PRINTABILITY OF HARDWOOD AND NONWOOD PAPERS

A DISSERTATION

Submitted in partial fulfilment of the requirements for the award of the degree

of

MASTER OF ENGINEERING

in

PULP AND PAPER TECHNOLOGY

By

MAYANK GARG

INSTITUTE OF PAPER TECHNOLOGY
(UNIVERSITY OF ROORKEE)
SAHARANPUR-247001 (INDIA)

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CANDIDATE'S DECLARATION

I hearby certify that the work which is being presented in the thesis entitled " **PRINTABILITY OF HARD WOOD AND NON-WOOD PAPERS"** , in the partial fulfilment for the degree of Master of Engineering in Pulp & Paper Technology, submitted at the Institute of Paper Technology (University of Roorkee) is an authentic record of my own work carried out during the period from August, 1997 to January,1998 under the supervision of Dr. S.P. Singh, Asst. Professor, Institute of Paper Technology, University of Roorkee, Saharanpur.

The matter embodied in this thesis has not been submitted by me for the award of any other degree.

[MAYANK GARG]

This is to certify that above statement made by the candidate is correct to the best of my knowledge.

[Dr. S.P. SINGH]
Asst. Professor
Institute of Paper Technology
(University of Roorkee)
Saharanpur - 247001

Date : 31 Feb 1998

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SYNOPSIS

Most of the paper produced is printed. Besides wiriting and printing papers, newsprint, packaging papers and boards are printed by one means or the other. Therefore the paper maker should know about the behaviour of paper under various printing condition. Inspite of the extensive research work carried out in this area, the relationships between morphological structure of paper making fibers, physical properties of paper as tested in a laboratory and its performance in a printing press are not very well established. Printability evaluation of papers, thus, generally involve actual printing of the paper. Ink-paper relationships involving ink transfer characteristi .cs, print density, optically covered area and show through are critical aspects in the evaluation of printability.

Many authors have discussed various ink transfer parameters to study the printability of papers. The present work was intended to study these parameters in order to evaluate ink transfer, print density and show through for various types of pulps under a set of printing conditions.

Chapter 1 of this thesis deals with the introduction to the present work. Chapter 2 gives an review of literature in this area. Chapter 3 deals with experimental work and the procedure for printing experiments. For three types of pulps hand made sheets, inculuding one mill made bagasse paper were examined in the present work. The results and discussion of the results are given in chapter 4. The conclusions drown form these discussions are given in chapter 5.

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LIST OF FIGURES AND TABLES

CHAPTER 1

1. INTRODUCTION:

Most of the paper produced today is printed by one or the other methods of printing. In any printing process, three essential elements are involved; the printing ink, the printing press, and the paper. Often it is focused that after the best utilization of the available inks and printing machinery, it is the paper which has a major contribution in controlling the final appearance of a print. Thus printability of paper is an important property consideration before the paper maker. However, it is not easy to quantitatively define printability. Printability is a broad term encompassing a number of demands placed on paper to achieve good printed results. This includes the ability of paper to smoothly pass through the printing presses withstanding all the stresses on high speed machine. This is referred to as runnability of the papers. On the other hand, the paper must be able to produce uniform, clear and high contrast images. The term printability is used to describe this ability of paper.

To achieve a desired set of properties in any grade of paper, the paper machine has several variables at its disposal; the selection of raw materials, the pulping and bleaching process, the refining of the pulp, the addition of fillers and other chemicals, and finaly the operating condition at the paper machine. All these factors contribute in a complex manner to the properties of the final product.

In the present study an attempt has been made to study the effect of the type of pulp on the printability of paper. For this study hand sheets of three types of bleached chemical pulps, namely, hardwood, bagasse, soft wood were used. A mill made bagasse printing paper was also included for the sake of comperison.; A number of printability related parameter for these sheets were determined using a laboratory IGT printability tester. The results obtained in this study indicate that the selection of paper making raw material significantly influence the printability of paper.

CHAPTER - 2

2. REVIEW OF LITERATURE:

Printing, also known as graphic arts and / or graphic communications, is a complex colloidal phenomenon. It involves the application of a liquid or plastic material (the printing ink) to a colloidal fibrous membrance (the paper) under certain printing conditions (pressure and speed). Slight variations in the printing ink, plate, paper or press conditions can throw the system out of balance.

All printing process consist of a system that uses an inked printing plate or image carrier to produce numerous reproductions of the subject on the paper in a printing press, on which pressure is used to transfer the ink image to the paper. In all printing processes, the printing plate consists of two areas :

(i) Printing or image areas that are inked to produce the image.

(ii) Non printing or non image areas that remains clean or unprinted.

Five major printing process are :

- Letter Press
- Flexography
- Gravure
- Lithography
- Screen Printing

For many years the term printing was synonymous with letter press, the most common of the printing processes. In recent years, however, the other process have much advanced than the letter press. The lithography is perhaps the most widely used printing process of today.

2.1 PRINTING INK TRANSFER :

An important approach to understand and evaluate the influence of the paper surface on printing, is through the study of the transfer of ink to paper during the printing impression. Best printing results are obtained with the minimum amount of ink necessary for the desired intensity of colour.

One problem that occurs when printing halftones is uneven transfer of ink from the printing plate than from solid areas. Compensation for this can be made by adjusting the ink on the press, so that the area of solid printing and other areas of heavy coverage receive the greatest amount of ink. When plates have solid areas adjacent to halftone dots, the pressman may provide excessive ink to the halftone in an effort to get full coverage in the solid areas. The results can be an undesirable enlargement of the dots or even complete filling in between them. So, the ink transfer from the plate to the paper during the printing impression, is the very heart of the printing process, that determines the quality of the print.

Walker and Fetsko[1] proposed a more compreshensive theory of ink transfer in printing that has been widely used and studied. It is based on the assemptions that .

1. When an ink bearing printing plate comes in contact with paper, some of the ink penetrates the surface of the paper or is trapped in surface voids. This ink is tightly held or "immobilized" by the paper.

2. The remaining "free" ink between the paper and the plate splits at the end of impression.

A constant percentage of this "free" ink is transferred to the paper. This is generally less than 50% and depends on the materials and printing conditions used.

The foregoing concept has been expressed as an equation of the following linear form:

$$y = b + f(x-b) \tag{2.1}$$

Where y = ink transferred per unit area to the paper surface.

x = ink originally on the plate

b = ink immobilized by the paper surface.

x-b=non immobilized or "free" ink film thickness.

f = fraction of free ink transferring to the paper.

This equation is rapidly applied to merasured data in its transposed from

$$y = b\ (1-f) + fx \tag{2.2}$$

Experimental data of Walker and Fetsko and others indicate that the equation (2.2) applies quite accurately for large values of x. The actual ink transfer data deviate significantly for smaller values of x , and particularly for uncoated rough papers. To make the equation more comprehensive Walker and Fetsko introduced corrections. The equation becomes:

$$y = (1-e^{-kx})\ [\ b\ (1-e^{-x/b}) + f\ (x-b\ (1-e^{-x/b})\ ] \tag{2.3}$$

Where e = base of natural logarithms

k = Smoothness constant for paper

At very low ink flim thickness there is insufficient ink on the plate for complete contact with the paper surface. As the film thickness increases the area of the paper accepting ink increases rapidly until full coverage is attained. thus the transfer increase rapidly.

The term ($1-e^{-kx}$) is the fraction of the paper surface contacted by the ink. It is zero when x is zero and increases to approach 1.0 as the ink film increases. For smoother paper k is large and this fraction approaches 1.0 much more rapidly. The term ($1-e^{-x/b}$) is introduced to correct b, the amount of ink that can be immobilized by the paper surface, for low film thickness, where that much of ink may not be available. Both of these correction factors approach 1.0 at medium to high ink films and thus reduce this equation to the simpler form.

Schaeffer and coworkers(2) extensively studied the transfer and penetration aspects of ink receptivity for a large number of papers of different grades. They studied the effect of variables such as the ink, paper, the pressure and speed of printing. The extract of their experimental studies are as mentioned below:

- The transfer parameter, b, includes only the ink immobilized during the time in which the paper is being compressed in the nip.

- The decrease in the amount of ink immobilized with decreasing printing speed can be due to the increased extent of paper compression and the decrease in effective capillary diameter.

- The transfer parameter, f, includes both the ink transferred by capillary flow during the decompression of the paper in the nip plus the "free" ink film which splits torwards the paper surface.

- The increase in f with decreased printing speeds is due to the increased fraction of ink transferred to the paper by capillary flow during the prolonged and more extensive decompression of the paper stock.

2.2 PRINTABILITY OF PAPER :

Printability is not a signle property of paper but it is the combined effect of physical and optical properties of paper that contributes to produce good quality print. Properties of paper affecting the printability are :

(i) Moisture content
(ii) Ink receptivity
(iii) Smoothness and compressibility
(iv) Porosity
(v) Gloss
(vi) Brightness
(vii) Opacity

Because, so many factors combine to influence printability, it is possible to make serious misjudgements from the analysis of individual tests and this is the reason why printability is costumarily measured by an actual printing of the paper. The best method of testing printability is by printing on a commercial press. The next best method is by laboratory tests on a proof press or print testers. Very useful print testers have been made available by Insituut Voor Grafische Technik (IGT) and by FOGRA. For gravure printability an instrument has been designed by Gravure Research Institute (GRI).

2.3 INFLUENCE OF SURFACE SMOOTHNESS AND COMPRESSIBILITY ON PRINT EVENNESS:

Inadequate contact of the paper surface with the ink film results in an broken or incomplete image. It is the smoothness of the paper surface that permits full contact. It is not really the smoothness of the free surface, but the "printing Smoothness" under the dynamic printing pressure, that controls the print quality.

During compression in a printing nip, thick parts of the paper are compressed more than thin part. Thus the higher the printing pressure, larger is the area of the paper surface which comes in contact with ink on the printing surface.

Uddo Ullman and Ingrid Quarnstrom(3) had investigated the influence of certain factor upon unevenness of solid print, such as surface roughness, compressibility of papers, pressure in the printing nip and the hardness of the backing in the press. Some of the conclusions of their experimental work, are as follows:

- Surface roughness is the paper property which predominantly influences the print unevenness. Variations in the surface roughness has a significant influence, which can be partially controled by printing conditions.

- Parker print surfmeasurements gives better correlations than Bendtson measurements to print quality.

- Conventional laboratory measurements of compressibility or hardness correlates poorely with printing hardness and occasionally may be misleading.

- The hardness of the backing and the printing pressure each have such a great influence on the printing results, that variations in paper properties including compressibility can be compensated.

2.4 ABSORBENCY AND INK RECEPTIVITY OF PRINTING PAPERS:

These are important properties of printing paper, because they have a strong effect on the successful transfer of the ink film to the paper surface. High absorbency tends to drain the ink vehicle into the sheet and leave a dull ink film. High absorbency is usually associated with a rough paper surface and high porosity of paper; it tends to produce a rough printed film. On the other hand, low absorbency or high ink hold out gives a smoother glossier ink film with a cleaner, more saturated colour. Usually high hold out sheets are smoother, requires less ink for converage and high print dessity and gloss.

2.5 OPTICAL EVALUATION AND EXAMINATION OF PRINT QUALITY FOR A SOLID PRINT :

Good print quality is the final goal in printing. The perceptual print quality is the subjective impression an observer experiences when viewing the solid print area appears to be covered with ink and on the nature of uniformity. So the visual examination of the print will be the final estimation of the quality of the print. But attempts had been made to prepare optical quality factor to investigate the printability of papers and printing process conditions which strongly influence the non uniformity of the print and which are of interest to printer and paper maker alike.

The optical parameters to evaluate the print quality are as such:

(i) Print density

(ii) Optically covered area.

(iii) Print through

Print Density [4] :

The print density is the optical contrast between a printed and unprinted surface. The density of a print can be increased by increasing the amount of ink on the printing plate. It is mathematically calculated as

$$PD = \log\left(\frac{R_\infty}{R_p}\right) \qquad (2.4)$$

Where

R_∞ - Reflectance of paper sheet backed by a pile of same paper

R_p - Reflectance of the printed paper, backed by a pile of same unprinted paper.

Print Through [4] :

The undesirable effect of the print being visible through the reverse side of the paper is called print-through (or show through). It depends upon the opacity and porous nature of the paper. A higher ink application to improve print density will also have the adverse effect of increasing print through. It can be calculated mathematically as :

$$PT = \log\,(R'_\infty / R'p) \qquad (2.5)$$

Where R'_∞ = Reflectance of the unprinted sheet on the reversed side to be printed backed with a pad of same paper.

$R'p$ = Reflectance of the reversed side of a print back with a thick pad of same unprinted paper.

Larson and Trollsas divided the print through of paper containing oil based ink in to three components:

(i) Direct show through, PT_{ST}. This is the unprinted opacity component i.e. without the ink penetration into the sheet.

(ii) Pigment penetration, PT_p .

(iii) Loss of opacity due to vehicle oil penetration ,PT_v..

The total print through (PT) and the component are calculated from

$$\underbrace{\log(R'_\infty/R'_P)}_{PT} = \underbrace{\log(R'_\infty/R'_x)}_{PT_{ST}} + \underbrace{\log(R'_x/R'_{PP})}_{P_{TP}} + \underbrace{\log(R'_{PP}/R'_P)}_{PT_v} \quad (2.6)$$

Where,

R_x = The reflectance of the unprinted sheet backed with 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 mentioned below

$$R_x = [(R_0 + R_p) - R_0 R_p (1/ R'_\infty + R'_\infty)] / (1- R_0 R_p) \quad (2.7)$$

R_0 = The reflectance of the unprinted sheet with a black backing.

R_{PP} = The reflectance of the reverse side of the print into which pigment has penetrate and which has been extracted for vehicle oil.

NOTE: All the reflectancesare to be measured through y filter.

Optically covered Area [5] :

The uniformity or evenness of the print is related to the uniformity of the distribution of the ink over the paper surface. When a paper is printed, ink transferred mainly to those surface elements of the paper that are in contact with the ink under the printing pressure. As a result of the deformation of the ink layer by this pressure, however, the ink also reaches some elements that are actually lower than the contact plane between the paper and the printing form.

One possible way of describing, how the ink pigment is present on a solid print is to assess the proportion of the printed area that is optically covered by pigment. If the optically covered proportion of the printed area is denoted by A, the reflectance of the print is given by:

$$R_p = A.\ R_{ink} + (1-A)\ R_{\infty} \qquad (2.8)$$

Which gives

$$A = (R_{\infty} - R_p)/(R_{\infty} - R_{ink}) \qquad (2.9)$$

Where R_{∞} = Intrinsic reflectance of the paper.

R_p = Mean reflectance of the print.

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

The assumption here is that each surface element of a solid print has a reflectance factor equal either to that of a contineous pigment layer or to that the unprinted paper.

Optically covered area mainly depends upon properties such as surface roughness, volume proportion of fiber in the paper compressibility of the paper, and the scattering coefficient of the paper. Light entering the paper in areas not covered by pigment is scattered, so that part of light is absorbed in adjacent pigment covered area. As a consequence a small unprinted spot of a print reflects less incident light than does an area of the same size surrounded by unprinted paper. So scattering coefficient of paper along with smoothness and compressibility plays an important roll in estimating optically covered area.

CHAPTER 3

3. EXPERIMENTAL PROCEDURE :

3.1 PREPARATION OF HAND SHEETS AND SELECTION OF MILL SHEETS :

Three different types of handmade sheet were prepared from soft wood , hardwood and bagasse respectively on the square sheet former, by recirculating the white water to have uniformity in sheets. Degree of beating was maintained in between 40°SR to 45°SR. Though the experiment is for offset printing in which oil based ink is used then also to have the standard cobb value of 22 for writting and printing grade of paper rosin and alum were added. For softwood and hardwood the percentage of rosin and alum added was 1% and 4% respectively and in bagasse 2% rosin and 8% alum was added, to attain cobb value near about 20. The grammage of the sheets were tried to maintain 80 gsm.

Another sample, a mill made bagasse printing paper was selected for the sake of better comparision for the printability of three different pulps.

3.2 PHYSICAL AND OPTICAL PROPERTIES DETERMINATION

A series of different types of physical and optical tests were conducted onthe prepared handsheets and mill made bagasse printing paper. The properties tested are as mentioned below:

1. Grammage
2. Caliper
3. Apparent density
4. Bulk

5. Cobb number

6. Smoothness (on bendston and Parkre Print surf.)

7. Porosity

8. Gloss

9. Brightness

10. Opacity.

The values of these properties for different samples are given in table-1.

3.3 PRINTING EXPERIMENT

Apparatus discription:

IGT PRINTIBILITY TESTER AIC 2-5 :

This tester manufactured by M/s. Raportest B.V., The Netherlands can be considered as a mini, laboratory scale printing press. All parts of the printing press are in it. It consists of a impression cylinder (called sector), a printing forme (called printing disc) and a paper sample clamped to the sector. It is possible to adjust the thickness of ink layer, the printing force, the printing speed, the packing, similar to that of a real press. With this tester, it is possible to work with a constant speed between 0.2 and 5 m/sec. or with an increasing speed between 0.5 and 7 m/sec. In the constant speed mode there is a possibility to stop the sector after half of the rotation during a preset time interval of between 0.2 and 9.9 seconds. Intervals of more than 10 seconds can be realized by making two printing runs in succession. In the increasing speed mode the speed is increasing proportionally with the length of the print. The maximum print width can be 50 mm, resulting in a large printed area,which enables the visual judgement of evenness of print in a glance. For safety reasons there are two starting buttons that have to be pressed simultaneously to rotate the sector.

In starting position the printing disc is an contact with the sector. At the end of the print, there is a provision for lifting the printing disc when the sector has made a revolution. There is an option of second printing disc, which is suitable for multi-colour printing and set-off tests.

Procedure :

Prepared hand made sheets were square sheets of 16.5 length, so to get the required length for printing (atleast above 23 cm) two sheets were pasted together. Our experiment was on offset printing for which a printing load of 200 N and a printing speed of 1.0 m/s were used.

Two hard rubber discs of same dimensions (0.01025 m^2 Surface area) were used as printing discs. Inking time of 150 seconds was used to transfer ink on the printing discs from IGT inking unit AE.

The weight of uninked printing disc was taken (a gm). After 150 seconds of inking time on inking unit, the weight of inked disc was taken (b gm). Printing was done with the disc on the strip of paper, clamped to the sector of the IGT printability tester, at above mentioned printing conditions.

After printing, the weight of the printed disc was taken (c,gm) and the disc was cleaned with an organic solvent to remove the remaining ink on the printing disc. The procedure was repeated for each strip for all samples.

Quantity of ink on printing disc = x = (b-a)/A g/m^2

Quantity of ink transferred to the paper y = (b-c)/A g/m^2

Where A is the area of printing.

3.4 EVALUATION OF PRINTS :

Appratus used - Technibrite Micro TB-1C:

The reflectance values for the printed and unprinted paper sheets of all samples were taken.for one strip five values of each reflectance were taken and the mean of these five values was used for further calculations. Optical parameter for evaluating print quality were calculated as mentioned in the section 2.5.

CHAPTER - 4

4. RESULTS AND DISCUSSION :

4.1 EXPERIMENTAL DATA :

Table -1	Physical and optical properties of prepared and selected paper sheets.
Table -2	Observation table for printing on IGT tester.
Table -3	Optical observation table.

4.2 RESULTS :

4.2.1 Determination of ink transfer parameter :

Walker (6) suggested a method for calculating the values of f,b,k. The most accurate values are obtained after third approximation. A plot for y versus x was plotted as shown in fig - 1.

The same procedure was followed to calculate values of f,b,k.. A computer programme in Q-BASIC was written to check the results. The procedure is as mentioned below:

First or linear approximation :

For maximum values of x and y a straight time is to be plotted the values of b_1 and f_1 are to be calculated as per the equation by the regression:

$$y = b\ (1\text{-}f) + f\ x \qquad (4.1)$$

Then the values of k for lower values of x has to be calculated after substituting b_1 and f_1 values to the equation:

$$k = -1/x\ \ \ln\ [1-\ y/(b(1-e^{-x/b})\ (1-f) + f\ x)\ ] \qquad (4.2)$$

Then the calculated values of k has to be extrapolated to x = 0. The value of k. at x=0 will be the most accurate value .

Second Approximation :

Using above calcuated values of b_1, f_1 and k, and maximum values of x as taken in first approximation, the corresponding values of y has to be calculated by equation.

$$y = (1-e^{-kx})\ [b\ (1-e^{-x/b})\ (1-f\ ) + f\ x\ ] \qquad (4.3)$$

Once again b and f values were calculated by equation –4.1 for high values of x and corresponding y calculated and designated as b_c and f_c.

The true value of b_2 is determined from the following equation.

$$b_2 = b_1^{\ 2} / b_c \qquad (4.4)$$

and f_2 is calculated for maximum ink point by the equation mentioned below:

$$f_2 = f_1 - (b_2 - b_1)\ (x - y)\ /\ (x - b_1)^2 \qquad (4.5)$$

If error still occurs between y actual and y calculated then we have to go for third approximation.

Third Approximation:

To determine a more accurate value of b, the equations used are as follows:

$$b_3 = b_1 + b_1^2 (b_1 - bc) / bc^2 \qquad (4.6)$$

and f_3 is calculated as :

$$f_3 = f_1 - (b_3 - b_1)(x - y) / (x - b_1)^2 \qquad (4.7)$$

The values of b_3 and f 3 will be most accurate for b and f .

For our experimental data for different samples the values after third approximations are as follows:

	b	f	k
Softwood	4.81	0.113	0.111
Hardwood	4.98	0.1	0.14
Bagasse	5.23	0.157	0.144
M.M.Bagasse	8.175	0.04	0.114

4.2.2. Determination of optical parameter:

Optical parameters are calculated as from the formulae as mentioned in section 2.5. Calculated values of print density, print through and optically covered area are given in the table - 4. Three graphs were plotted as follows.

Print density versus	x (fig-2)
Optically covered area versus	x (fig.-3.1 and fig. -3.2)
Print through versus	x (fig.-4)

4.3 DISCUSSION :

4.3.1 Visual observations:

The ultimate measurement and evaluation of print quality is visual appearance of a printed strips visual observations are as such.

Appearance	Hardwood & Baggase > Softwood > M.M.Bagasse
Print Uniformity	Hardwood >Bagasse > Softwood > M.M.Bagasse
Glossy Print Surface	Softwood > Bagasse > Hardwood > M.M.Bagasse

Hardwood and bagasse sheets show best print appearnace. Softwood shows a inferier appearance. It may be due to surface smoothness of hardwood and bagasse is better to softwood. Print uniformity of hardwood and bagasse seems better, because of having smooth surface, physically covered area is better.

Although as far as glossyness of print surface is concerned softwood is superior because of its low porosity. Bagasse also being less porous gives better glossy print surface than hardwood and M.M.Bagasse.The oil present with the ink pigment has penetrated through the pores of paper surface of hardwood and M.M.Bagasse and leaves the print surface giving a dull appearance. Softwood sheets gives better pigment deposition and oil retention over its surface.

4.3.2 Ink Transfer

In our experiment, we have printed about nineteen to twenty strips for each sample, for decreasing values of x, i.e. the amount ink applied to the printing roll before printing.

For a value of x we have got a corresponding value of y, i.e. the amount of ink transferred to the paper for all samples. On plotting a graph between y versus x for different samples, the curves obtained are as shown in fig.-1. For medium and higher values of x the curves are straight, but at low values of x i.e. below 10 g/m2 , they deviates to the lower side of the straight lines, and approches to zero. These results match with the literature as reported by Walker and Festko.

If we compare the curves, it can be easily observed that for same value of x, minimum value of y, the amount of ink transferred to the paper is for softwood, and bagasse and M.M.bagasse shown the maximum ink transferred to the paper. Secondly both non wood samples show nearly equal ink transfer for same value of x. Hardwood lies between these two i.e. softwood and bagasse. So it seems that, the amount of ink transferred to the paper is a function of type of fiber.

The ink transfer constants b, f and k for these curves between y versus x for different samples are determined for the ink transfer equation proposed by Walker and Festko by the procedure given by Walker, are as mentioned below:

Ink transfer constants.	softwood	hardwood	bagasse	M.M.Bagasse
b	4.81	4.98	5.23	8.175
f	0.113	0.1	0.157	0.04
k	0.111	0.14	0.144	0.114

Bagasse and mill made bagasse are showing maximum immobilization of ink into the paper surface. As hand made bagasse being less porous shows lower value for b as compared to mill made bagasse paper. Minimum immobilization is in softwood. So immobilization of ink into paper surface is also a function of pulp type.

k is definitely a smoothness dependent constant rough paper surface gives lower value of k and smooth surface gives higher values for k.

4.3.4 Optical Evaluation of Prints.:

There are three main optical parameter to evaluate the print quality as reported in literature they are,

(i) Print Density (ii) Optically Covered Area

(iii) Print Through

Print density is the contrast of the printed area with respect to unprinted Fig-2 shows the graph of print density against x for four samples. The nature of the curve for all samples shows that the print density increases with increase in x the amount of ink applied on the plate before printing and at medium and high values of x, print density becomes constant i.e. further increase in value of x will not effect the print density.

The fig.-2 shows that maximum print density is achieved in softwood i.e. 1.19 but rise in print density with x is quite lower, then hardwood and bagasse. Hardwood sheets show maximum rise in print density with x, though it comes on third position, when maximum P.density value is considered:

Sample No.	Max. P.D.Attained.
Softwood	1.19
Bagasse	1.15
Hardwood	1.125
M.M.B.	1.0

So, softwood, having largest fiber length shows best ink hold out, better ink pigment deposition over its surface. Bagasse and hardwood are nearer but comes after softwood. As per table-5, the valaue of 1 for print density is achieved at 7.5 g/m^2 for hard wood and 8.5 g/m2 for bagasse where as for softwood very high values of x are required and also the ink transferred to the paper is minimum for hardwood. So the ink requirement to obtain a value of one for print density is minimum of hardwood. Similar is the case at print density = 0.5.

Optically covered area :

Optically covered area, as a parameter for measuring print quality was introduced by Larsson and Sunner Berg (5). In our experiment softwood sheets shows maximum values of optically covered area (A) then comes bagasse and hardwood. The graph plotted between A versus the amount of ink applied to the printing roll before printing (x) shown same nature as it is for print density versus x. The value of A for hardwood and bagasse become constant for very low values of x as compared to softwood and mill made bagasse. The maximum value A for different samples are mentioned below

Sample name	Maximum A
Softwood	0.98
Bagasse	0.965
Hardwood	0.952
M.M.Bagasse	0.944

Maximum value of A for soft wood is due to it morpholigical structure fibers, which provides it better print evenness. Under the dynamic printing load softwood is providing larger paper surface in contact with ink film as compared to others. The value of A becomes constant for very high values of x for softwood, it is due to it high surface roughness as measured by Parker print surf smoothness tester. Hardwood and bagasse are having more smoother surface gives constant A at very low values of X. The M.M. bagasse having short fibers and high surface roughness than bagasse and hardwood shown lowest rise in A value with x and also the constant value of A is lowest for it.

Larsson and sunnberg has also developed an model for calculating A for a unprinted paper, if its Bendtson Smoothness and Scattering coefficient value are known, it is as follows:

For felt side of paper (smooth side)

$$A = 0.99 - 0.0100G - 0.898S$$

for wire side of paper (rough side)

$$A = 0.968 - 0.128G - 0.345S$$

248018.

Where A is expressed as fraction, G roughness in $(ml/min)^{1/3}$ and S, scattering coefficient in m^2/g.

The numerical value of G is approximately 100 times of S, i.e. the influence of roughness is stronger than the scattering coefficient of the paper. Less, but scattering coefficient of paper affects the area optically covered in print quality evaluation. For higher value of S, the optically covered area will be low. As table - 1 shows that scattering coefficient of softwood sheets it very less as compared to others and it shows maximum value of A. Hardwood has highest scattering coefficient and after it is M.M.Bagasse though also hardwood shows higher optically covered area, it is due to roughness factor. Hardwood being more smoother than M.M.Bagasse gives better surface coverage by ink pigment.

Print Through :

Fig-4. indicates that maximum print through is for softwood and lowest for hardwood. Bagasse and M.M.Bagasse are in between. It is all due of the opacity variation of paper sheet of four sample. So print through is inversely proportional to the opacity of the paper sheet.

Table 1 : Physical and optical properties of prepared and selected papers.

SAMPLES/ PROPERTIES	SOFTWOOD	HARDWOOD	BAGASSE	M.M. Bagasse
GRAMMAGE (g/m)	76.3	78.4	83.2	80.0
CALIPER(µm)	124	124	123	109
APPARENT DENSITY(g/cm)	0.615	0.632	0.676	0.733
BULK(cm /g)	1.63	1.58	1.48	1.36
SOLID FRACTION	0.41	0.42	0.45	0.48
COBB No.	24	17	11	11
BENDTSEN SMOOTHNESS (ml/min.)	495.7	70.5	67.1	302.5
PARKER PRINT SURF ROUGHNESS (µm) 5*	>6	3.45	4.2	>6
10*	6	3.5	3.86	4.93
20*	6	2.89	3.45	4.25
PARKER PRINT SURF POROSITY (ml/min.)	32.6	213	31.7	369.5
GLOSS	17.62	16.24	25.6	8.6
BRIGHTNESS	67.54	73.1	72.16	84.84
Ro	60.4	74.94	72.2	71.26
R∞	73.52	79.26	80.6	77.2
SPECIFIC SCATTERING COEFFICIENT S (m /g)	0.043	0.0629	0.0592	0.0539
OPACITY	82.15	94.55	89.6	92.2

* Parker print surf tester measures roughness at three clamp pressures (5, 10, 20 kgf/cm^2)

Table 2 : Observation table for printing on IGT tester.

Sample No.	a	b	c	X(g/m²)	Y (g/m²)
22A	269.7288	270.0164	269.9266	28.05826	8.760888
4A	269.7296	269.9412	269.8612	20.6437	7.8048
5A	269.7315	269.9088	269.8397	17.29739	6.741396
6A	269.733	269.8842	269.8247	14.75107	5.80482
7A	269.7328	269.864	269.8058	12.79987	5.677992
8A	269.7332	269.8439	269.7971	10.79989	4.565808
9A	269.7334	269.825	269.7858	8.936496	3.824352
10A	269.7336	269.8145	269.7821	7.892604	3.160944
11A	269.7338	269.8015	269.7758	6.604812	2.507292
12A	269.735	269.789	269.7716	5.26824	1.697544
13A	269.7347	269.7806	269.7674	4.478004	1.287792
14A	269.7332	269.7726	269.7625	3.843864	0.985356
15A	269.7332	269.7675	269.7602	3.346308	0.712188
16A	269.7331	269.7611	269.755	2.73168	0.595116
17A	269.7343	269.7569	269.753	2.204856	0.380484
18A	269.7341	269.7535	269.7504	1.892664	0.302436
19A	269.7338	269.7499	269.7481	1.570716	0.175608
20A	269.7343	269.7468	269.7454	1.2195	0.136584
25A	269.7134	269.7209	269.7205	0.7317	0.039024
19B	269.7148	269.9822	269.9104	26.08754	7.004808
1B	269.7196	269.9286	269.8694	20.39004	5.775552
2B	269.7157	269.9015	269.8472	18.12665	5.297508
3B	269.7168	269.8763	269.8305	15.56082	4.468248
4B	269.7184	269.8526	269.8128	13.09255	3.882888
5B	269.7179	269.8336	269.7983	11.28769	3.443868
6B	269.7182	269.8175	269.7864	9.687708	3.034116
7B	269.7183	269.8003	269.7774	7.99992	2.234124
8B	269.7189	269.7871	269.77	6.653592	1.668276
9B	269.7178	269.7783	269.7614	5.90238	1.648764
10B	269.7188	269.7693	269.7589	4.92678	1.014624
11B	269.7186	269.7607	269.75	4.107276	1.043892
12B	269.719	269.753	269.7463	3.31704	0.653652
13B	269.719	269.7483	269.7436	2.858508	0.458532
14B	269.7185	269.7436	269.7394	2.448756	0.409752
16B	269.7184	269.7397	269.7361	2.078028	0.351216
17B	269.7192	269.7364	269.7342	1.678032	0.214632
18B	269.7188	269.7339	269.7321	1.473156	0.175608
26B	269.7134	269.7209	269.7205	0.7317	0.039024
				CONTINUED...........	

Table 2 (Continued)

2C	269.716	269.9428	269.8672	22.12661	7.375536
3C	269.7159	269.9104	269.836	18.97542	7.258464
5C	269.7151	269.8804	269.8165	16.12667	6.234084
6C	269.7159	269.857	269.799	13.76572	5.65848
7C	269.7149	269.8359	269.7828	11.80476	5.180436
8C	269.7144	269.8176	269.7715	10.06819	4.497516
9C	269.7147	269.8021	269.7608	8.526744	4.029228
10C	269.7147	269.7873	269.7521	7.082856	3.434112
11C	269.7141	269.7753	269.7477	5.970672	2.692656
12C	269.7146	269.7651	269.7432	4.92678	2.136564
13C	269.7138	269.7575	269.7404	4.263372	1.668276
14C	269.7151	269.7503	269.7375	3.434112	1.248768
15C	269.7149	269.744	269.7349	2.838996	0.887796
16C	269.7149	269.7397	269.7323	2.419488	0.721944
17C	269.715	269.7355	269.7296	1.99998	0.575604
18C	269.7132	269.7315	269.7272	1.785348	0.419508
19C	269.7053	269.7203	269.7174	1.4634	0.282924
25C	269.713	269.7176	269.7174	0.448776	0.019512
1D	269.7291	270.0804	269.9938	34.27283	8.448696
2D	269.7304	269.97	269.8985	23.37538	6.97554
3D	269.7308	269.9382	269.877	20.23394	5.970672
4D	269.7303	269.9084	269.8513	17.37544	5.570676
5D	269.73	269.8834	269.8267	14.9657	5.531652
6D	269.7304	269.861	269.811	12.74134	4.878
7D	269.7301	269.8397	269.7984	10.69258	4.029228
8D	269.7297	269.8235	269.7866	9.151128	3.599964
9D	269.7304	269.8093	269.7785	7.697484	3.004848
10D	269.7293	269.797	269.7712	6.604812	2.517048
11D	269.7286	269.7858	269.765	5.580432	2.029248
12D	269.7289	269.7766	269.7613	4.653612	1.492668
13D	269.7289	269.7688	269.757	3.892644	1.151208
14D	269.7305	269.7633	269.7542	3.199968	0.887796
15D	269.7292	269.7565	269.7501	2.663388	0.624384
16D	269.7295	269.7533	269.7477	2.321928	0.546336
17D	269.7286	269.7499	269.7457	2.078028	0.409752
18D	269.7284	269.7461	269.743	1.726812	0.302436
19D	269.7207	269.7356	269.7331	1.453644	0.2439
25D	269.7133	269.7187	269.7185	0.526824	0.019512

Table 3(a) Aptical observation table for reflectance of printed surface.

Sample no	RP1	Rp2	Rp3	Rp4	Rp5	Avg. Rp
A 22	6.55	9.97	9.42	6.5	6.24	7.736
A 4	7.74	7.14	6.67	9.64	10.66	8.37
A 5	7.6	12.32	9.49	7.26	8.56	9.046
A 6	8.03	11.68	11.29	14.13	15.94	12.214
A 7	9.9	9.08	8.26	6.52	6.43	8.038
A 8	11.4	15.6	16.4	13.1	10.3	13.36
A 9	13.3	12.6	8.71	10.5	10.8	11.182
A 10	11.8	16.7	17.8	20.9	19.9	17.42
A 11	13.3	19.6	22.3	15.7	13.2	16.82
A 12	15.9	22.6	22.7	30	29.4	24.12
A 13	21.3	31	28.5	23	24.4	25.64
A 14	27.8	26.3	23.9	32.7	34	28.94
A 15	29.3	38.1	31.6	29.1	29.1	31.44
A 16	31.9	27.6	32.7	35.5	39.9	33.52
A 17	43.7	40.8	39.6	42.7	39.6	41.28
A 18	44.5	47.1	42.3	48.2	49.4	46.3
A 19	47	46.4	48.4	49.4	45.3	47.3
A 20	51.1	50	51.8	52.5	49.6	51
A 25	64.5	65.9	66.1	62.9	62.9	64.46
B 19	4.5	5.2	5.8	3.9	3.8	4.64
B 1	4.1	5.4	6.9	4.5	4.2	5.02
B 2	5.3	6	6	5	4.7	5.4
B 3	7.3	8.1	8.3	6.3	5.3	7.06
B 4	8.6	9	9.6	6.7	5.6	7.9
B 5	7	9.4	12.7	7.5	6.7	8.66
B 6	11.4	8.4	11.6	6.1	7.1	8.92
B 7	12.9	11.7	14.7	16.8	11.6	13.54
B 8	16.1	15.3	17.5	14.5	13.4	15.36
B 9	20.6	17.3	21.9	16	17.1	18.58
B 10	19.9	18.2	21.5	21.8	20.3	20.34
B 11	13.4	14.1	18.4	22.5	18.4	17.36
B 12	17	22.7	24.1	31.5	34.4	25.94
B 13	33.9	29.7	28.7	28.8	28.3	29.88
B 14	27.3	28.8	27.5	22.1	22.9	25.72
B 16	28.5	30.2	30.1	24.9	27.3	28.2
B 17	39.6	39.2	46.6	37.8	38.5	40.34
B 18	34.8	33.7	32.3	30.7	28.5	32
B 26	52	53.4	55.4	55.7	54.3	54.16
C 2	5.6	5.6	7.3	6.1	5.5	6.02
C 3	6.6	6.1	6.8	5.7	5.5	6.14
C 5	5.7	7.2	6.4	6	5.9	6.24
C 6	6.1	6.9	6.1	6.5	7.7	6.66

CONTINUED...

Table 3(a) Continued

C 7	5.9	7.6	9	6.3	6.3	7.02
C 8	8.5	7.8	8.4	6.2	6.4	7.46
C 9	6.2	7.4	7.9	7.4	7.2	7.22
C 10	6.8	6.9	6.9	6.8	7.4	6.96
C 11	8	8.4	9	7.5	7.2	8.02
C 12	9.2	8.7	9.9	9.2	9.2	9.24
C 13	10.3	11.4	12.6	10.4	9.2	10.78
C 14	13.6	13.8	15	13.7	12.5	13.72
C 15	17.7	18.6	17.7	14	13.2	16.24
C 16	20.8	20.4	20.2	20.9	19.4	20.34
C 17	24.1	24.6	27	22	22.5	24.04
C 18	28.8	28.2	27.7	26.4	25.9	27.4
C 19	34.4	33.8	34.2	34.9	33.2	34.1
C 25	51.3	48.9	49.8	51.3	50.8	50.42
C 26	61.6	61.7	66.2	64.8	63.3	63.52
D 1	3.7	5.5	5.2	13	9	7.28
D 2	4.9	7.8	5	5.8	4.5	5.6
D 3	4.7	8.2	9.5	6	6.4	6.96
D 4	6	6.1	7.9	4.3	6.1	6.08
D 5	6.2	6.6	6.3	5.2	5.7	6
D 6	6.1	6.5	6.1	5.3	5.1	5.82
D 7	6.8	5.9	8	7.1	6	6.76
D 8	6.7	7	8	6	7.2	6.98
D 9	8.3	6.6	7	6.7	6.8	7.08
D 10	9.3	11.2	10.1	10.1	9.9	10.12
D 11	11.5	14.7	12.4	11.7	11.3	12.32
D 12	12.7	12.6	14.9	15.3	13.6	13.82
D 13	15.3	19.1	18.6	13.8	13.3	16.02
D 14	17.1	18.3	17.1	18.9	18.9	18.06
D 15	23	21.6	25.7	25.2	23.7	23.84
D 16	28.9	29.8	30.5	22.2	22.4	26.76
D 17	33.1	30.3	33.7	25.1	27.3	29.9
D 18	30.7	32.3	32.9	31.6	29.6	31.42
D 19	38.6	37.3	38.3	37.6	40.1	38.38
D 25	61.1	61.7	66.2	64.8	63.3	63.42

Table 3(b) Optical observation table for reflectance of reverse side of print surface.

Sample no.	Rp′ I	Rp′ 2	Rp′ 3	Rp′ 4	Rp′ 5	ARp′
A 22	59.97	60.84	62.38	61.45	61.41	61.21
A 4	62.02	61.49	63.51	64.85	63.11	62.996
A 5	62.6	62.14	61.88	64.36	64.96	63.188
A 6	59.71	61.46	62.36	63.78	63.69	62.2
A 7	66.76	66.29	65.11	64.7	65.22	65.616
A 8	66.5	66.3	66	65.5	66	66.06
A 9	67.5	66.7	66.5	66.7	66.9	66.86
A 10	67.8	67.7	68	68.2	67.6	67.86
A 11	69.1	69.3	69.1	68.9	68.6	69
A 12	68.4	68.7	68.9	68.9	66.5	68.28
A 13	69.5	69.3	68.9	68.9	68.8	69.08
A 14	69.9	70.1	70.4	69.7	69.3	69.88
A 15	70	69.9	70.1	69.9	70.2	70.02
A 16	71	70.4	70.7	70.7	70.2	70.6
A 17	69.8	69.7	70.1	69.7	69.8	69.82
A 18	70.6	69.7	70.2	70.2	70	70.14
A 19	70.4	70.6	70.5	70.6	71.5	70.72
A 20	70.4	70.3	70.1	70.1	70	70.18
A 25	71.8	71.5	71.8	72.1	71.7	71.78
B 19	55.5	57.9	57.7	55.7	55.8	56.52
B 1	55.9	56.3	57.2	55.6	54.4	55.88
B 2	53	53.1	53.6	59	57.7	55.28
B 3	54.3	54.9	54.2	54.4	54.5	54.46
B 4	55.6	55.5	55.6	56.2	57.1	56
B 5	52.5	52.9	53.9	53.6	52.8	53.14
B 6	58.1	57.7	58.6	56.5	57.8	57.74
B 7	55.8	56.6	56.4	58.5	59.6	57.38
B 8	57	57.3	56.1	56.6	55.7	56.54
B 9	59.2	58.9	58.8	57.3	56.6	58.16
B 10	55.7	55.9	57	55.4	55.4	55.88
B 11	60	59.2	59.3	58.1	59	59.12
B 12	59.3	58.7	60.3	60.6	60.3	59.84
B 13	60.1	59.7	60.7	58.8	58.2	59.5
B 14	60.4	59	59.8	58.6	57.7	59.1
B 16	60.4	60.6	61.2	59.7	59.8	60.34
B 17	59.7	59.2	60.1	60.4	60.3	59.94
B 18	59.4	59.5	59.1	59	59.5	59.3
B 26	63.1	62.1	62.8	62.4	61.5	62.38
C 2	71.7	71.3	72.5	73.3	72.2	72.2
C 3	73.6	73.2	73.3	72.7	72.5	73.06
C 5	72.7	72.6	73.3	73.8	73.6	73.2
C 6	73.2	74.4	74.8	73.8	73.2	73.88

CONTINUED....

Table 3(b) Continued

C 7	73.7	73.5	74.1	73.5	73.1	73.58
C 8	73.8	73.9	73.4	73.9	73.7	73.74
C 9	73.6	73.8	74.2	73.6	73.1	73.66
C 10	73.7	74.1	74.1	74	73.5	73.88
C 11	75.2	75.3	75.3	74.2	74.1	74.82
C 12	74.9	74.8	74.9	75.3	75	74.98
C 13	75.1	75.1	75.2	75.6	75.5	75.3
C 14	74.6	75	74.9	75.1	74.6	74.84
C 15	75.4	75.1	75	74.2	74	74.74
C 16	74.9	75	75.1	75	74.8	74.96
C 17	75.1	74.9	74.6	75.7	75.4	75.14
C 18	74.2	74.2	74.3	74.2	74	74.18
C 19	74.1	74.9	74.9	74.7	74.1	74.54
C 25	68.8	68.3	68.3	68.7	72	69.22
C 26	74.3	73.8	73	73.6	73.4	73.62
D 1	70	70.3	70.5	69.6	68.5	69.78
D 2	69.5	70	70.8	70.5	70.3	70.22
D 3	67.8	68.1	66	65.3	65.6	66.56
D 4	68.2	68.5	69	64.8	64.6	67.02
D 5	69.6	70.1	70.1	68.5	69.4	69.54
D 6	70.4	69.8	69.2	70.1	70.1	69.92
D 7	69	68.7	68.9	69.2	68.9	68.94
D 8	68.6	68.2	68.3	69.3	68.8	68.64
D 9	68.5	68.7	68.2	69.7	68.8	68.78
D 10	68.2	69	69	68.8	69.2	68.84
D 11	71.3	71.5	70.4	69.9	69.3	70.48
D 12	71.4	71.1	70.1	70.1	69.3	70.4
D 13	70.5	71.1	71	69.7	69.4	70.34
D 14	68.9	69.2	69.6	71	71.2	69.98
D 15	70.9	70.8	71.3	71.6	72.2	71.36
D 16	72.3	72.2	71.9	70.3	69.5	71.24
D 17	72.8	73	72.9	71.6	71.4	72.34
D 18	72.2	72.1	72.1	72.3	71.7	72.08
D 19	71.6	71.5	71.2	69.6	69.5	70.68
D 25	74.3	73.8	73	73.6	73.4	73.62

Table 4 : Print density, Print through, optically covered area corresponding to their sample.

S.No	A.Rp	A.Rp'	PD	Rx	PT	ST	PT-ST	A
A 22	7.736	61.21	1	75.3	0.08997	0.08999	-2E-05	0.945
A 4	8.37	63	0.965	75.3	0.07748	0.0775	-2E-05	0.937
A 5	9.046	63.19	0.932	75.3	0.07616	0.07617	-1E-05	0.927
A 6	12.21	62.2	0.801	75.3	0.083	0.08301	-4E-06	0.884
A 7	8.038	65.62	0.983	75.3	0.05979	0.0598	-2E-05	0.941
A 8	13.36	66.06	0.762	75.3	0.05686	0.05686	-1E-06	0.869
A 9	11.18	66.86	0.84	75.3	0.05163	0.05163	-6E-06	0.898
A 10	17.42	67.86	0.647	75.3	0.04518	0.04518	4E-06	0.814
A 11	16.82	69	0.662	75.3	0.03795	0.03794	4E-06	0.822
A 12	24.12	68.28	0.506	75.3	0.0425	0.04249	1E-05	0.722
A 13	25.64	69.08	0.479	75.3	0.03744	0.03743	1E-05	0.702
A 14	28.94	69.88	0.427	75.3	0.03244	0.03243	1E-05	0.657
A 15	31.44	70.02	0.391	75.3	0.03157	0.03156	1E-05	0.623
A 16	33.52	70.6	0.363	75.3	0.02799	0.02798	1E-05	0.595
A 17	41.28	69.82	0.272	75.3	0.03282	0.0328	2E-05	0.489
A 18	46.3	70.14	0.222	75.3	0.03083	0.03081	2E-05	0.421
A 19	47.3	70.72	0.213	75.3	0.02725	0.02724	2E-05	0.407
A 20	51	70.18	0.18	75.3	0.03058	0.03056	2E-05	0.357
A25	64.46	71.75	0.079	75.3	0.02097	0.02095	2E-05	0.174
B 19	4.64	56.52	1.2	72.54	0.10814	0.10836	-2E-04	0.98
B 1	5.02	55.88	1.166	72.53	0.11308	0.11328	-2E-04	0.974
B 2	5.4	55.28	1.134	72.53	0.11777	0.11795	-2E-04	0.969
B 3	7.06	54.46	1.018	72.52	0.12426	0.12439	-1E-04	0.945
B 4	7.9	56	0.969	72.52	0.11215	0.11226	-1E-04	0.933
B 5	8.66	53.14	0.929	72.52	0.13492	0.13502	-1E-04	0.922
B 6	8.92	57.74	0.916	72.52	0.09886	0.09896	-1E-04	0.919
B 7	13.54	57.38	0.735	72.51	0.10158	0.10163	-5E-05	0.853
B 8	15.36	56.54	0.68	72.51	0.10798	0.10802	-4E-05	0.827
B 9	18.58	58.16	0.597	72.5	0.09571	0.09574	-3E-05	0.781
B 10	20.34	55.88	0.558	72.5	0.11308	0.1131	-2E-05	0.756
B 11	17.36	59.12	0.627	72.5	0.0886	0.08863	-3E-05	0.799
B 12	25.94	59.84	0.452	72.5	0.08335	0.08335	-7E-06	0.677
B 13	29.88	59.5	0.391	72.5	0.08582	0.08582	-9E-07	0.621
B 14	25.72	59.1	0.456	72.5	0.08875	0.08876	-7E-06	0.68
B 16	28.2	60.34	0.416	72.5	0.07973	0.07974	-3E-06	0.644
B 17	40.34	59.94	0.261	72.5	0.08262	0.08261	1E-05	0.472
B 18	32	59.3	0.361	72.5	0.08728	0.08728	2E-06	0.59
B26	54.16	62.38	0.133	72.5	0.06529	0.06528	2E-05	0.275
C 2	6.02	72.2	1.127	78.81	0.03799	0.03802	-3E-05	0.952
C 3	6.14	73.06	1.118	78.81	0.03285	0.03287	-3E-05	0.95
C 5	6.24	73.2	1.111	78.8	0.03202	0.03204	-3E-05	0.949

CONTINUED...

Table 4 (Continued)

C 6	6.66	73.88	1.083	78.8	0.028	0.02802	-2E-05	0.943
C 7	7.02	73.58	1.06	78.8	0.02977	0.02979	-2E-05	0.939
C 8	7.46	73.74	1.034	78.8	0.02882	0.02884	-2E-05	0.933
C 9	7.22	73.66	1.048	78.8	0.02929	0.02932	-2E-05	0.936
C 10	6.96	73.88	1.064	78.8	0.028	0.02802	-2E-05	0.939
C 11	8.02	74.82	1.002	78.8	0.02251	0.02253	-2E-05	0.926
C 12	9.24	74.98	0.941	78.8	0.02158	0.02159	-1E-05	0.91
C 13	10.78	75.3	0.874	78.8	0.01973	0.01974	-8E-06	0.89
C 14	13.72	74.84	0.769	78.8	0.02239	0.02239	-2E-06	0.852
C 15	16.24	74.74	0.696	78.8	0.02297	0.02297	1E-06	0.819
C 16	20.34	74.96	0.598	78.8	0.0217	0.02169	4E-06	0.766
C 17	24.04	75.14	0.525	78.8	0.02066	0.02065	7E-06	0.718
C 18	27.4	74.18	0.469	78.8	0.02624	0.02623	8E-06	0.674
C 19	34.1	74.54	0.374	78.8	0.02414	0.02413	1E-05	0.587
C 25	60.56	76.8	0.124	78.8	0.01116	0.01115	1E-05	0.243
D 1	7.28	69.78	1.037	78.91	0.05582	0.0534	0.002	0.944
D 2	5.6	70.22	1.151	78.91	0.05309	0.05069	0.002	0.965
D 3	6.96	66.56	1.056	78.91	0.07633	0.07392	0.002	0.948
D 4	6.08	67.02	1.115	78.91	0.07334	0.07094	0.002	0.959
D 5	6	69.54	1.121	78.91	0.05731	0.05491	0.002	0.96
D 6	5.82	69.92	1.134	78.91	0.05495	0.05254	0.002	0.962
D 7	6.76	68.94	1.069	78.91	0.06108	0.05866	0.002	0.95
D 8	6.98	68.64	1.055	78.91	0.06297	0.06055	0.002	0.947
D 9	7.08	68.78	1.049	78.91	0.06208	0.05967	0.002	0.946
D 10	10.12	68.84	0.894	78.91	0.06171	0.05927	0.002	0.907
D 11	12.32	70.48	0.808	78.9	0.05148	0.04903	0.002	0.879
D 12	13.82	70.4	0.759	78.9	0.05197	0.04952	0.002	0.859
D 13	16.02	70.34	0.694	78.9	0.05234	0.04989	0.002	0.831
D 14	18.06	69.98	0.642	78.9	0.05457	0.05211	0.002	0.805
D 15	23.84	71.36	0.522	78.9	0.04609	0.04362	0.002	0.731
D 16	26.76	71.24	0.472	78.9	0.04682	0.04435	0.002	0.693
D 17	29.9	72.34	0.423	78.9	0.04017	0.03769	0.002	0.653
D 18	31.42	72.08	0.402	78.9	0.04173	0.03926	0.002	0.633
D 19	38.38	70.68	0.315	78.9	0.05025	0.04777	0.002	0.543
D 25	52.05	69.22	0.183	78.9	0.05932	0.05683	0.002	0.367
D 26	63.52	73.62	0.096	78.9	0.03255	0.03007	0.002	0.22

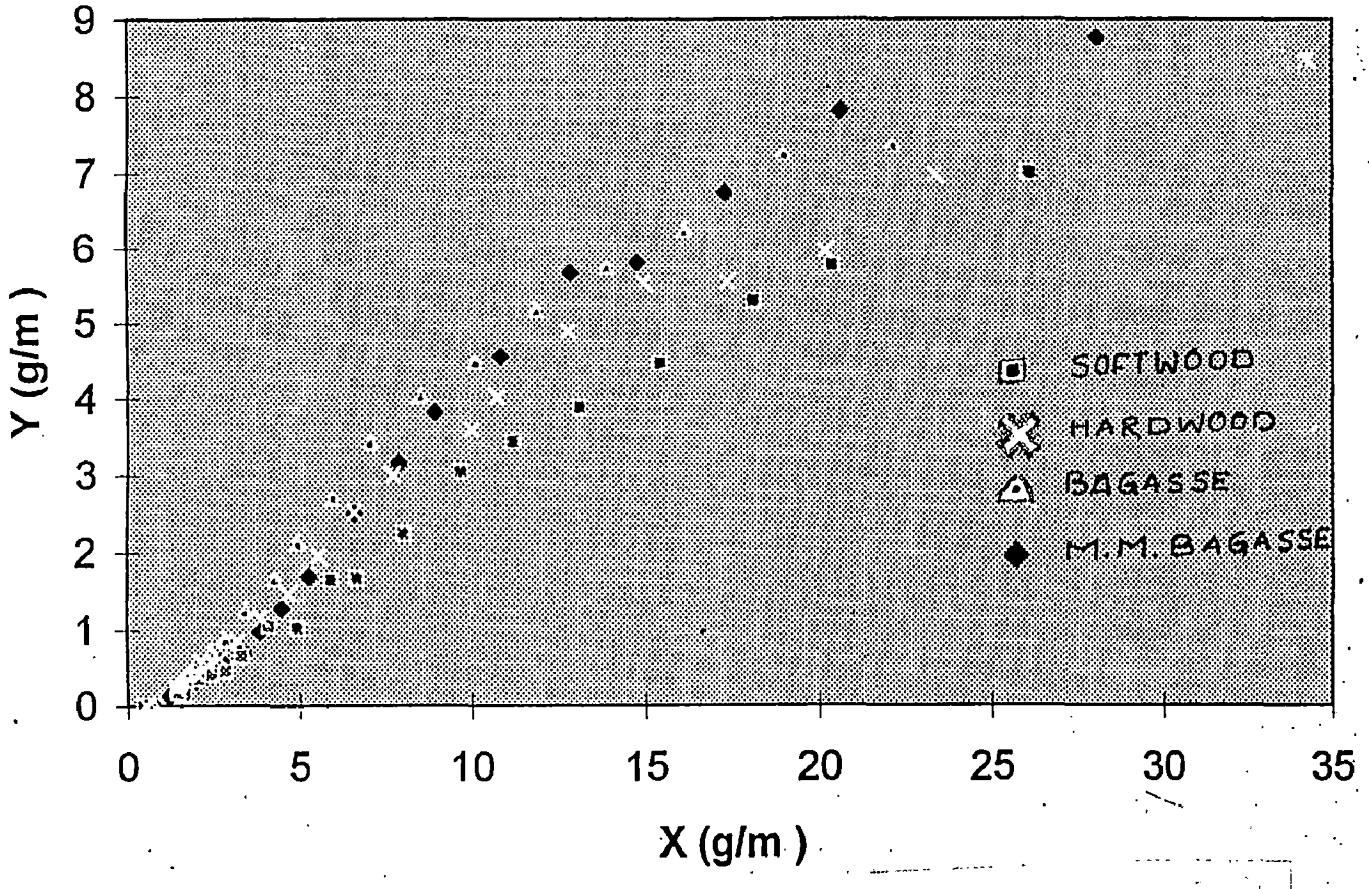

Figure 1 : Ink transferred to the paper (y) versus ink originally on the printing roll (x).

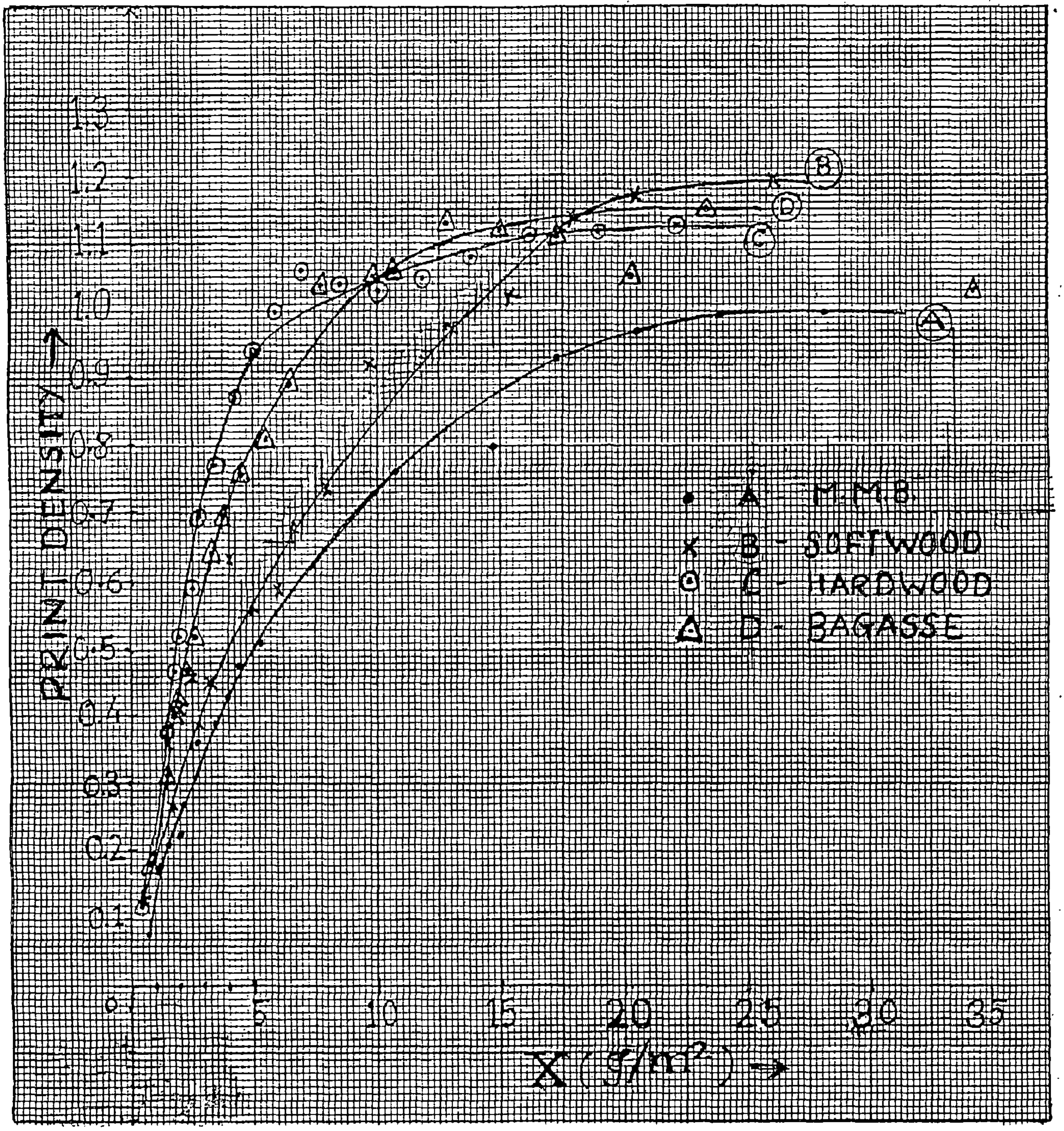

Fig.2 : Print density (PD) versus ink originally on the roll (x).

Fig. 3 Optically covered area versus ink originally on the printing.

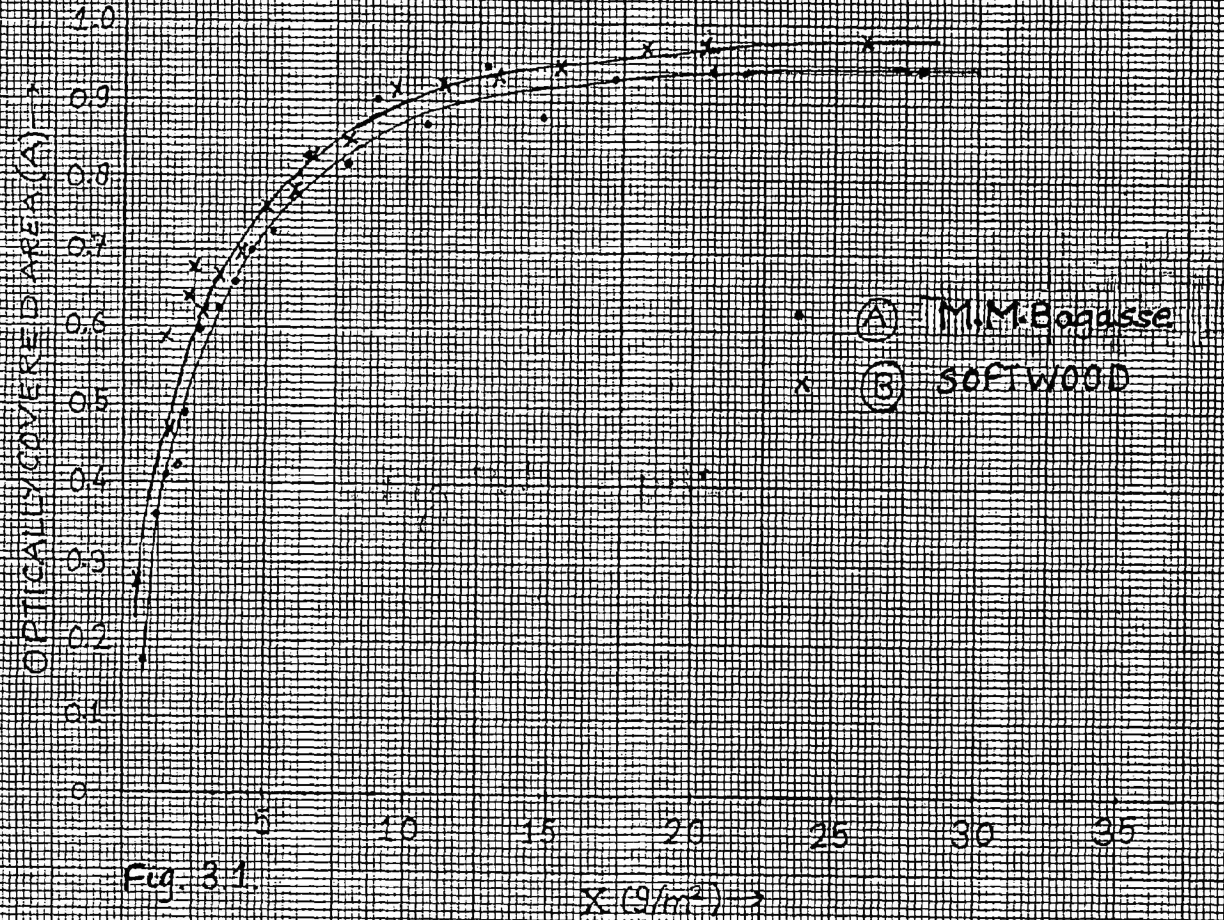

Fig. 3.1.

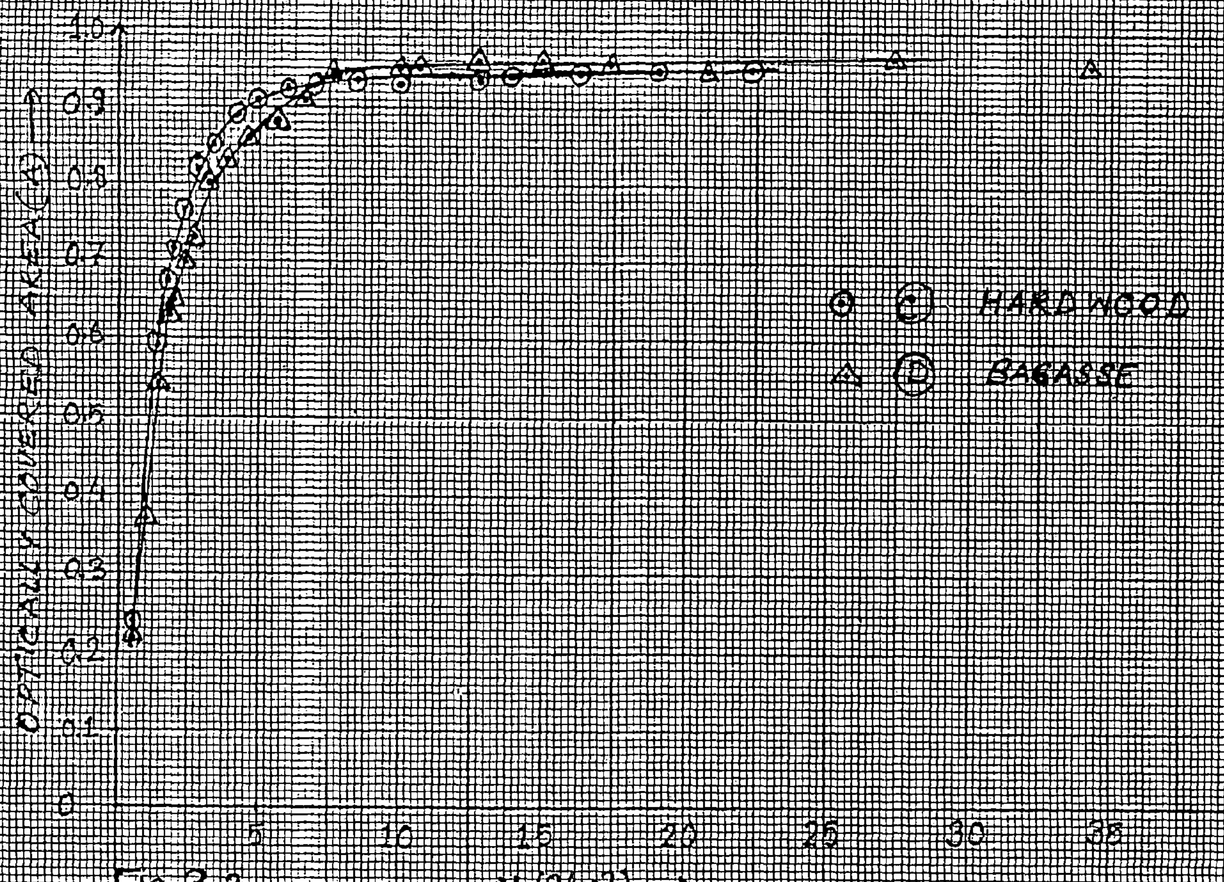

Fig. 3.2.

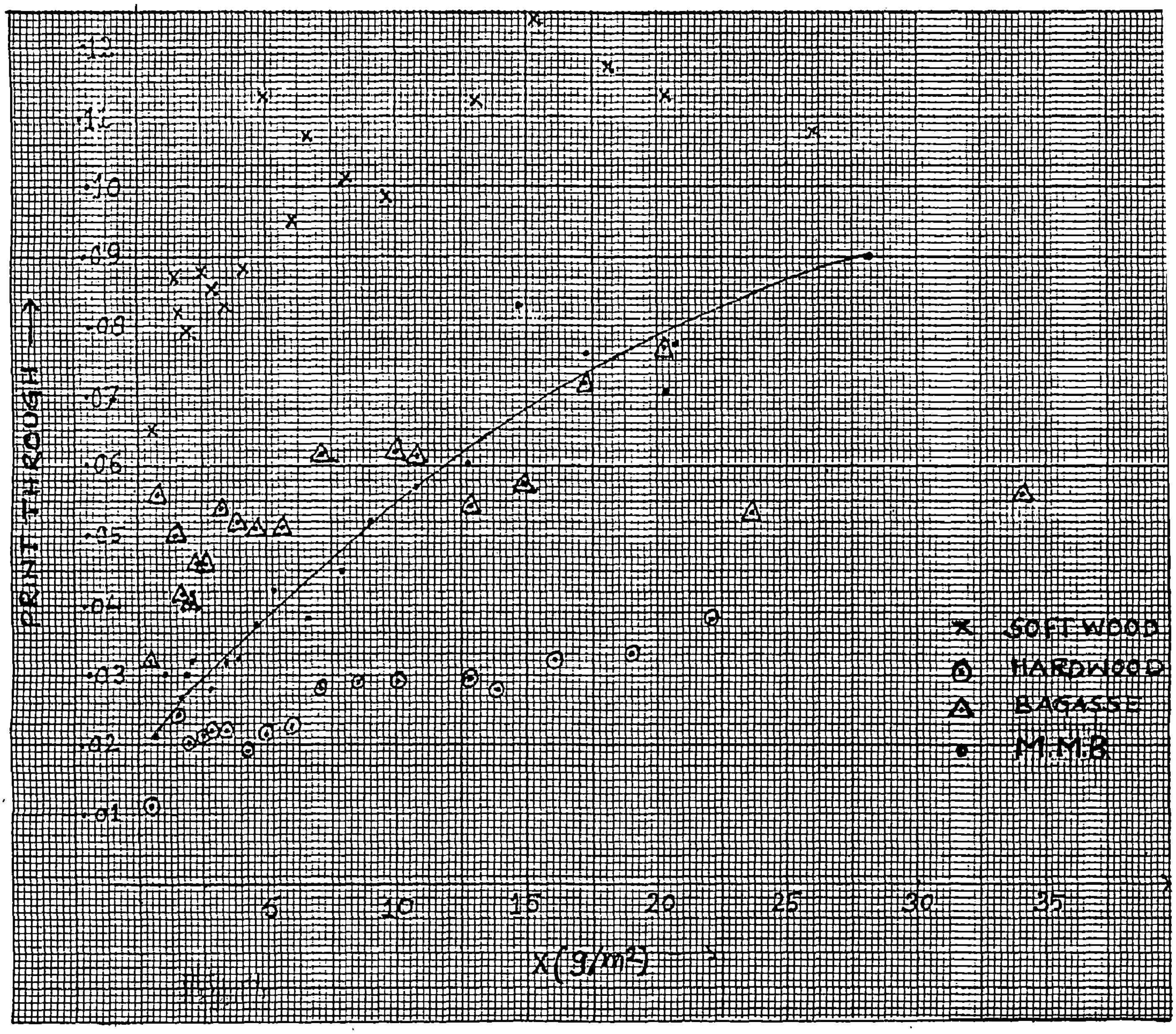

Fig.4 : Print through versus ink originally on the printing roll.

Table 5 : Comparision for ink requirement at same print density and optically covered area of different samples.

SL.No.	SAMPLE NAME	FOR PD=1			FOR PD=0.5			FOR A=0.95			FOR A=0.5		
		X	Y	A	X	Y	A	X	Y	PD	X	Y	PD
1.	SOFTWOOD	14	4.1	0.94	4.0	0.7	0.7	16	4.6	1.07	1.75	0.2	0.29
2.	HARDWOOD	7.5	2.9	0.93	1.75	0.3	0.7	15	5	1.1	1.125	0.15	0.29
3.	BAGASSE	8.5	4.0	0.95	2.25	0.7	0.7	8.0	3.9	0.98	1.38	0.3	0.29
4.	M.M.B.	24	9.0	0.94	5.0	1.5	0.72	27.5	10.3	1.0	2.125	0.35	0.27

CHAPTER 5

5. CONCLUSION :

The results obtained under this experimental work concludes that the printability of the paper also depends upon the type of pulp used for making paper. Bagasse and Hardwood show better ink coverage on printed area even for lower amount of ink applied to the print plate. Because bagasse and hardwood being short fiber pulp give better surface smoothness. But as bonding between the fibers is not as strong as that in softwood gives porous structure. The oil present in the offset printing ink penetrates through these voids and leaves, a dull print surface. Bagasse and hardwood both give high immobilization of ink in to the paper surface.

Smoothness itself does not control the ink transfer to the paper surface, it is also a function of pulp type by which the paper is produced. Softwood papers accept lowest amount of ink from the printing plate.

Print through is directly related to the opacity factor, higher will be the opacity lower will be the print through. Soft wood being less opaque gives high print through. Hardwood shows greater opacity values, creates less print through problems.

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