STUDY OF SURFACE STRUCTURE OF INDIAN PRINTING 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

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CANDIDATE'S DECLARATION

I hereby declare that the work, which is being presented in this dissertation entitled **"STUDY OF SURFACE STRUCTURE OF INDIAN PRINTING PAPERS"** in partial fulfillment of the requirements for the award of the degree of **Master of Engineering** submitted at the Institute of Paper Technology (University of Roorkee) Saharanpur, is an authentic record of my own work carried out during the period from Aug. 1995 to March 1996 under the supervision of Dr. S.P. Singh, Reader, 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.

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

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ABSTRACT

Printing is the most fundamental end use of paper. During printing process there are number of variables affecting the printability of paper like type of paper, type of ink, type of printing process and condition of press. The behaviour of paper in a printing process is of prime concern to the paper maker. Although large number of paper properties control the runnability and printability of paper, the Smoothness of paper surface plays a vital role for good print quality. In the present study, the surface patterns of different papers are studied by actual printing of paper by partial coverage area method. A brief review of the relevant literature is presented in Chapter 2. The description of the experimental set up and experimental procedure are given in Chapter - 3. The results of the present study and a discussion on the results is presented in Chapter 4. A number of ways to characterize 8 grades of printing papers have been attempted and the values of various parameters are reported. The important conclusion of the study and recommendation for future work are given in Chapter 5.

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INTRODUCTION

1.1 General

Printing is the most fundamental end use of Paper. The primary interest of printer is to make a true reproduction on paper surface of original image given to him and to do so economically. In any printing job, the type of paper, the type of ink, the type of printing process, and the physical conditions of the press are all important for good result. For good printing grade, the structural, mechanical, optical and sizing properties of paper must be carefully balanced.

Smoothness is the most important property of paper and paper board affecting printability. In a printing process a printing forme bearing a thin layer of ink on its image portions is pressed against the paper surface for a few milliseconds. When the forme is separated from the paper, the ink transfers to paper and a print is created. The smoothness of paper surface controls the ease and uniformity with which ink transfers to the paper and thus determines final print quality. It determines how well the paper surface contacts the ink film making printing possible with low ink quantity and low pressure. The smoothness in which the printer is interested is not the smoothness of paper under normal unstressed conditions but rather the smoothness of paper under pressure of printing forme, this is called printing smoothness.

There are several laboratory instruments for measuring the smoothness. The methods are broadly classified as (i) Air leak methods (ii) Optical methods (iii) Methods based on actual test printing and liquid film application (iv) surface profilometry. These methods have been reviewed by Singh [12].

1.2 Objectives of present study

The main objective of present work is to characterize different paper surfaces, using a method based on test printing. The samples were printed in an IGT printability tester with small amount of ink on smooth metallic printing disc and at low printing pressure to allow only a partial coverage of paper surface by ink. In this type of printing the peaks in paper surface receive more ink and deeper valleys remain unprinted. These black and white patterns show the contour structure of paper surface for visual assessment. These patterns can also be used for instrumental evaluation, a number of ways to describe the paper surface quantitatively on the basis of reflectance studies are presented.

CHAPTER - 2

LITERATURE SURVEY

Most laboratory smoothness measuring methods differ from actual printing conditions. The important differences are

(i) Printing occurs under dynamic forces. The forces involved vary considerably for various printing processes, being largest in letter press and decreasing in gravure and offset processes. The duration varies between 1/25 and 1/50 sec.

(ii) The paper surface required to contact with a flexible ink film on printing forme rather than a hard surface.

(iii) The entire paper surface should achieve contact a flexible ink film on the forme. Methods giving average values may often not give enough weight to the surface defects in paper which are determinental to its printability. Poor prints are obtained of defective positions not withstanding what the average values an obviously, the evaluation of paper surface smoothness should be more relevant from printability view point if it based on method in which the paper is actually printed under conditions similar to those encountered in real printing. A number of studies have been reported in the literature. In most of these methods the paper is printed on a laboratory printability tester under controlled conditions of ink film thickness, pressure and speed of printing, a series being printed with increasing amount of ink on the printing forme. A number of ways have been reported to analyse these data.

2.1 Minimum Ink Demand for Complete Coverage

When the paper is printed with small amount of ink, the paper surface does not establish complete contact with the ink layer on printing forme. The ink from the forme is transferred to those portions of paper which make contact and results in discontinuous print on the paper. As amount of ink is increased on the forme, more and more of paper receives ink during printing. The minimum amount of ink required to give continuous coverage is reported to good measure of printing smoothness but the point at which this occurred was subjectively (Fetsko, 1958[1]; Luey 1959[2], Tricet, 1973[3], Broadway, 1979[4]).

Luey [1959][2] studied the letter press printability of box board using vandercook proof press model number 4. He used a step wedge printing plate which carried an ink layer of varying thickness from one end to the other.

An important observation was that the results were affected by the impression i.e. the excess of board plus packing over nip gap, because this affected the effective printing pressure. The method is therefore not pure measure of roughness compressibility, but it may give valuable information concerning the effective surface roughness in this type of press.

Trice et al [1973] [3] used the same method as that of Luey [2] but stressed for need for rigid control of printing variables. Besides controlling the type of ink, printing speed, and ink film thickness they pointed out that a printing pressure rather than the printing impression should be standardized since the pressure impression relationship is altered by compressibility of packing of paper. The values of printing smoothness have been reported to vary from about 3 μm for a very smooth coated paper to about 15 μm for medium density coarse paper.

Since the term "ink film thickness" is not relevant in gravure printing, the number of dots per square inch which do not transfer from half tone with screen ruling of 100 lines/inch has been found to be good roughness index (Broadway, 1979).

The Helio test attachment to the IGT printability tester is based on SIMILER concept but uses an engraved cylinder with progressively increasing cell depth. This method can however be tedious and time consuming.

George [1976] [5] developed a gravure print smoothness tester to count the missing dots. The method involves scanning a printed tone area by means of a modified telephoto transmitter. The scanner output is converted to optical density and passed through band pass filter centered on dominant frequency of skip signals. When the scan passes over a skip. The reduction in density produces a signal at filter output. The number of signal pulses gives an index number related to the coincidence of missing dots on print.

2.2 Coefficients in ink-transfer equation

From measurements of amount of ink transferred to the paper 'y'. Corresponding to the amount of ink on the forme of Walker and Fetsko [1955] [6] showed that the data could be expressed as

$$y = b + f(x-b)$$

where b = amount of ink immobilized by the paper.

f = fraction of non-immobilized ink which transfer to the paper (the value of f is close to 0.5)

For small values of x, when only partial coverage of surface occurs, the experimental values do not obey the above equation. The ink transfer equation was therefore modified by Walker and Fetsko to

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

The term $(1-e^{-kx})$ is postulated to represent the fractional area of paper surface which comes in contact with the ink film thickness 'x', on the forme and approaches unity with increase 'x'.

The constant k accounts for how quickly the ink covers the total surface with increasing ink film thickness on the forme represents the smoothness of paper. Karthunen (1970) pointed out the term $(1-e^{-kx})$ falls zero as x approaches zero even though there will be some contact between the surface and the forme due to applied pressure. He suggested that

Walker-Fetsko equation could be modified by replacing the term $(1-e^{-kx})$ with new term

$$A(x) = (1-e^{-kx}) A_0$$

Where A_0 represents the limiting value of A(x) as x approaches zero.

Both k and A_0 are characteristics of paper surface. A_0 represents the flattened fraction of the surface due to printing pressure.

2.3 Ink-Transfer Data as a Print Density Curve

Tollenaar et al (1966) [7] proposed that the ink transfer data could be expressed by equation

$$D = D_\infty (1-e^{-mx})$$

D = optical density

D_∞ = saturation density; the density approached by theoretical curves if the ink film thickness is increased infinitely

m = a constant for paper.

Tollenaar and Ernest (1962) [8] had found in earlier work that equation

$D = D_\infty (1-e^{-mx})$ fitted the experimental data better when amount of ink transferred to the paper, 'y', was used in equation in place of 'x'.

However for evaluation of surface roughness the amount on the printing disc is more relevant and equation is found to express the experimental data satisfactorily at the intermediate values of 'x' found under practical conditions.

The constant 'm', the density smoothness, is closely related to the printing smoothness 'k' introduced by Walker - Fetsko equation and the constant 'm' of equation of Tollenaar et al should be equal to if prints with partial coverage were true black and white images, i.e. if the printed portions were printed to saturation density. In practice, the 'm' values is some what lower than 'k' value. The value of m and D_∞ are characteristics of the paper if testing procedure is suitably standardized.

Tollenaar et al (1966) [7] suggested that the values of 'm' and D_∞ can be obtained reasonably accurately by test printing at only two ink film thickness such that $x_2 = 2x_1$ in which case

$$m = 1/x_1 \ln \left(\frac{D_2}{D_1} - 1 \right)$$

The optimum accuracy is obtained if x, is chosen such that

$$\frac{D_1}{D_2} = \frac{e}{e+1} = 0.73$$

This means that choice of x_1 is dependent on the roughness of paper. Tollenaar et al suggested that following values of x_1 could be taken as rough guide.

x_1 = 2.4 μm for medium quality of paper

x_1 = 3.2 μm for rough paper

x_1 = 1.6 μm for smooth paper

When comparison were made on four machine coated papers, the obtained value of m gave the same ranking as the visual examination. O'Neill (1959)[9] used an IGT printability tester to determine the printing smoothness of paper. The initial ink film thickness was kept below that which provides complete coverage of paper surface structure to accentuate the coverage difference. The different surface structures of papers show up clearly on those prints. The average optical density of these prints was determined by scanning the print by densitometer over 300 mm length. The diameter of illuminated area of print was 4 mm. The mean value of density on prints obtained under standardized conditions was found to be a good measure of printing smoothness. He found that the method had a power to discern differences in paper surfaces even when the chapman tester completely failed to show differences.

2.4 Distribution of Depression in Paper Surface

Hsu (1962, [10],1963) [11] developed an elegant technique to derive expressions for the distribution of depressions in paper surface using information obtained from printing experiments.

When a printing forme bearing an ink layer of thickness 'x' is pressed against the paper surface, the ink layer will seek to conform to the shape of surface and the area A to which ink is transferred provides information about distribution of depressions.

Hsu postulated that depth was given by

$$\delta = \int_{0}^{x} \frac{dx}{1-A}$$

and the distribution function by

$$\phi(\delta) = \frac{1}{1-A} \frac{dA}{dx}$$

This was valid for a flat bed printing, but slightly different expression was obtained for the case of printing under rolling pressure, where lateral flow of ink is possible. In this case $\delta = x$ and $\phi(\delta) = \phi(x) = \frac{dA}{dx}$. The distribution curve passes through a maximum and corresponding value of δ represents the depth of the most frequently occurring depression and may be taken as an index of surface roughness. It is not necessarily equal to commonly used mean depth which is given by $\int_0^\infty \delta(\phi)\ (\delta)\ d\delta$.

For papers the mean depth is usually greater than the depth of most frequently occurring depression.

To determine the distribution curve, the area covered by ink on each print has to be determined. Hsu suggested that it could be determined (a) by planimetrically (b) by taking the ratio of masses of printed and non printed portions cut from as magnified photo graph of print or from reflectance measurements.

From studies of number of paper grades Hsu observed that frequency distribution may be assumed to be logarithmic normal type i.e. the gaussian function of the logarithmic normal type i.e. the Gaussian function of the logarithmic of δ.

The mean value of ln δ gives the values of x for 50% coverage i.e. $x_{0.5}$ at A = 0.5. In a printing operation under rolling pressure the frequency of occurrence of depression x in the surface measured from the printing forme is given by

$$\phi(x) = \frac{dA}{dx}$$

A = fraction of the surface covered by ink

x = thickness of ink on printing forme Hsu suggest that 'A' and x can be related by equation

$$\frac{A}{1-A} = k_H . x^n$$

where 'K_H' and 'n' are constants of given paper. Another interesting observations made by Hsu was that the frequency distribution of depressions in a paper surface is of the log normal type. He suggested that the size of most frequently occurring depressions could be measure of surface roughness.

Singh [12] has presented several methods of characterizing paper surface. Based on the approach of O'Niell & Hsu a method of partial coverage printing has been suggested. In this method paper is printed under condition of partial coverage (low printing pressure, and low ink on disc) and prints obtained evaluated using reflectance measurements and image analyser.

In the present work an approach similar that of Singh was used. The prints were analysed using only reflectance measurements. Besides the measuring the coverage area it give parameters related to appearance of surface. The characterization of different paper are evaluated with both experimental and analytical studies.

EXPERIMENTAL SETUP

It consists of (i) IGT printability tester (ii) IGT inking unit (iii) Parker print surf (PPS tester) (iv) Technibrite reflectance tester. All strip printing is carried out with IGT printability tester with its accessories.

3.1 IGT Printability Tester (AIC-2-5)

This tester is developed version of earlier IGT version AI-3 and A2-3 series. In carrying out a test the strip is clamped to sector, the printing disc is pressed onto paper with an adjusted force and the sector is turned either with an increasing or constant speed. It can accommodate two printing discs for two colour printing and wet on wet printing. The system is flexible for variety of printing conditions, i.e. it work on three modes of speeds (i) constant uninterrupted speed (ii) constant interrupted speed (iii) Increasing speed.

(i) Constant Uninterrupted speed : The speed is continuously adjustable between 0.2 and 5.0 m/s. The interval, the time elapsing between two prints, on wet on wet printing and set off sets.

(ii) Constant Interrupted Speed : In this mode the rotation of sector is stopped halfway and continued after a pre set extra interval. The extra interval range is 0.2 to 9.9 sec.

(iii) Increasing speed :By the incorporation of special speed converter increasing speeds are available as well. In the increasing speed mode the speed is increasing proportionally with length of print.

IGT Inking Unit-AE : The IGT inking consists of two inking arrangements with common drive. This makes it possible to test two oils or inks simultaneously. The inking arrangement features a combination of two anodized aluminium cylinders and one rubber roll. The front cylinders have an oscillating motion of few centimeters in order to distribute the ink evenly over the surface.

PRINTING DISCS: A wide range of printing discs are available for use on the IGT printability tester. The aluminium discs are anodized and are available in two types (milled and smooth edges) in widths of 10,20,32, and 50 mm. Discs covered with a special offset blanket are available in addition to the offset printing discs.

3.2 Parker Print Surf Tester (PPS Tester)

It is used to measure the surface roughness of paper under high pressures comparable to actual printing pressure. It is widely used air leak instrument to correlate paper roughness and printability of paper. It consists of sensing head, which is circular consists of three concentric rings bonded together and designed so that the two narrow gaps between them may be connected to source of air to a flowmeter. The roughness of paper is sensed by the middle, which is 51 μm wide. The wide inner and outer annulie prevent air leakage from annular passage ways. There are two deformable backing are available. The hard backing, comprising polyster film covering litho blanket. The softer backing of standard litho blanket is used for testing new print, gravure and offset papers.

TECHNIBRITE MICRO TB-1C : This instrument is specifically intended for the measurement of diffuse reflectance of pulp, paper and related products including clay, pigments etc. This instrument employ an integrating sphere optical system as defined by ISO standard 2469. The upper portion of the technibrite micro TB-1C is refered to as optical console. The integrating sphere, lamps and all associated optical components are located in this housing. The optical system of Micro TB-1C is based on a large integrating aluminium sphere of 150 mm diameter which is coated with a high reflectance barium sulphate paint. Two quartz tungsten halogen lamps and respective projection lenses direct beams of light through the holes on each side the sphere wall. Multiple reflections from sphere wall produce a highly diffuse illumination of sample, which covers 34 mm dia opening located in the bottom of sphere. A spring loaded sample holder presses the sample against the flat bottom of the sphere. The light reflecting from sample in viewed by photo cell.

3.3 Printing Papers

During these experimentation we collected various types of papers from different mills and further classified them into three categories i.e. News prints,(NP) cultural papers (SSML, OSP, CW) and coated categories (art paper, coated cream wove). These papers physical properties are checked before experimentation. The physical properties are given in Table no.(1).

GRADES OF PAPER STUDIES

The papers of following grades were includes in this study.

NPH
NPM — News Prints
NPT

SSML Surface Sized Maplitho

OSP Speciality printing

CW Creamwove

CCW — Coated Papers
APB

PRINTING INK : During these experiments commercially available offset inks supplied by M/S 'United ink and Warnish Company Limited", Bombay were used.

3.4 Experimental Procedure :

A series of samples were printed in an IGT-AIC2-5 laboratory printing press. Polished aluminum discks were used for the printing. A rubber blanket was used as backing. The samples were printed at speed of 1.2 m/s with different amounts of ink on the disc and a with printing force of 200N on a strip of (56 mm) width. The amount of ink on the printing disc and amount of ink transferred to the paper were determined by weighing the disc before and after printing. The size of prints was 56x238 mm^2.

After printing the strips the prints were evaluated by the Technibrite reflectometer.

TECHNIBRITE REFLECTOMETER MEASUREMENTS

The reflectance factor of the prints was determined using technibrite reflectometer with FMY/c filler, each print being placed over a thick pad of unprinted paper. Average values were obtained for three independent measurements on circular fields with diameter of 30 mm. The area of printed region was then determined by assuming that reflectance factor was the mean value of reflectance factors of full-tone print and of unprinted paper weighted in proportion to the area of printed and unprinted regions, according to expression.

$$R = AR_p + (1-A)\, R_\infty \qquad (3.1)$$

$$A = \frac{R_\infty - R}{R_\infty - R_p}$$

Where R = Reflectance of printed strip backed by a thick pad of unprinted paper.

R_{∞} = Intrinsic reflectance of paper

R_p = Reflectance of thick layer of ink on paper

A = Fraction of paper surface covered by ink

The value of R_p has been assumed to be equal to 2% for all the papers. Strictly speaking this value is paper dependent and should be measured experimentally for each paper but the differences are small and under conditions of partial coverage the error caused in the calculation of area of coverage is reported to be of the order of 2-3% [12]. The difference is much less than the internal variations in the prints.

RESULTS AND DISCUSSION

4.1 Visual Observations of the Prints

Different grades of paper printed by partial coverage printing methods. The differences in the surface structure of various papers are clearly visible on these prints. For example the prints on two coated papers indicate a much more uniform surface texture than on uncoated papers. Among the uncoated paper studied, the print on creamwove paper presents the most motted appearance. The visual appearance of these prints also seem to be dependent on the formation of the sheet.

During printing of strips a printing force of 200 N and at a printing speed of 1.2 m/s. The strips having nearly 50 percent of the paper surface covered by the ink were chosen for comparison. It was observed that the differences in surface structure of various papers were clearly shown even at other printing conditions.

4.2 Relationship between Coverage Areas and Ink on Forme

On a newsprint sample, NPH, for different amounts of ink on the printing forme, x. For smaller values of x, the fraction of the paper surface covered by the small, and large portions of unprinted surface appear in the print. As the value of x is increased, the area covered by the ink also increases and the paper attains a higher print density.

The fractional area covered by the ink, A was determined for each strip using the reflectance measurements and Equation 3.1. Fig. (4.1, 4.2 and 4.3) show plots of A as a function of x for different grades of paper. As shown in these figures the fractional coverage area increases as the amount of ink on the printing forme increases. For a given amount of ink on the printing forme the fractional coverage area depends on surface smoothness of paper. The smoother the paper surface the greater will be the fractional area covered by ink for a constant amount of ink on printing forme. For any given amount of ink on the printing forme, the fractional area covered is the greatest for CCW followed by APB, other uncoated papers. These values follows more or less the same order as indicated by the roughness values measured by Bendsten tester as shown in Table 2. But there are few disagreement between the Bendsten roughness values and coverage area. This clearly indicates that the printing performance cannot be predicted based on smoothness measurement by air-leak testers alone.

4.3 Mathematical Relationship between A and X

Hsu observed that the area of coverage 'A' could be related to the ink on frome x by

$$\frac{A}{1-A} = k_H \cdot x^n \qquad (4.1)$$

Hsu's equation was fitted to the experimental data obtained in this study. The experimental data were found to give a good fit in the equation as shown in fig. (4.4) for C.C.W. The correlation coefficient values were found within 0.8 to 0.93.

The values of "k_H" and " n" were determined for each grade by fitting the experimental data in Hsu's equation using least Square method of curve fitting. The values thus obtained are given in Table (3).

The two constants k_H and n are not correlated. The constant k_H is basically a smoothness parameter, since k_H is equal to A/1-A where x is equal to one and higher value of k_H is therefore associated with higher degree of coverage. From the data it is observed that the value of k_H for coated creamwove is greater than those for other samples.

From the values of k_H and n it is possible to calculate two important parameters which are more closely related to the physical motion of roughness & roughness distribution.

a) The amount of ink on the printing forme which would give 50% fractional area coverage on printing. This is expressed as $x_{0.5}$.

$$x_{0.5} = (1/k_H)^{1/n}$$

The values of $x_{0.5}$ is an expression of the depth of surface cavities. A high value of $x_{0.5}$ indicated a high roughness of the surface

b) The slope of A Vs x curve at $x = x_{0.5}$ expressed as $(dA/dx)_{0.5}$ which will be given by

$$(dA/dx)_{0.5} = 0.25\ k_{n}\, n\ (1/k)^{(n-1/n)}$$

A high value of $(dA/dx)_{0.5}$ says that the surface voids are shallow and further coverage, would be easy to achieve either by increasing the ink quantity on printing forme or by increasing the printing pressure. This may, however be noted that the values of $x_{0.5}$ and $(dA/dx)_{0.5}$ are function of k and n only, they do not principle provide any additional information, but only a means of expressing k and n in more useful form. These values of $x_{0.5}$ and $(dA/dx)_{0.5}$ for different papers have been reported in **Table(4).** The values of $(dA/dx)_{0.5}$ for coated papers are much higher than the values of uncoated papers.So the coverage of coated papers can be achieved more easily by increasing the amount of ink or printing pressure.

For a smooth surface able to achieve complete contact with this ink layer, the values of $x_{0.5}$ should be small and values of $(dA/dx)_{0.5}$ should be large. The product of $x_{0.5}$ and $1/(dA/dx)_{0.5}$ gives combined measure of these two effects. Singh [12] observed that the this product was very close to the surface roughness determined by the Parker print surf roughness tester at a clamping pressure of 10 kgf/cm^2, PPS(10). This roughness index was expressed by the symbol Z. The values of Z, and PPS(10) for the papers studied are repeated in Table 4. These relationship as observed by Singh [12] is confirmed) by these results. A plot of PPS(10) as a between is shown in fig. 4.5. The relationships between the Parker print surf roughness, PPS(10) values and $x_{0.5}$, k_H and n are shown in figures 4.6, 4.7 and 4.8 respectively. While PPS(10) appears to be directly proportional to $x_{0.5}$, it is inversely related to k_H. These appears no correlation between PPS(10) and n.

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

1. Eight different varieties of papers have been tested.

2. A visual observation of prints obtained on these papers (at near to 50% fractional coverage area) indicate differences in the surface structure and formation.

   2(a) Coated paper have much more uniform surface (texture) than Newsprints and other uncoated printing papers.

   2(b) Creamwove paper have less uniform surface even wild formation appears on print.

3. The fractional area covered as a function of ink on forme x has been determined for each grade of paper. From these data amount of ink required for 50% fractional coverage, $x_{0.5}$, the slope of A, Vs x curve at $x_{0.5}$ were determined. $x_{0.5}$ represents depth of depressions on paper surface and $(dA/dx)_{0.5}$ represents the slope of cavities in paper surface is observed that for $x_{0.5}$ is lower for smoother papers like coated paper and $x_{0.5}$ is higher for Newsprints and other printing papers. $(dA/dX)_{0.5}$ is higher for coated grades and it is less for newsprint grades.

4. A roughness index Z, defined as $Z = \sqrt{\frac{X_{0.5}}{(dA/dx)_{0.5}}}$ was also determined. It is observed this factor is very well correlated with Parker Print surf roughness values (PPS).

5.2 Recommendations

1. During this study the commercially available offset ink is used. It was observed that ink is drying on ink spreading unit within half an hour. It is recommended that more stable inks should be used for such experimental works.
2. More grader of paper should be included in the study.
3. The effect of printing conditions such as printing speed and printing load should be studied for a wider range.
4. As reported in the literature, the charactrization of paper surface from printability is quite complex. Several methods of surface characterization should be used to arrive at the useful results.

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Table No. 1 Physical Properties of Printing papers

Type of Paper	Grammage (g/m^2)	Brendsten smoothness (ml/min)	Cobb (60) Seconds	Y-value (R_∞)(%)	Opacity (%)	Brightness (%)
NPH	48	172	64.17	52.33	94.10	45.26
NPM	49	240	78.42	56.65	93.85	48.80
NPT	48	185	52.63	57.61	90.87	46.32
Osp	52.5	112	16.49	69.81	86.91	61.26
SSML	58.0	107	16.32	66.52	89.50	62.47
CW	59	289	13.65	66.40	93.66	62.17
APB	135	68	22.4	71.68	99.72	72.55
CCW	96.4	88	21.26	83.62	90.08	73.55

* Y-value represents the intrinsic reflectance factor, R_∞, using FMY filter (green filter)

** Brightness is the value of R_∞ using a blue filter having a dominated wavelength of 457 nm.

*** Opacity is defined as the ratio of R_0/R_∞ using filter FMY. Here R_0 is the reflectance of paper backed by a black cavity.

Table 2 : Grading of different papers based on Bendtsen smoothness and printing results

Type of Papers	Roughness Bendtsen	Roughness By Printing
APB	1	2
CCW	2	1
OSP	4	7
CW	8	8
NPH	5	4
NPM	7	5
NPT	6	6
SSML	3	3

Table 3 : Surface Constant on Hsu's Equation for different papers

Type of Papers	n	k_H
APB	1.58	0.47
CCW	1.12	0.55
OSP	1.49	0.20
CW	1.82	0.16
NPH	2.03	0.13
NPM	1.11	0.44
NPT	1.61	0.16
SSML	1.68	0.52

Table 4 : Surface Characteristics derived by considering different surface constants

Type of Papers	X 0.5 (g/m^2)	(dA/dx) 0.5	Z	PPS (10) µm
APB	1.59	0.24	2.53	1.85
CCW	1.71	0.26	2.56	1.96
OSP	2.85	0.13	4.68	4.80
CW	2.68	0.17	3.96	5.40
NPH	2.65	0.19	3.72	4.26
NPM	2.06	0.13	3.90	4.26
NPT	3.08	0.13	4.86	4.33
SSML	1.94	0.16	3.03	3.86

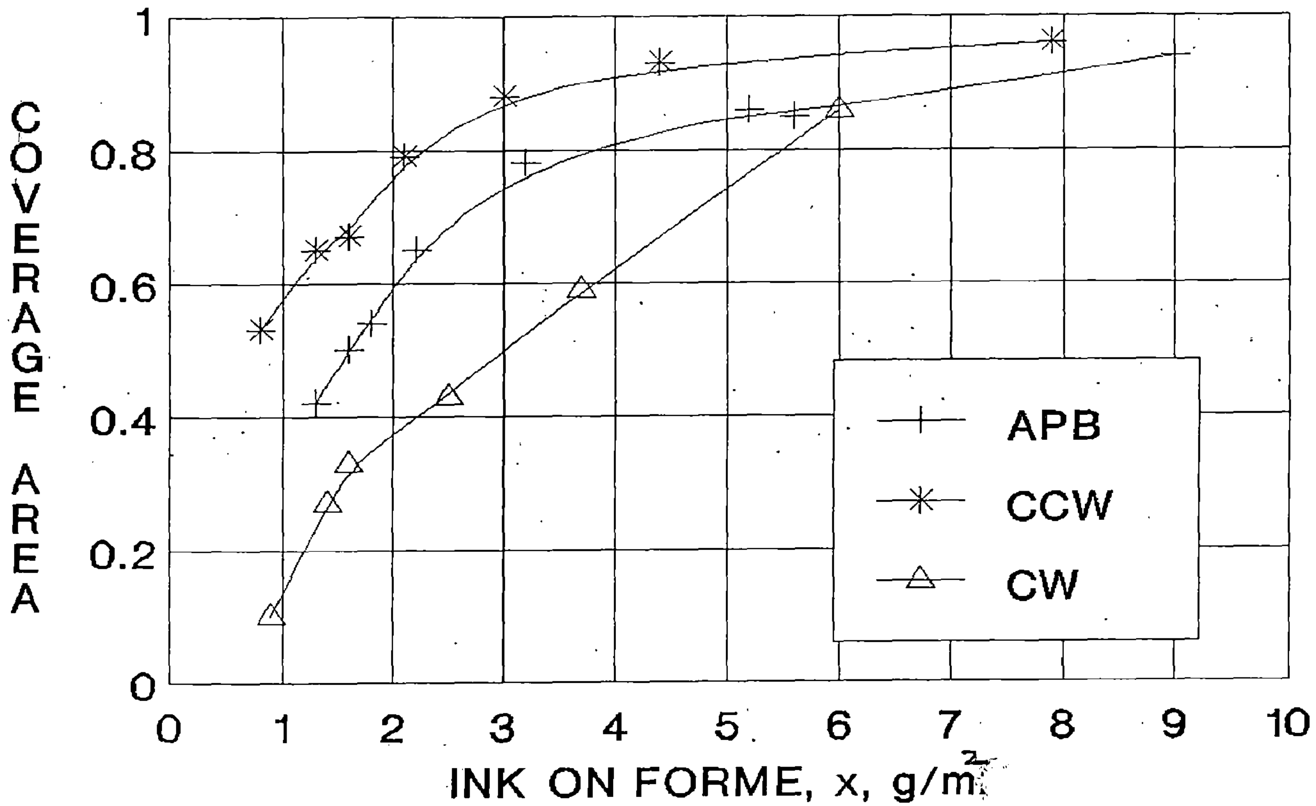

Fig.4·1 Plot of coverage area Vs the amount of ink on printing forme for APB, CCW, CW

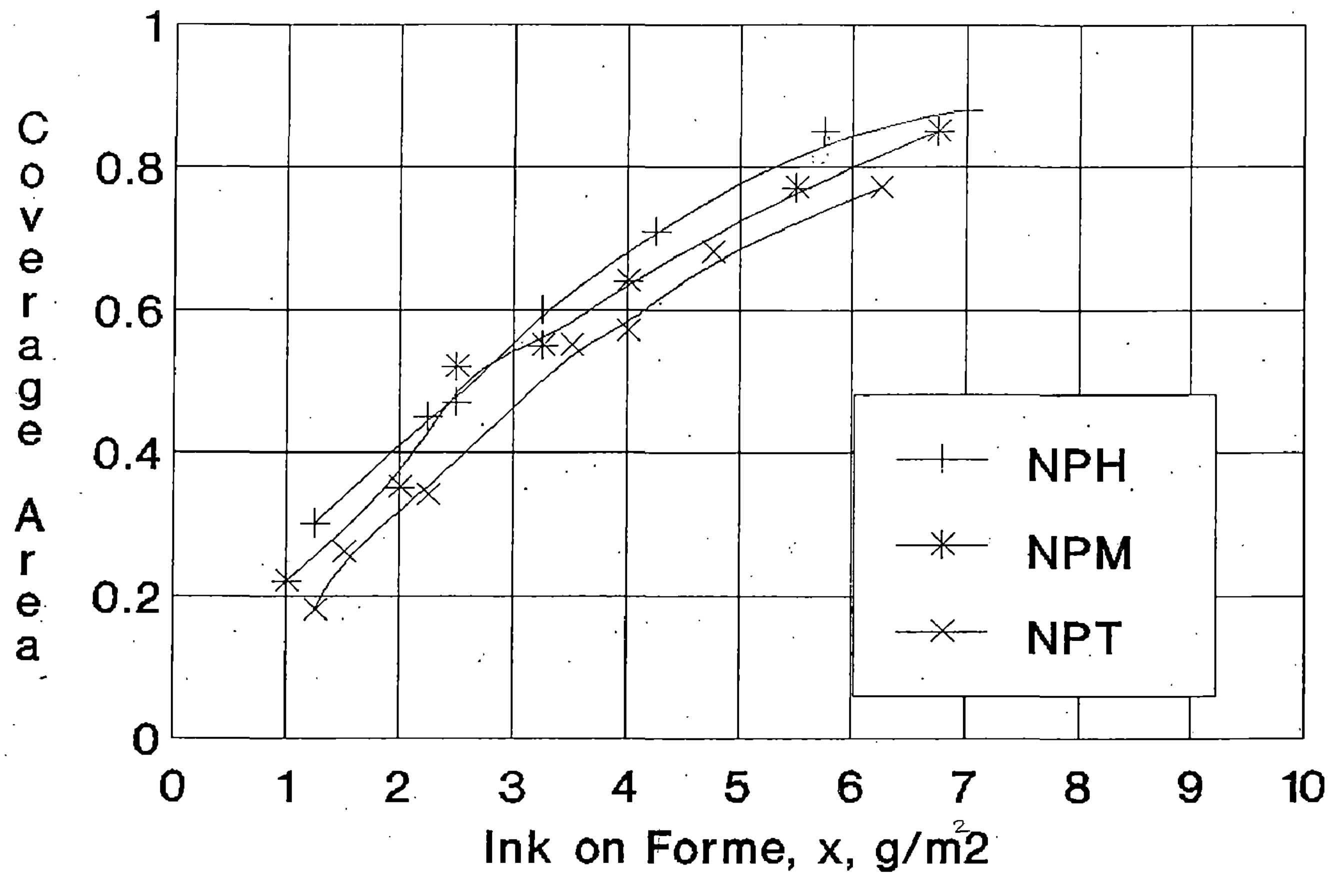

Fig.4 2 Plot of Coverage area Vs the amount of ink on printing forme for NPH, NPM, NPT

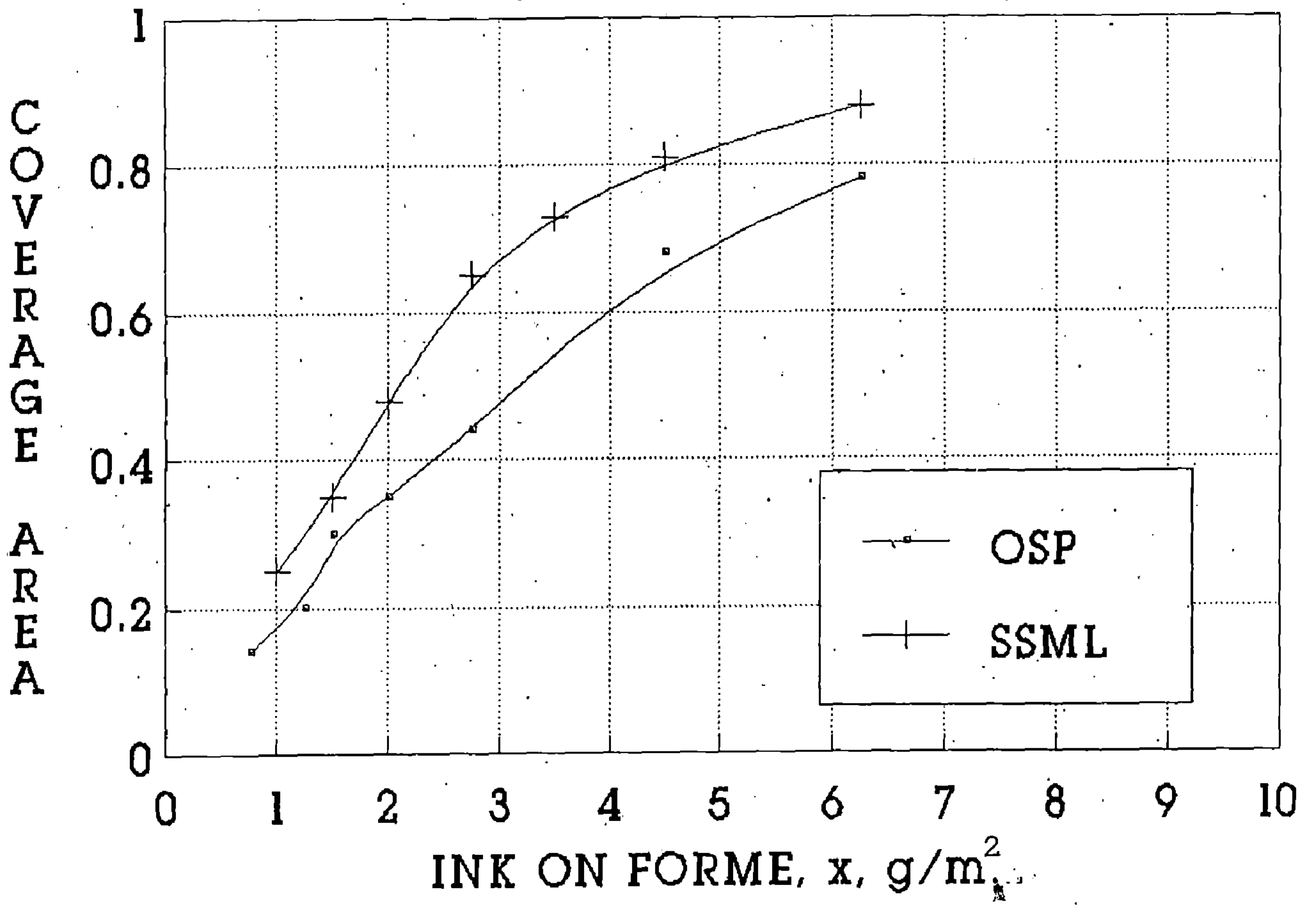

Fig.4.3 Plot of coverage area Vs the amount of ink on forme for OSP, SSML

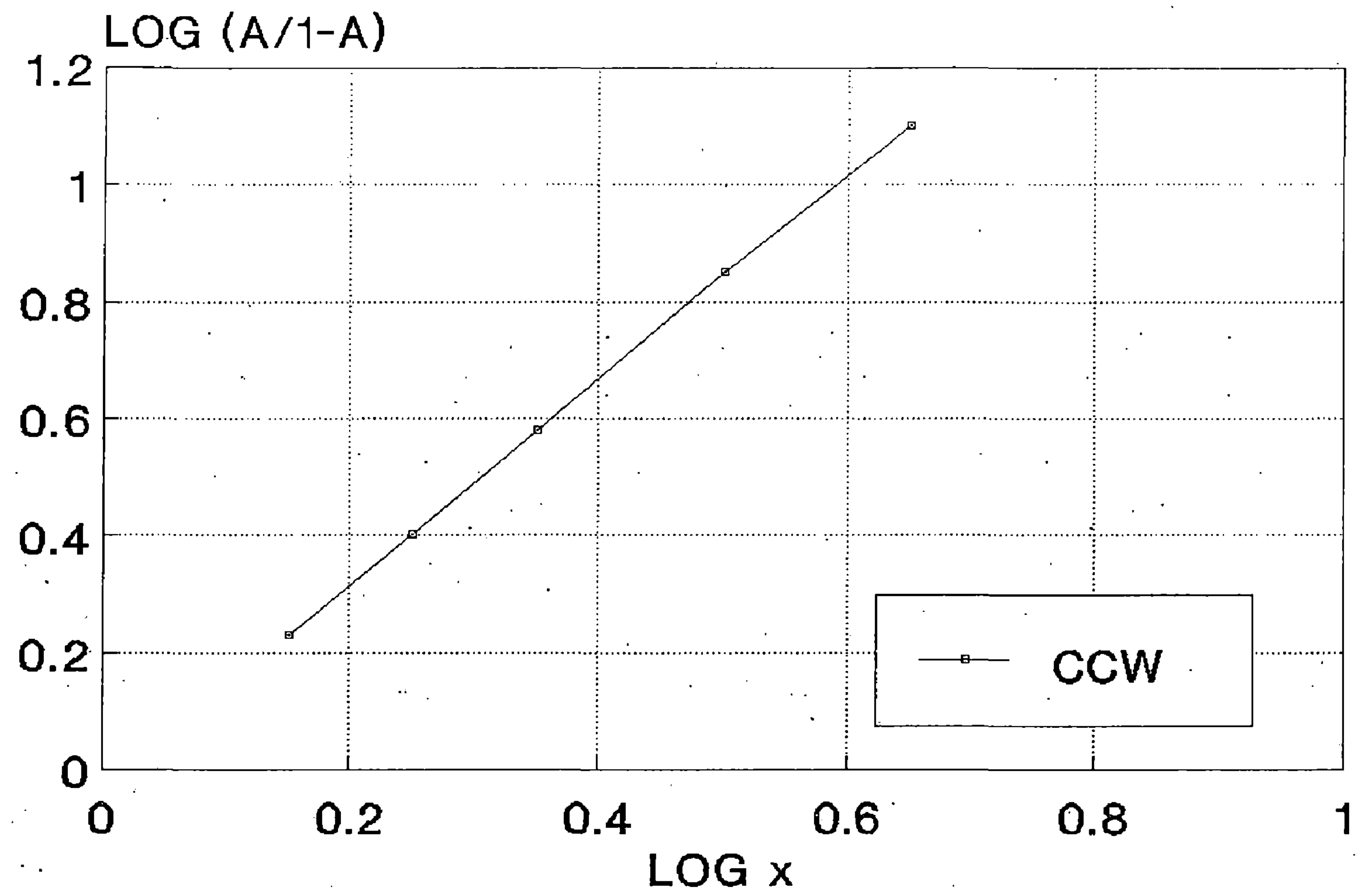

Fig. 4.4 A plot showing the goodness of fit of experimental data to equation ($A/1-A = k_H X^n$)

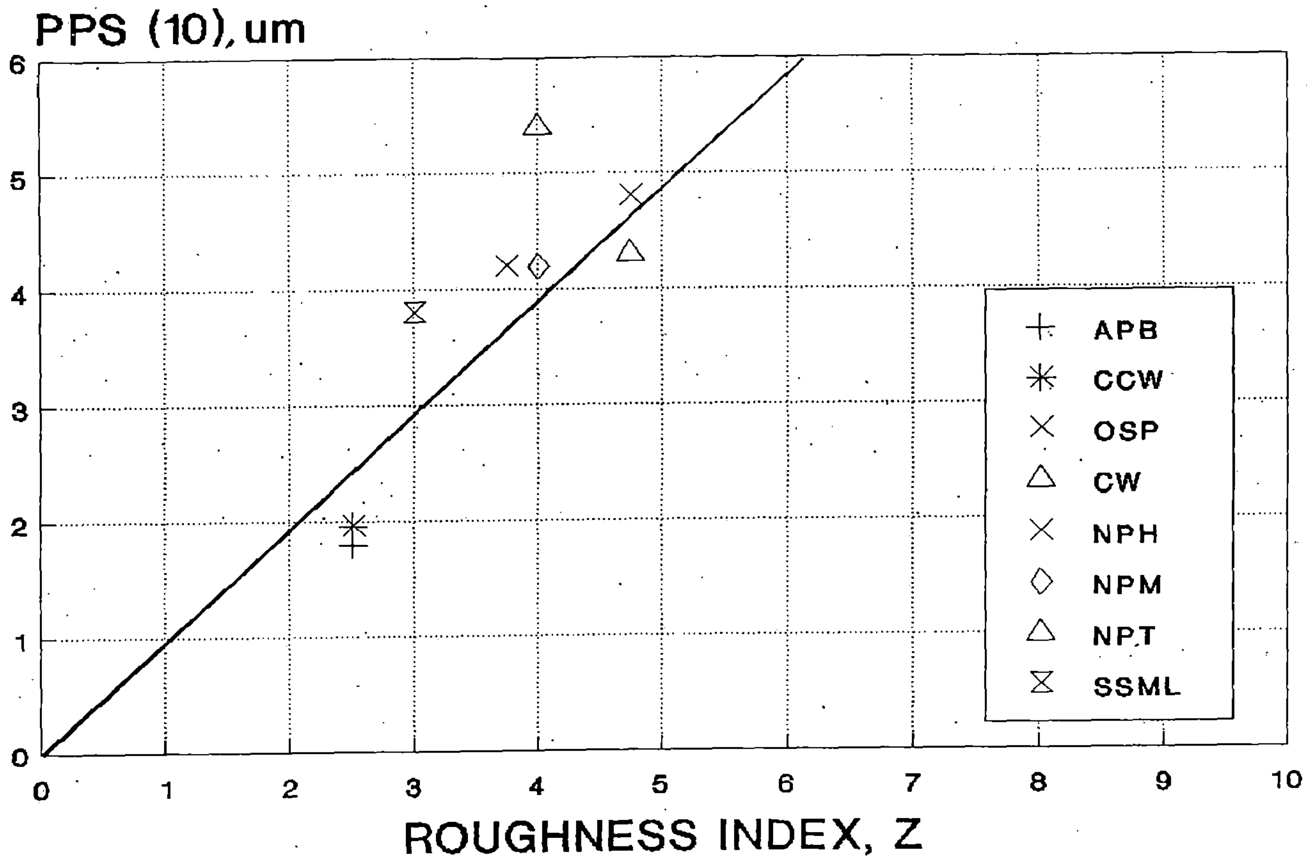

Fig. 4.5 Plot of roughness index, Z Vs PPS showing some agreement between two parameters.

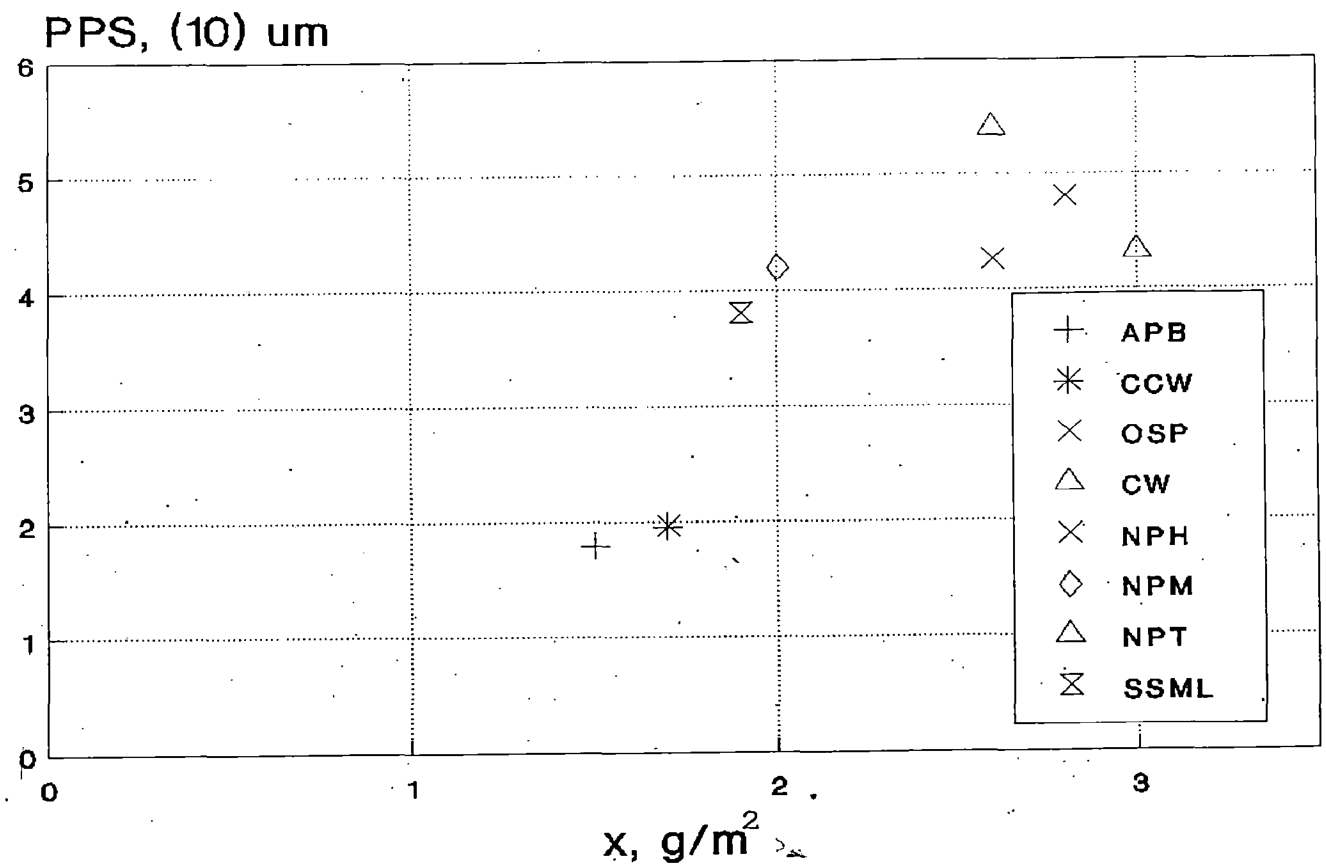

Fig. 4.6 Relationship between X at A = 0.5 Vs PPS values.

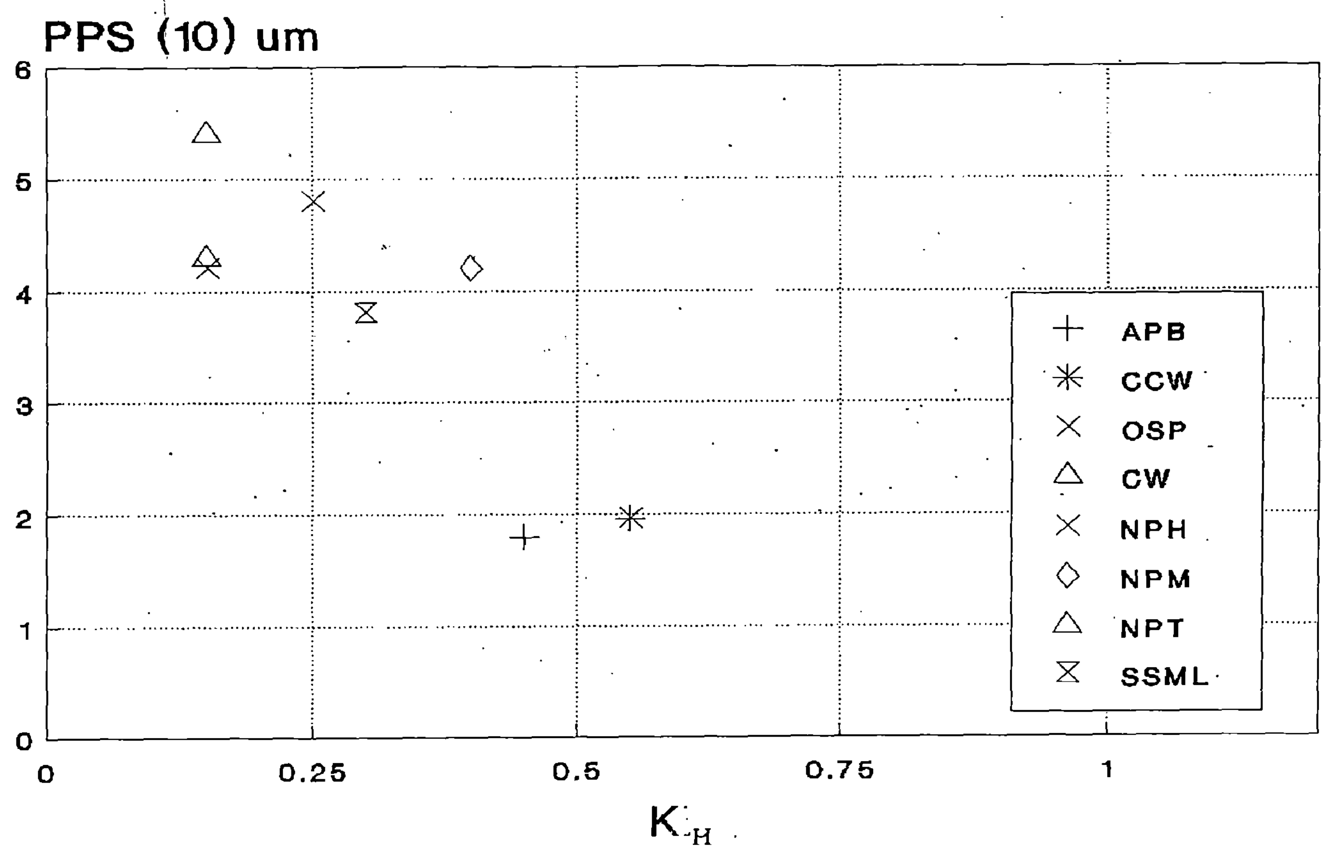

Fig. 4.7 Relationship between K_H and PPS values.

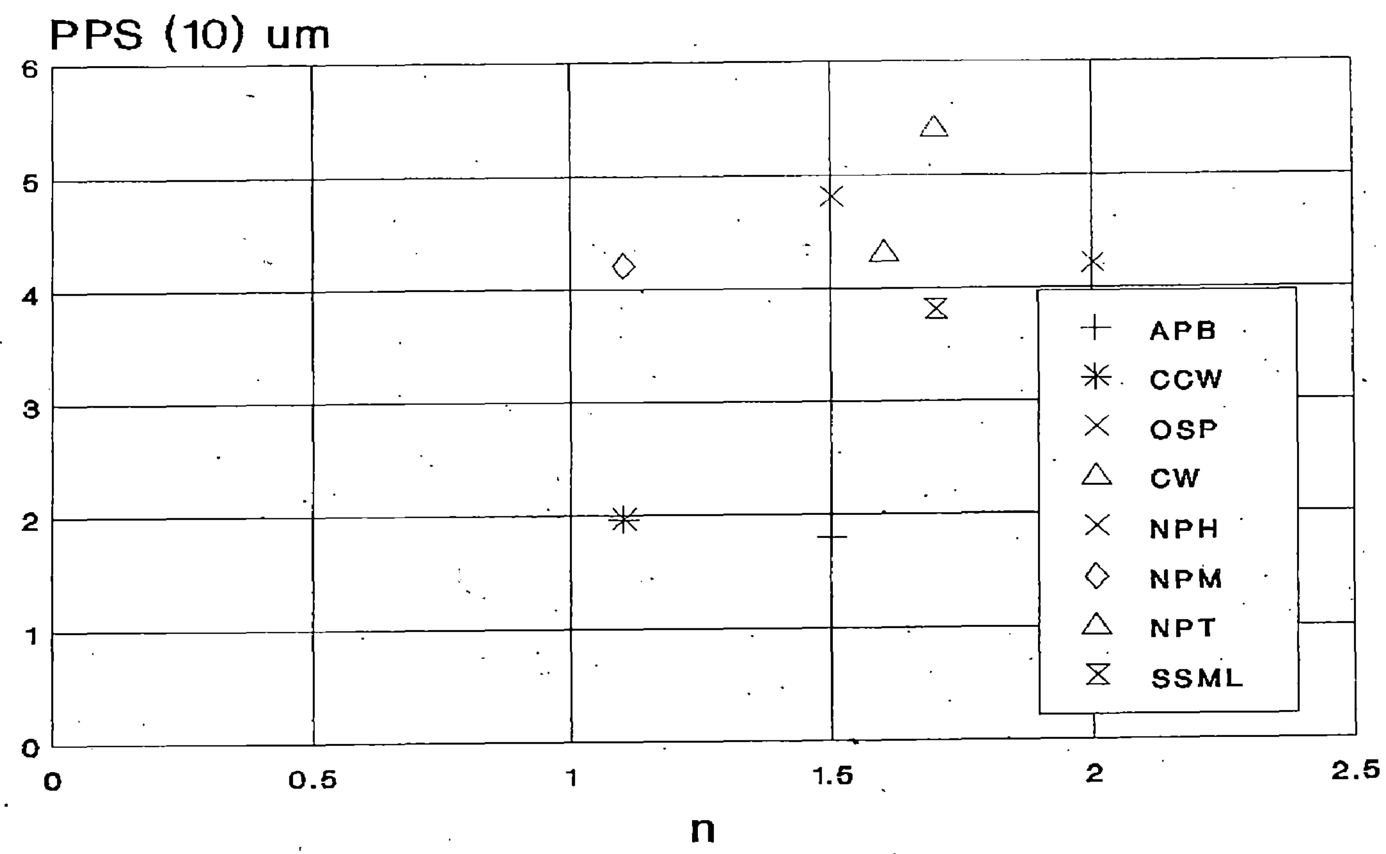

Fig. 4.8 Relationship between n and PPS values.