Comparison of Printability of Hardwood and Bagasse Papers with Softwood Papers

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ABSTRACT

Handsheets from commercial bleached pulps of hardwood, bagasse, and softwood were prepared in a laboratory sheet former. The sheets were evaluated for several printability parameters such as ink-transfer, print density, print through and printing smoothness. The sheets could be graded in order of increasing printability as softwood, bagasse and hardwood.

INTRODUCTION

In any printing process there are three major components, namely, the printing press, the printing ink and the paper. After the best utilization of printing press and printing ink it is the paper which has a major contribution in controlling the printing output. Printability of paper is a broad term encompassing a number of print quality attributes such as print density, print uniformity and runnability of paper in high-speed printing presses.

All the structural and optical properties of paper influence the printability. These properties, in turn are controlled by the choice of pulp, the wet-end additives and the operating parameters on the paper machine. In the present work an attempt has been made to study the effect of the type of pulp on the printability of paper, Handsheets of three types of bleached chemical commercial pulps, viz., softwood, hardwood, and bagasse were prepared in the laboratory and were evaluated for various print quality parameters.

EXPERIMENTAL WORK

Appropriate SCAN (1) and Tappi (2) standard procedures were used where required. A list of the test methods used is given in Table-1.

PREPARATION OF HANDSHEETS

Commercial bleached chemical eucalyptus, bagasse, and softwood pulps were used for this study. All the pulps were beaten to about 40°SR in a laboratory valley beater (1&2).

Handsheets were prepared from the beaten pulp on a laboratory sheet former conforming to SCAN C-26/M5 specification (1). The sheet former was provided with a backwater recirculation system. The sheets produced were square of 160mm X 160mm in size. the sheets were formed couched, pressed, and air dried (1). The handsheets were internally sized with rosin and alum to achieve a $Cobb_{60}$ value in the vicinity of 20g/m^2 (1). The Furnish was maintained at a pH of 4.5 ± 0.25.

EVALUATION OF HANDSHEETS

The handsheets were tested for the various physical properties. The values of these properties are given in Table-2.

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Table-1
List of test method used in the expriments

TEST NO.	DESCRIPTION
SCAN-C25:76	Pulps Laboratory Beating (Velley Beater)
SCAN-C19:65	Drainability of Pulp by the Shopper Riegler Method
SCAN-C26/M5	Preparation of laboratory sheets for Physical Testing
SCAN-P12:64	Water absorbency of sized paper and paper board by the Cobb Method
SCAN-P7:75	Paper and board - Thickness and Apparent Density
SCAN-P21:67	Roughness of Paper and Paperboard, Determined with the Bendtsen Tester
T 410	Grammage of Paper and Paperboard
T 555	Roughness of Paper and Paperboard (Print Surf Method)
T 460	Air resistance of Paper (Gurley Method)
T 525	Diffuse Brightness of pulp (d/0^0)
T 519	Diffuse Opacity of Paper (d/0^0 Paper backing)
T 442	Spectral reflectance factor, transmittance and colour of paper and pulp
T 404	Tensile Breaking Strength & Elongation of Paper and Paperboard. (Using Pendulum-Type Tester)
T 414	Internal Tearing resistance of Paper (Elmendrof type Method)

Table-2
Various Properties of Handsheets.

PROPERTIES	HARDWOOD	BAGASSE	SOFTWOOD
^{0}SR of Beaten Pulp	40	42	45
Average Fiber length (mm)	0.68	1.2	3.18
Average Fiber width (μm.)	9.4	13	28
Grammage (GSM)	78.4	82.2	77.3
Bulk (cm^3/g)	1.58	1.49	1.6
Tensile Index $Nm/g/m^2$	34.82	35.674	58.72
Tear Index $mN/g/m^2$	2.665	6.328	14.46
Bendtsen Smoothness (ml/min)	70.5	67.1	495.7
Parker Print Surf Roughness (μm)			
5 kg_f/cm^2	3.45	4.2	>6
10 kg_f/cm^2	3.45	3.86	6
20 kg_f/cm^2	2.89	3.45	6
Gurley Porosity (Sec/100ml)	56.3	275	521.5
Bendtsen Porosity (ml/min)	223.3	35.5	35
PPS Porosity (ml/min)	262.3	71.75	49.8
Gloss (%)	16.26	25.6	17.62
Brightness (%)	73.1	72.16	67.54
Opacity (%)	94.55	89.6	82.15
R_∞ (%) at 557 nm	79.26	80.6	73.52
R_0 (%) at 557 nm	74.94	72.2	60.4
Sp. scattering coefficient (m^2/kg)	62.9	59.2	43
Sp. absorption coefficient (m^2/kg)	1.71	1.38	2.05

LABORATORY PRINTING

The handsheets were printed in a laboratory printability tester (IGT Model AIC_2-5) (3) The following conditions were maintained for all printings.

Speed	1m/s
Ink	IGT offset ink (supplied by the instrument supplier)
Printing Force	200 N
Printing disc	Rubber covered disc (width=50 mm, Dia.=65.25 mm)
Backing material	none
Inking time	150 sec (Sufficient to uniformly distribute the ink).

The required size of paper strip for printing in IGT tester was 300 mm x 55 mm. To achieve this, two handsheets were pasted together. For each type of pulp, a series of 20 strips was printed with varying amounts of ink on the printing disc. In the beginning, a large quantity of ink was applied to the IGT inking unit. The printing disc was inked and the amounts of ink on the printing disc before and after printing were determined gravimetrically using an analytical balance with a least count of 0.1 mg. After each printing, the remaining ink on the printing disc was cleaned using a solvent and a soft cloth. The inking unit was not replenished with fresh supply of ink between the printing. Thus the total amount of ink in the inking unit continuously decreased after each printings. The amounts of ink on printing disc and the ink transferred to paper were obtained in g/m^2 by dividing by the printed area of the sheet.

EVALUATION OF PRINTS

The strips printed by the IGT printability tester were evaluated for the print density, the print through and the fractional area of the paper surface covered by the ink. These values were determined from the measurements of various reflectance values of printed and unprinted papers on a Technibrite Micro TB-1C reflector meter (4). All the reflectance values were measured using Y-filter and C-illuminant. The methods for determining these parameters are described later.

RESULTS AND DISCUSSION

Ink Transfer:

The amount of ink transferred to the paper, y

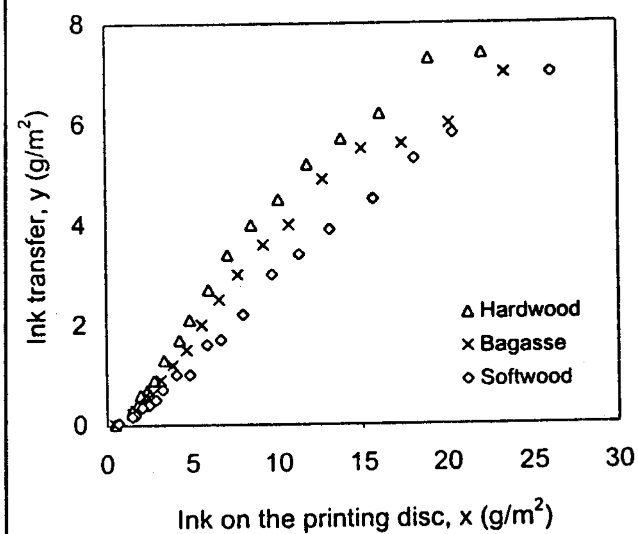

Fig. 1 Amount of ink transfer as a function of ink on the printing disc.

(g/m^2), as a function of amount of ink on the printing disc, x (g/m^2), for the three types of pulps are shown in Fig.1. The shape of the ink transfer curves is similar to that reported by Fetsko and Walker (5). For a given values of x the amount of ink transferred to the paper is the greatest for the hardwood sheets and the lowest for the softwood sheets Similar inference is drawn from the Fig.2, where, percentage ink-transfer, (100.y/x), is plotted as a function of x. The percentage ink transfer remains less than 50% for all types of sheets which is typical for uncoated

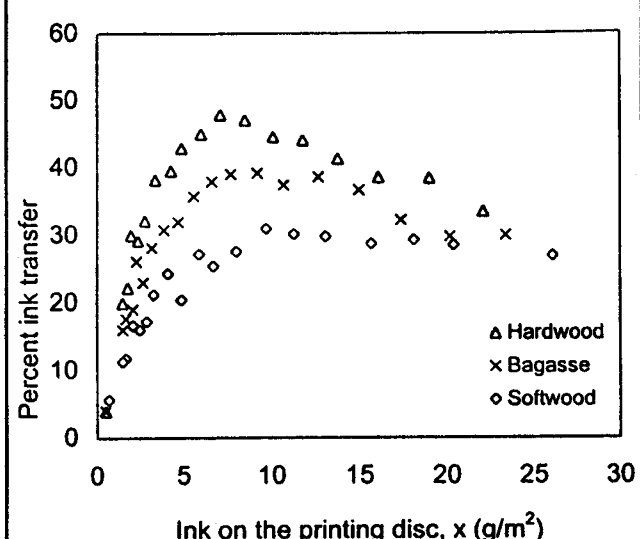

Fig. 2 Percent ink transfer as a function of ink on the printing disc.

papers. To quantitatively analyze the ink transfer curves; the experimental data were fitted to the Fetsko-Walker equation (5):

$$y = (1-e^{-kx})[b(1-e^{-x/b})(1-f)+fx]$$

Where

y = Amount of ink transferred to the paper, g/m^2

x = Amount of ink present on the printing disc, g/m^2

b = Amount of ink immobilized by the paper, g/m^2

Table-3

Ink transfer parameters

Sample	b	f	k	Reg. coef.
Hardwood	5.731	0.1205	0.1902	0.99986
Bagasse	5.563	0.0864	0.1403	0.9983
Softwood	4.0587	0.164	0.09	0.9991

f = Ink split factor.

k = A constant dependent on the smoothness of paper.

The values of ink transfer parameters, b, f, and k (Table-3) were determined from a least square curve fitted to the experimental data. A direct search sequential simplex method (6, 7) was used for the curve fitting. In general, the values of b, f, and k are dependent on the sheet characteristics, the printing ink, and the printing condition (8). In the present study the printing ink and the printing conditions were maintained constant for all the sheets and the variation in b,f, and k, is considered due to the difference in the pulps used in making these sheets.

In the Fetsko-Walker model, the value of b represents the amount of ink immobilzed by the paper in the printing nip. The value of b for softwood sheets is the lowest and it is nearly same for bagasse and hardwood sheets. Apparently the value of b is positively related with air permeance of the paper. The factor k is the printing smoothness. The values of k seem to be well correlated with the smoothness values determined by the air-leak methods. The smoothness values measured by the Bendtsen tester and PPS tester are reported in Table-2. As seen from the Table the PPS values give a better correlation with the printing smoothness k, because both these methods measure smoothness of paper under compressed state.

PRINT DENSITY (PD)

The print density is the optical contrast between printed and unprinted surfaces. The print density values were calculated from the reflectance values of printed and unprinted sheets as (9):

$$PD = \log (R_\infty/R_p)$$

Where

PD = Print density

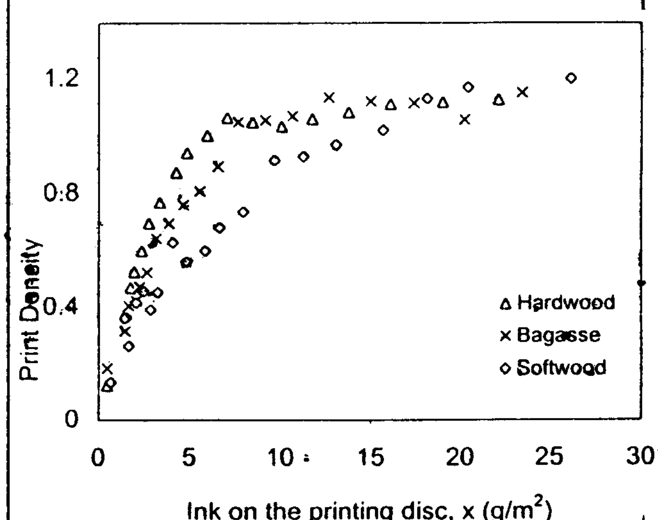

Fig. 3 Print density as a function of ink on the printing disc.

R_p = reflectance of the printed sheet backed by a pile of unprinted sheets of the same paper.

R_∞ = reflectance of a thick pile of paper sheets.

Fig.3 and fig.4 show print-densities of the three types of sheets as a function of amount of ink on the printing disc x and amount of ink transferred to the paper, y. The print -density increases with x and y and attains a saturation value of nearly 1.1 for all

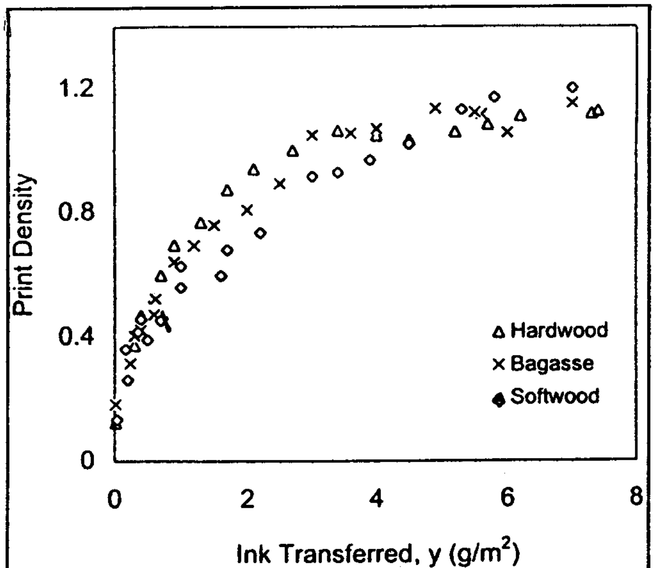

Fig. 4 Print density as a function of ink transferred.

the three types of sheets for $y > 4$ g/m². For a given amount of ink transferred to the sheet of paper, the hardwood and bagasse handsheets show a much larger values of print-density than the softwood sheets. This may be partly due to (1) the higher intrinsic reflectance of hardwood and bagasse than softwood and, (ii) better ink holdout on the surface of hardwood and bagasse handshets as they are made of short and thin fibres.

INK MILEAGE

An important printability parameter is the requirement of ink to attain a given print density. The amount of ink required on the printing disc and the ink transferred to the paper surface to achieve print densities of 0.9 and 0.7 for three types of handsheets are given in Table -4. Hardwood and bagasse sheets require less ink than the softwood sheets for the same print density. It is interesting to note that the ink requirement for hardwood sheets is less than that for bagasse sheets even when the porosity of hardwood sheets is greater than bagasse sheets while they have nearly the same intrinsic reflectance and surface smoothness. This is possibly due to the fact that the lower length and width of hardwood fibres allow the ink to be retained in the surface of the sheet rather than penetrating into the middle.

PRINT THROUGH

The print through refers to the undesirable effect of a print in which the printed image on a paper sheet is visible from the reverse side. It is defined as the contrast between the printed and unprinted portions of the sheet when viewed from the reverse side of the print. Print through is quantitatively expressed as (9).

$$PT = \log (R_{\infty,rev}/R_{p,rev}) \quad (3)$$

Larson and Trollsas (10) suggested that the

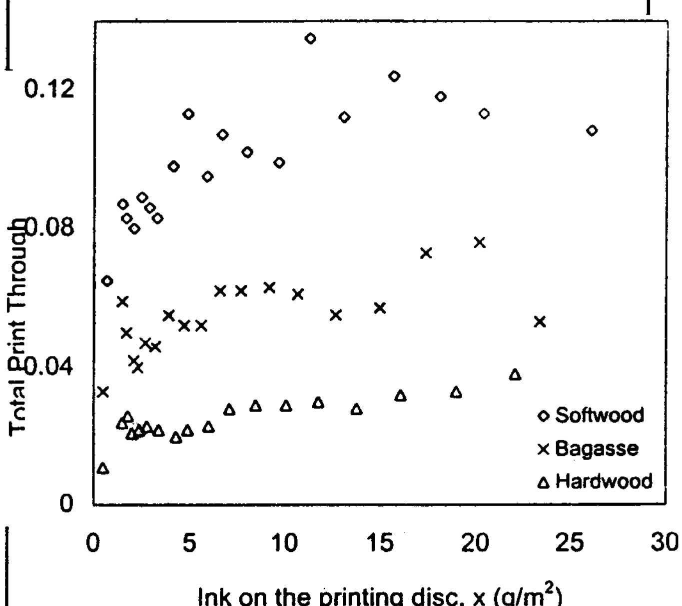

Fig. 5 Total print through as a function of ink on the printing disc.

Table-4

Ink requirement at 0.9 & 0.7 print density

Sample	PD = 0.9		PD = 0.7	
	x	y	x	y
Hardwood	4.264	1.67	2.84	0.89
Bagasse	6.605	2.52	3.89	1.15
Softwood	9.69	3.03	6.654	1.67

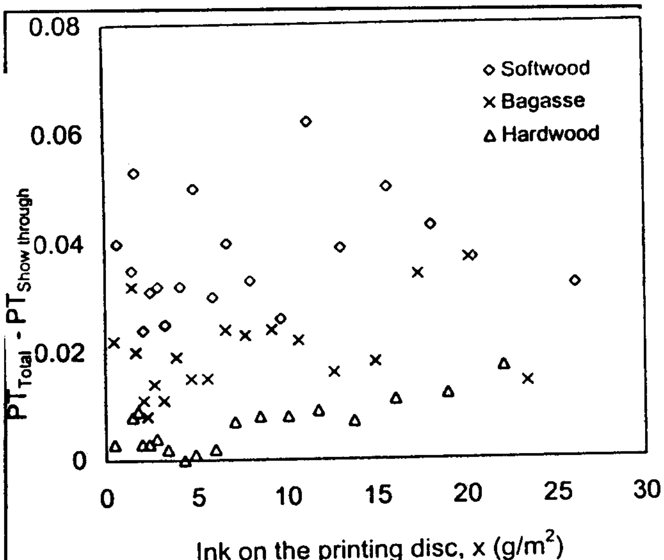

Fig. 6 Print through component due to pigment penetration and pigment-vehicle separation

print through is a combined effect of the following three factors:

(i) Show through due to lack of opacity of paper.

(ii) Penetration of pigment into the paper.

(iii) Loss of opacity of paper due to vehicle - pigment separation.

The component of print through due to lack of paper opacity was calculated using the equations developed by Bristow (11)

$$PT_{ST} = \log (R_{\infty,rev}/R_x) \quad (4)$$

$$R_x = [(R_o+R_p) - R_oR_p(1/R_{\infty,rev}+R_{\infty,rev})]/1-R_oR_p) \quad (5)$$

Where

$R_{\infty,rev}$ = Reflectance of reverse side of unprinted sheet backed by a pile of same paper.

R_0 = Reflectance of sheet backed by a black cavity.

R_{prev} =Reflectance of reverse side of printed sheet backed by a pile of unprinted sheets of the same paper.

R_x =The reflectance of unprinted sheet backed by a sheet of the same paper printed with a known amount of ink and known optical density. It can be calculated directly by the equation (5).

The difference ($PT-PT_{ST}$) will indicate the print through propensity due to ink penetration and pigment - vehicle separation. Fig. 5 shows the total print through as a function of x for all the three types of sheets. Softwood sheets have the highest print through whereas the hardwood sheets have the lowest. Fig. 6 shows the print through component when the influence of translucency of the sheets is subtracted from the total print through. Softwood shows the greatest ink penetration and the hardwood the lowest.

FRACTIONAL AREA COVERED (A)

Printing a paper with a thin ink film on the printing disc leaves some portion of paper surface uninked. Ink is transferred mainly to those surface elements that come in contact with the ink under printing pressure. So, fraction of paper surface area covered by the ink is related to the uniformity and evenness of the paper surface. The fractional area covered may be determined by measuring the reflectance of printed and unprinted area (12).

$$R_p = (1-A)\ R_{\infty} + A\ R_{ink} \quad (6)$$

Where,

A = Fractional Area Cover

R_{ink} = Reflectance factor of a continuous layer of pigment.

The experimental data of x and A were fitted

Table-5

Surface coverage parameters for different sheets.

	k_h	n	$x_{0.5}$	$(dA/dx_{0.5})$	Z
Hardwood	0.82	1.356	1.159	.293	1.987
Bagasse	.48	1.58	1.59	.248	2.53
Softwood	.535	1.0	1.87	.134	3.739

$$\frac{A}{1-A} = k_h x^n \quad (7)$$

Where k_h and n are constants

The data gave good fits for all the three types of sheets with the coefficient of regression more than 0.94. The values of k_h and n have been reported to be the characteristics of the surface of the sheet (13). From the values of k_h and n, it should be possible to calculate two useful parameters. $x_{0.5}$ which represents the amount of ink required on the printing disk to achieve a 50% coverage on the surface. similarly, $(dA/dx_{0.5})$ that represents the slope of the A vs. x curve at 50% surface coverage. A small value of $x_{0.5}$ and a high value of $(dA/dx_{0.5})$ should point to a better printing surface. The values of these parameters for three types of sheets are given in Table-5. The last column of the Table-5 shows a roughness index calculated from these parameters (14). The parameter, z, appears to be a better predictor of the surface smoothness of printing papers than the roughness measured by the air-leak methods, for example, PPS. The hardwood sheets have the lowest value of z and show the best ink transfer performance.

CONCLUSIONS

Handsheets of hardwood, bagasse and softwood pulps have been compared with respect to a number of printability related properties of the sheets. The important observations are:

1. Under the given printing conditions, the hardwood sheets showed the greatest ink transfer and the softwood sheets the lowest.
2. The value of the Fetsko-Walker ink immobilization parameter, b, was the greatest for hardwood sheets and lowest for softwood sheets. This is in agreement with the porosity of the sheet measured by the Gurley method However for a given amount of ink transferred to the paper, the hardwood sheets had the minimum print through, indicating a minimum penetration of pigment into the hardwood sheets. This to attributable to the fine pore structure of hardwood sheets due to short and thin fibers, which helped in relating the ink pigment close to the paper surface.
3. The saturation print density for all the handsheets was about 1.1. Almost complete coverage of paper by ink was observed for print density 0.9 or greater. The minimum amount of ink required to attain print density of 0.9, was the lowest for hardwood sheets and the greatest for softwood sheets.
4. Surface of the hardwood sheets was adjudged the best when evaluated using the partial coverage printing method (14). For hardwood sheets value of $x_{0.5}$ was lowest and value of $(dA/dx_{0.5})$ was the gretest, indicating the best surface topography from the printability point of view.

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