T452
Opacity	TAPPI T425
Roughness	Parker Print Surf
Δ Gloss	60° Gardner Gloss
Tonal Response	Densitometric

Procedure. Initially, the post-consumer deinked pulp was analyzed to gain some insight as to how it would react on the papermachine. It was characterized with respect to fiber length distribution, Canadian Standard Freeness, and ash content. A beater curve was derived for the secondary fiber and, it was mixed with the virgin pulp according to the substitution

levels to determine the freeness of the combined slurry. The results from this initial lab work, shown in Table 3, reveal that no significant change in drainage resulted from the addition of the fines in the secondary fiber.

Paper was produced on the fourdrinier pilot papermachine. The virgin and secondary pulp were refined separately to a Canadian Standard Freeness of 350 ml. The control sheet consisted of 50% hardwood and 50% softwood furnish. The secondary pulp and virgin stock were mixed in the machine chest at the substitution levels of 25%, 50%, and 100% post-consumer waste as indicated in Table 3. The sheet was manufactured at a basis weight of approximately 41#/3000 ft^2 with internal size added to the white water at an addition rate of 3#/ton.

Table 3. Results of Furnish Evaluation

	Control 0% PCW	25% PCW	50% PCW	100% PCW
Canadian Std. Freeness (ml)	339	346	342	351
% Fines (< 0.14 mm)	17.2	15.7	18.7	22.0
% Ash	0.0	•	•	4.3

The paper was rewound and slit down to a 20" width, with all conditions on a single roll for each printing press. The roll printed on the rotogravure press was supercalendered under 1900 pli and then printed with a toluene-based cyan ink. The gravure press operated at a speed of 250 fpm with the ESA (electrostatic assist) on. The flexographic sheet was printed at 200 fpm with a water-based reflex blue ink.

The paper was evaluated for changes in strength, optical, and printing properties. The physical characteristics impacting runnability that were tested include tensile, stretch, tensile energy absorption,

delamination strength, and density. The optical properties tested include opacity and brightness, while the printability of the sheet was characterized by roughness, tonal response, and Δ gloss. See Table 2 for method used.

Results

Table 4. Mean ($\bar{x}$) and Standard Error of the Mean (s.e.) of Paper Testing

	0 % PCW		25 % PCW		50 % PCW		100 % PCW	
	$\bar{x}$	s.e.	$\bar{x}$	s.e.	$\bar{x}$	s.e.	$\bar{x}$	s.e.
Basis Wt (g/m^2)	64.49	.286	70.35	.136	66.23	.411	69.28	.302
Density	.651	.010	.645	.008	.637	.011	.635	.008
Brightness	86.74	.067	81.64	.108	77.69	.121	74.49	.134
Opacity	78.44	.273	82.82	.395	82.84	.347	87.45	.243
Scott Bond	174	3.95	208	3.51	253	5.71	320	7.31
Tensile								
MD Index ($\cdot 10^{-4}$)	7.03	.111	5.90	.172	5.43	.161	4.96	.067
CD Index ($\cdot 10^{-4}$)	2.73	.040	2.68	.030	2.52	.021	2.39	.021
MD Stretch	2.18	.056	1.75	.073	2.00	.100	2.20	.076
CD Stretch	3.98	.138	4.08	.130	3.98	.136	4.73	.16
MD Energy Absorption	.0677	.0029	.0458	.0034	.0503	.0042	.0535	.0027
CD Energy Absorption	.0545	.0027	.0574	.0025	.0526	.0023	.0624	.0029
Roughness (μ)								
Flexo H-10	5.2	.054	5.5	.057	5.8	.044	5.8	.062
Flexo H-20	4.4	.049	4.7	.057	4.9	.041	5.0	.049
Gravure H-10	2.9	.013	3.0	.013	3.0	.017	3.1	.013
Gravure H-20	2.5	.013	2.5	.012	2.6	.015	2.6	.014
Δ Gloss								
Flexo	2.5	.068	2.3	.045	2.1	.044	2.0	.038
Gravure	1.47	.034	1.2	.028	.94	.035	.62	.019

where $\bar{x} = (\Sigma x)/n$ and $s.e. = (\sigma_{n-1})/ n^{.5}$

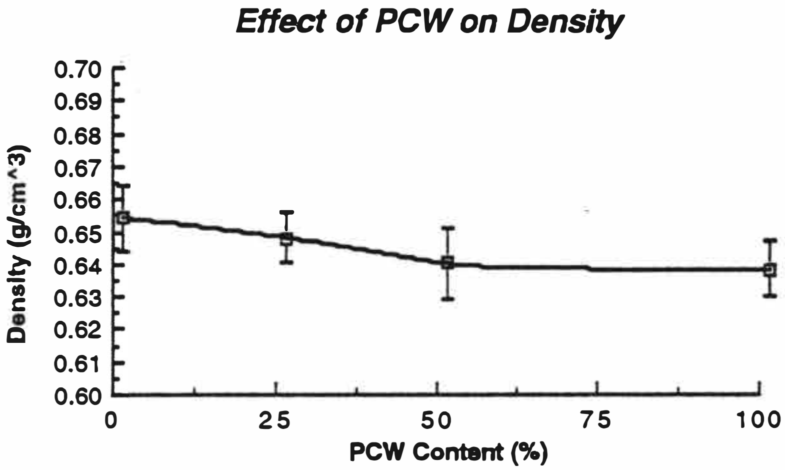

Figure 3. Density vs. PCW Content

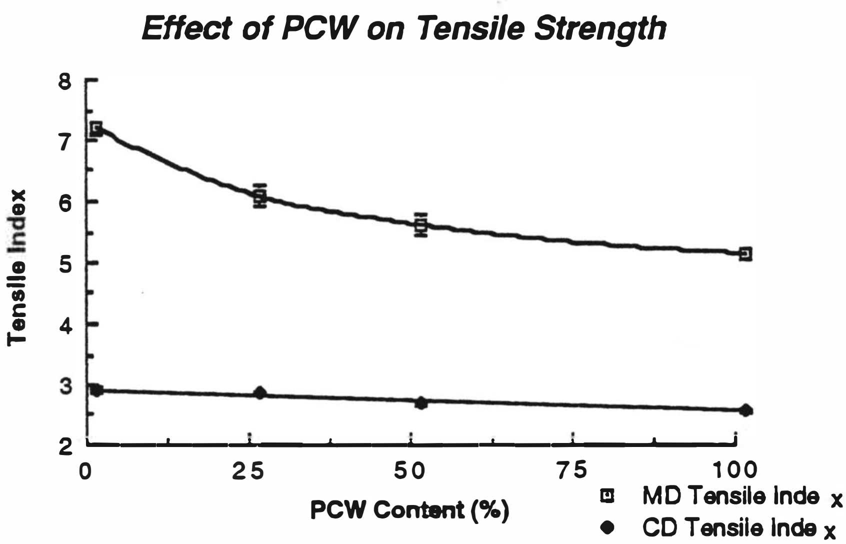

Figure 4. Tensile Index vs. PCW Content

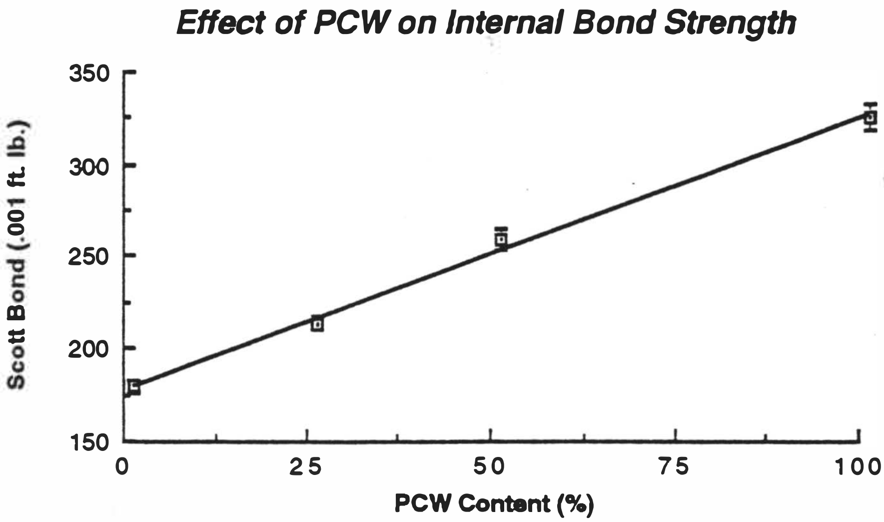

Figure 5. Bond Strength vs. PCW Content

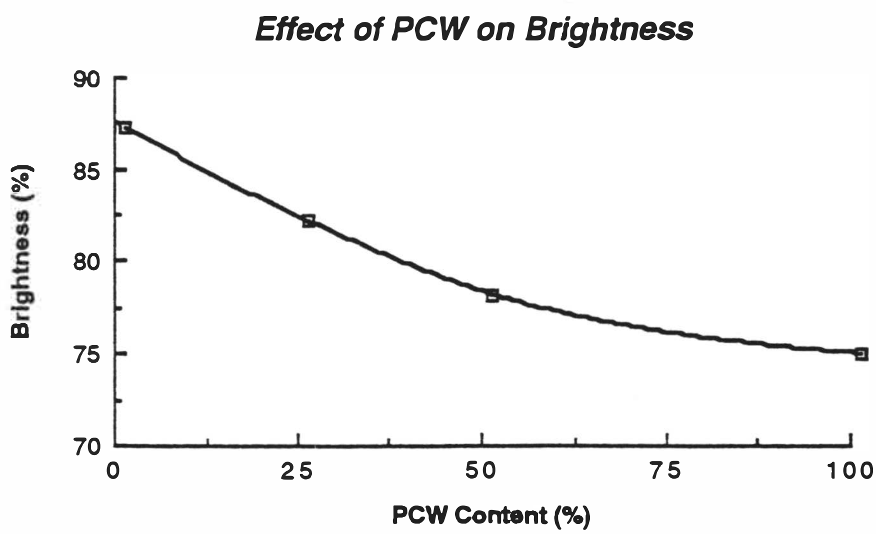

Figure 6. Brightness vs. PCW Content

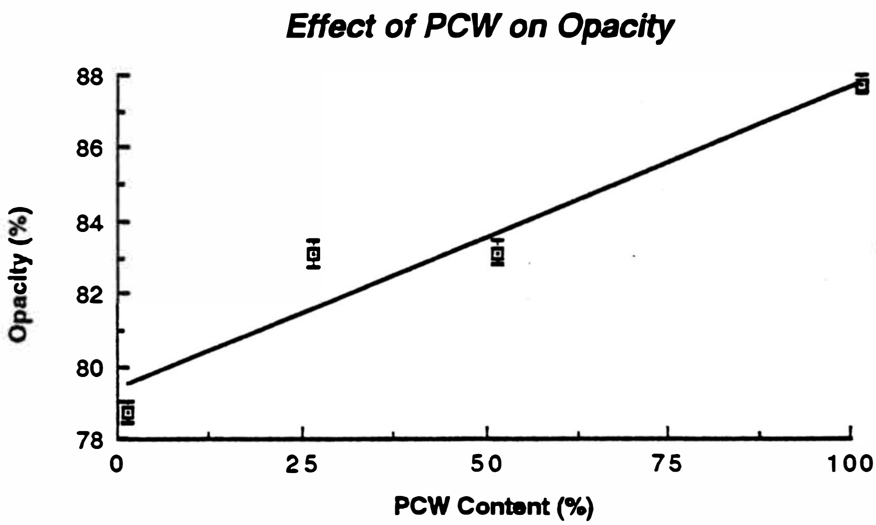

Figure 7. Opacity vs. PCW Content

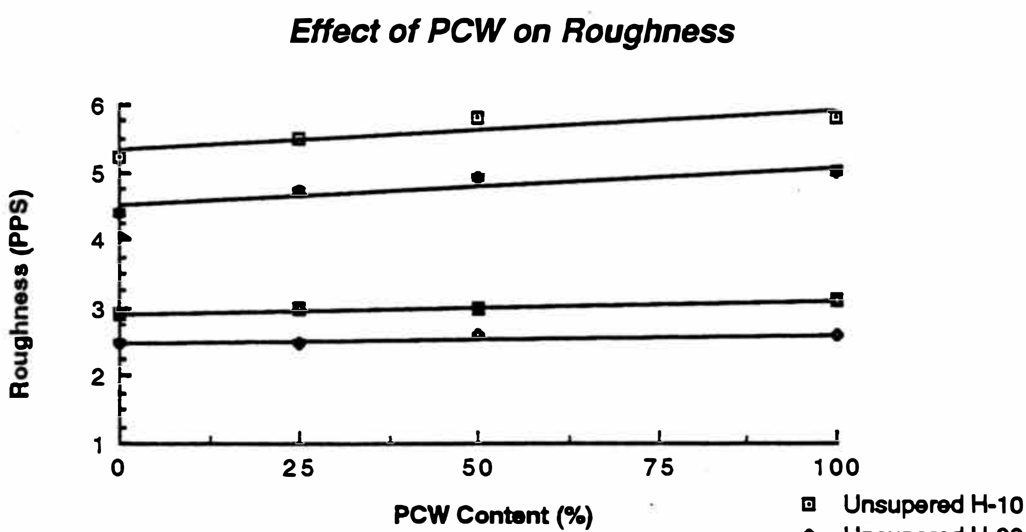

Figure 8. Roughness vs. PCW Content

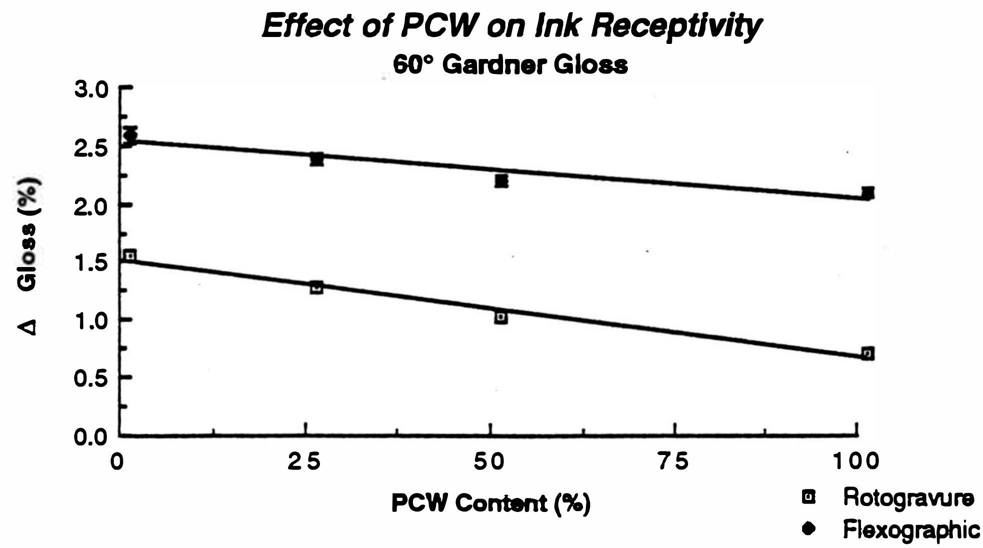

Figure 9. Loss in Gloss vs. PCW Content

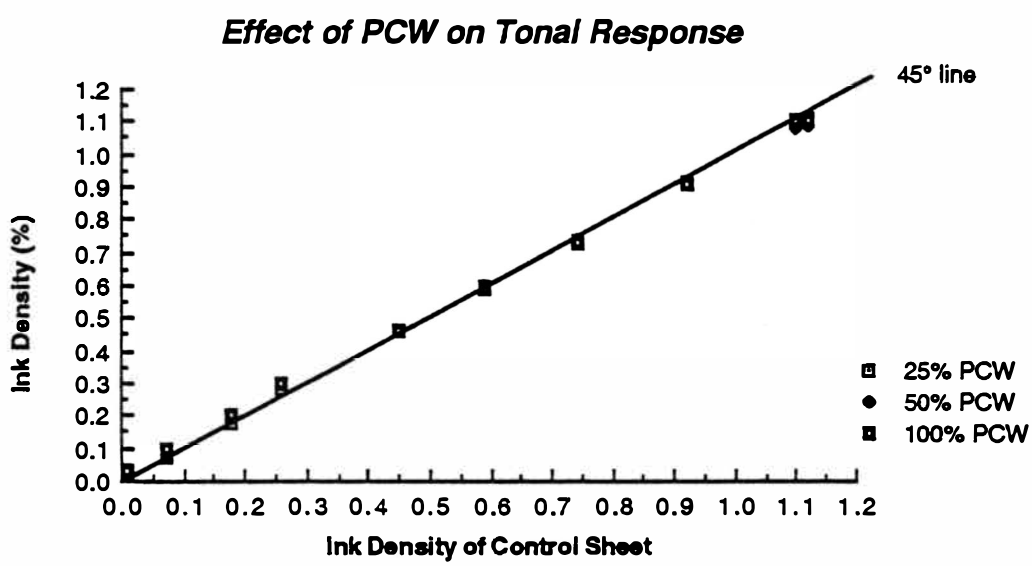

Figure 10. Tonal Response vs. PCW Content

Discussion of Results

The data gathered from the evaluation of the printability and runnability of the sheets containing secondary fiber (PCW) is presented in Table 4. Stretch and tensile energy absorption revealed inconclusive results and seemed to not be affected by the addition of post-consumer secondary fiber.

As shown in Figure 3, density decreases only marginally with the addition of post-consumer waste. The slight drop in density is not statistically significant since the standard error bars overlap. This could vary from the literature as a result of the deinked PCW not containing 100% kraft fibers or 100% groundwood fibers, but rather a mixture of both.

Tensile strength decreased in the machine direction, while the cross-machine tensile dropped only slightly. This is shown in Figure 4 as tensile index to correct for any changes in basis weight from sample to sample. The majority of strength loss is in the machine direction due to the predominate alignment of the fibers in the machine direction. Tensile strength is dependent on the fiber strength, bond strength, and relative bonded area. It can be reasoned that the loss in sheet strength was primarily caused by a decrease in fiber strength, since the bond strength almost doubled with the addition of secondary fiber (as shown in Fig. 5). This increase in bond strength was likely due to the increase in fines (see Table 3). It could also have been caused by the increase in contaminants present in the sheet. The number of stickies were a function of the PCW content and could have been "gluing" the fibers together to increase bond strength. It should be noted that the papermachine used has no cleaner system prior to the headbox that may have removed these contaminants.

Brightness drops off significantly, as shown in Figure 6, with the addition of deinked secondary fiber. This can be attributed to the ink particles dispersed over the secondary fiber. Figure 7 illustrates the effect of the post-consumer secondary furnish on opacity. The increase in opacity could be a result of the ash present in the secondary fiber, since the control sheet contained no filler at all. Another possibility for the increase in opacity is that the more rigid secondary fibers, being less conformable, could have increased the number of optically active sites and thus improved the scattering ability of the sheet.

Roughness, as measured by Parker Print Surf, increases with the addition of PCW. Figure 8 illustrates the relationship between sheet roughness and PCW content. The upper two lines represent the roughness for the flexographic sheet at clamping pressures of 10 and 20 kgf, while the lower two lines represent the same for the supercalendered rotogravure sheet. The supercalender achieved a smoother sheet at all points, however the supercalender could not compensate for the entire increase in roughness due to the secondary fiber. This was likely due to the more rigid secondary fibers resisting collapse.

As expected, the change in gloss, Δ gloss, is lower for the gravure printed sheet than the flexo printed sheet, as shown in Figure 8. Accordingly to the literature, this could be a result of the water based ink causing more fiber swelling than the toluene based ink. Some of the difference could be due to the effect of the supercalender closing up the surface of the sheet. Also shown is the trend for a lower Δ gloss with the addition of post-consumer secondary fiber. The more rigid secondary fibers could have resisted the penetration of ink and resulted in a lower Δ gloss.

Despite the increase in roughness with the addition of PCW, the ink transfer on the rotogravure press was not adversely affected. This is represented in Figure 10 as tonal response. The decrease in smoothness from the increase in secondary fiber content might lead to lower ink transfer. This would be evident with points falling below the 45° line. However, the points lie in very close proximity to this line, concluding that there was no significant change in ink density, and thus ink transfer. It should be noted that electrostatic assist was used on the rotogravure press throughout the run; and any changes in the sheet smoothness were within the control parameters on the printing press.

Conclusions

- The decrease in brightness and the increase in contaminants with the addition of the deinked post-consumer secondary furnish would likely prevent the use of this furnish in high quality uncoated printing grades. However, the appearance would not prevent it from being used in dyed grades and those for notebooks, etc.
- The resistance of the secondary fibers to swell could be an advantage when printing with water base inks.
- If the stickies could be dispersed so as to be invisible to the naked eye, they could be left in the sheet to improve bond strength.
- The secondary furnish caused no runnability during the press runs; however, the decrease in web strength may lead to runnability problems at higher speeds.

Recommendations

Much information was gathered from the work that was done and more research needs to be done to determine the paper - ink relationship and the interactions between the two. However, a logical extension of this work would be to study the impact of the post-consumer secondary furnish on the printability and runnability of the sheet over time (e.g. print quality after 5000 impressions, 10000 impressions, etc.)

Literature Cited

1. Cox G., Mississippi River Corp., personal conversation, (3/19/1992).

2. Davis, T. , Annual CPPA Conference, Canada, (1991).

3. Evanoff, P. C. , *Tappi Journal*, "Printing Trends " 67 (5) :53 (1984).

4. Ginman, R., *Advances in Printing Science & Technology*, "Paper Properties Required in Printing with Water Based Inks" 17 : 408-425 (1983).

5. Kasunich C. and B. Rutherford, *Gravure Process and Technology*, 1st ed., Gravure Association of America, Rochester, NY, 1991, p. 6.

6. Kline, J., *Lecture for Printing Course*, "Runnability, Printability, and Testing": B-12, 1992.

7. Lyne, B., *Tappi Journal*, "Paper Requirements and the Evolution of Printing", 72 (5) Special Supplement :33 (1989)

8. McKee, R. C., *Paper Trade Journal*, Effect of Repulping on Sheet Properties & Fiber Characteristics : 34-40 (1971).

9. Shulman, J. J., *TAPPI Proceedings: International Printing and Graphics Arts Conference*, "You Can Print Flexo on All Papers -- With Care" : 41-47 (1988).

10. Siconolfi, F. et. al., *Flexography Principles and Practices*, 4th ed., Foundation of Flexographic Technical Association, Ronkonkoma, NY, 1991, p. 20, 23.