STUDY OF PRINTABILITY OF INDIAN NEWSPRINTS

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

HIMANSHU SHEKHAR PRADHAN

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

MARCH, 1998

CANDIDATE'S DECLARATION

I hereby certify that the work which is being presented in the thesis entitled " **STUDY OF PRINTABILITY OF INDIAN NEWSPRINT** " 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~~ March, 1998 under the supervision of Dr. N.J.Rao, Professor, Dr. S.P.Singh, Astt. 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.

17.03.98

[HIMANSHU SHEKHAR PRADHAN]

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

Dated : 16.3.98

Dr. N.J.Rao
Professor

Dr. S.P.Singh
Astt. Professor

Institute of Paper Technology
University of Roorkee
Saharanpur - 247 001

ACKNOWLEDGEMENT

I am highly indebted to my guides Dr. N.J.Rao, Professor and Dr.S.P.Singh, Astt. Professor, Institute of Paper Technology for their inspirational guidance to me in carrying out the present thesis work.

I am thankful to Dr. N.J.Rao, Professor, Institute of Paper Technology, for his valuable cooperation, encouragement and helpful suggestions during my thesis work.

Last but not the least, I am also thankful to staff members of Paper Lab and my friends for their in time co-operation.

[HIMANSHU SHEKHAR PRADHAN]

ABSTRACT

In the present work the variation in total ink transfer and transfer parameters and their effect on print-ability of Indian newsprints with changing printing speed and pressure are studied. The total ink transfer increases with increasing printing pressure and decreasing printing speed;however the amount of ink immobili-zed by the stock as determined from the transfer parameter,b,does not parallel the trend in total ink transfer. The fraction of ink transfer associated with the calculated split of the free ink film,f,includes both the ink transferred during decompression as well as the ink split toward the paper. The extent of ink penetration during paper compression in the nip decreases rapidly with increasing printing speeds. The printing smoothness,k,of the newsprints is described by an exponential distribution function relating the area contacted to the ink film thickness on the printing disc. It increases with increasing printing pressure. The print density calculated from the optical contrast between the unprinted and printed part of the sheet, increases with increasing the amount of ink on the printing disc. An increase in amount of ink on the disc to enhance the print density, has an adverse effect on print through. Print- through, the undesirable property of the print being visible from the reverse side of print increases with increasing amount of ink on the printing disc. In the present work it is broken down into two additive components; direct show-through and print-through due to pigment penetration. The uniformity of print density is determined by the optically covered area. The optically covered area is independent of intrinsic luminous reflectance factor of the paper. The use of concept of optically covered area to describe the optical effect of the ink distribution over the printed area is discussed.

CONTENTS

LIST OF FIGURES AND TABLES

CHAPTER - I

INTRODUCTION AND LITERATURE REVIEW

1.1. INTRODUCTION

In terms of volume, newsprint is the most important member in the family of un-coated "wood-containing" printing papers. In the broadest sense, newsprint can be defined as "any paper capable of being run through a modern high-speed printing press and producing an acceptable sheet of newspaper at reasonable cost". The functional requirements of newsprint are runnability on the press, printability, good general appearance and low price. Newsprint furnish consists of mainly mechanical pulp and small amount of lightly refined chemical pulp. Of all the paper grades, newsprint comes closest to being a true commodity item. The basis weight and brightness levels of newsprint made by different manufacturers remain, more or less the same. But there exist differences in runnability, printability and appearence of newsprints made by various manufacturers.

Indian newsprint mills make use of different types of raw materials namely, hardwoods, grasses and bagasse. Typically, the Indian newprint furnish contains about 70% chemimechanical pulp and about 30% semibleached chemical kraft pulp. In general, the pulps used for newsprint manufacturers in India are quite different from those used in Europe and North America where these are mostly softwood mechanical pulps. This affects adversely not only the cost of production but also the quality of paper.

In the present study five newsprint samples made by different Indian mills have been evaluated for their printability characteristics. The samples of newsprint were printed in a laboratory printability tester to determine important printability parameters related to ink-paper interactions under conditions simulated to match the actual printing conditions. Efforts have been made to study the relationships between the printability parameters and other physical properties of the newsprint samples.

1.2. LITERATURE REVIEW :-

1.2.1. A brief review of Printing Processes :-

Printing is used to describe all the processes by which multiple reproduction are made from a plate or image carrier on a press on which pressure is used to tranfer the inked image to the paper. In all printing processes the image carrier consists of two areas: (1) printing or image areas that are inked to produce the image, and (2) nonprinting or nonimage areas that remain clean or unprinted. There are four major ways of achieving this image area and non image area separation on an image carrier.

Relief Printing : In this process the image areas are raised above the plane of nonimage areas. This principle is used in the typewriter and the printing processes of letterpress and flexography.

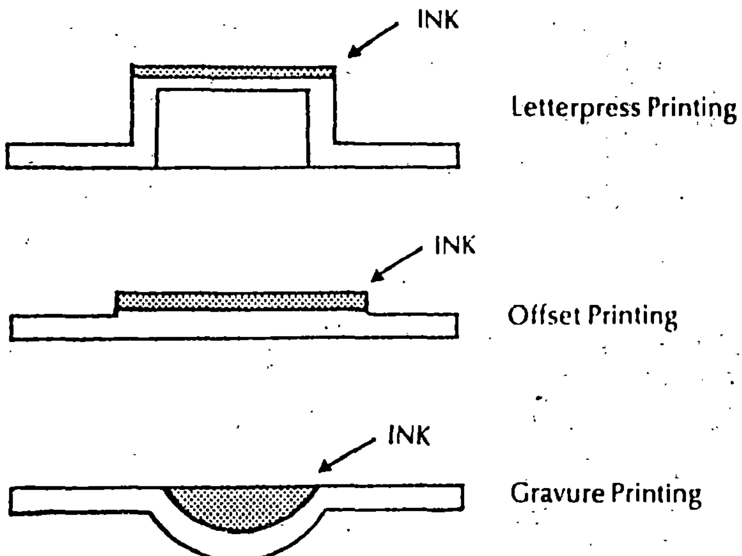
Intaglio Printing :- In this process printing is done from recessed areas. The image consists of tiny indentations or wells in a plate or cylinder that hold the ink; the nonimage areas are scraped clean with a wiper or metal doctor blade that cotacts the smooth outer surface of the plate cylinder. This is the principle of gravure printing.

Planographic Printing :- In planography,printing and nonprinting areas are essentially on the same plane but they differ in their receptivity to ink; the printing areas receive ink and nonprinting areas repell ink. This principle is used in lithography.

Stencil or porous Printing :- A metal, silk or nylon screen or a fibrous material is used on which the nonprinting areas are blocked so that the ink goes through only the porous areas which represent the image. This principle is used in screen printing and stencil duplicators.

Based on the above discussed image creating mechanisms, there are five major commercial printing processes in use, namely letterpress, flexography, gravure, lithography and screen printing . These processes are described briefly in the following paragraphs. The various printing methods are shown in the following figures.

PRINT METHODS



Letterpress:- Letterpres is the only process by which printing can be done directly from hand-set or machine-set cast matal type. Pictures or illustrations, however, must be printed from plates made by the processes of photoengraving. Letterpress has been used for magazine and newspaper printing and to some extent for book and advertising printing. However, the process is being largely replaced by offset lithographic printing.

Flexography:- It is a form of relief printing, which uses rubber or resilent plastic plates with a simplified inking system and solvent-type inks. It is used mainly for printing extensible films for packaging, to some extent for book printing, particularly paperbacks and low -cost magazines and for newspaper printing.

Gravure :- It is a form of intaglio printing process. Rotogravure uses cylinders and has the advantage of ease of changing printing length by changing cylinders. It is used extensively for printing of magazines, mail-order catalogs, newspaper preprints and supplements, long-run packaging, and specialities like plastic laminates and heat-transfer paper.

Lithography:- Lithography, which prints from a planographic surface using the principle that grease and water do not mix, has become the leading printing process.It is used extensively for printing advertising literature, newspapers, magazines, books, catalogs, greeting cards, posters, art reproductions, letterheads, business forms, cheques, labels, packages and so forth.

Screen Printing :- Screen printing, which was predominantly used for printing signs and displays made from manually produced stencils, is now an automated process using rotary screens and is used to print textiles, wall coverings, heat-transfer patterns, plastic bottles and other objects with irregular and unusual shapes.

1.2.2. Printing Ink Transfer :-

The essential feature of printing is transfer of ink from the image carrier to the paper surface, when the image carrier makes a contact directly with the paper surface the process is known as direct printing. Alternatively the ink may be transferred from the inked plate to an intermediate cylinder covered with a rubber blanket which then transfers it to the paper or other substrate. This process is called as offset printing. Letterpress, gravure and screen printing are essentially methods of direct printing, but they can also use offset principle . Lithography, on the other hand, is almost exclusively offset printing . Offset is the mostly used process for printing newspaper and magazines in India. The advantages of offset principle are as follows[1] :

1. The rubber printing surface of the blanket conforms to the irregularities in the paper surface. Therefor a less printing pressure is needed.
2. Paper does not contact the metal printing plate, thereby reducing the possibility of abrasive wear and increasing the life of the plate.
3. Speed of printing is increased.
4. The image of an offset plate is "straight" reading instead of reverse reading. This facilitates both preparation of the plates and correction of errors.
5. Less ink is required for equal coverage. This speeds up ink drying, reduces the tendency for the ink to smudge or set-off in the delivery pile and reduces problems with ink trapping.

1.2.3. Properties required from Printing Papers :-

Different printing process demand different properties from a printing paper. These properties can be broadly classified into two groups; runnability related properties and printability related properties.

(a) Runnability :-

The runnability of a paper in printing press can be considered a combination of all those factors which might cause the press to run at lower than necessary production speed. Poor runnability is characterized by breaks or slack tension on the press which leads to wrinkles and poor register. Paper properties important to runnability are strength, uniformity, moisture behaviour, freedom from defects and good mechanical condition of rolls or sheets . The relationship between runnability and strength properties has never been well defined, but pressroom operators feel that cross-direction tearing resistance provides the best indication of performance. Tearing resistance depends primarily on the relative amounts and qualities of the pulps used. Breaks in the paper usually attributed to defects at the edge of the sheet that precipitate failure. Generally, if the "break end" located , a flaw such as a shive, sliver, pin hole, etc. will be found.

(b) Printability :-

Printability (print quality) is the effect of the paper on the accurate reproduction of the printed image. Paper properties such as brightness, opacity, colour, gloss, smoothness, porosity and sizing are important , but the requirements vary with the printing process used. Generally, coated papers show better appearance than uncoated papers due to better smoothness, brightness and gloss.

Differences in printability are especially critical in the reproduction of the half-tone prints. In printing, the reproduction of tone originals is made possible by converting the original continuous tone into a discontinuous pattern of dots of different sizes, large well-joined dots in the shadows and small dots in the highlights of the picture. In general, the finer the pattern of dots, the more the eye is fooled into thinking the tone is continuous and the greater the details can be shown.

1.2.4. Important Printing Properties of Newsprint :-

The important properties considered for newspaper publishing are:

Runnability:- Ability to run the web through the press without breaks. The chemi-mechanical pulps used for newsprint production are usually blended with 30% of semi-bleached kraft pulp to get the necassary strength requirements.

The machine direction tensile strength of the newsprint must be adequate to sustain the tension during printing on the high-speed presses without breaks[2].

Printability:-

Ability to accept and preserve the ink pattern (with minimum rub-off, set-off and show through)[(2)].

Appearance (optical properties) :-

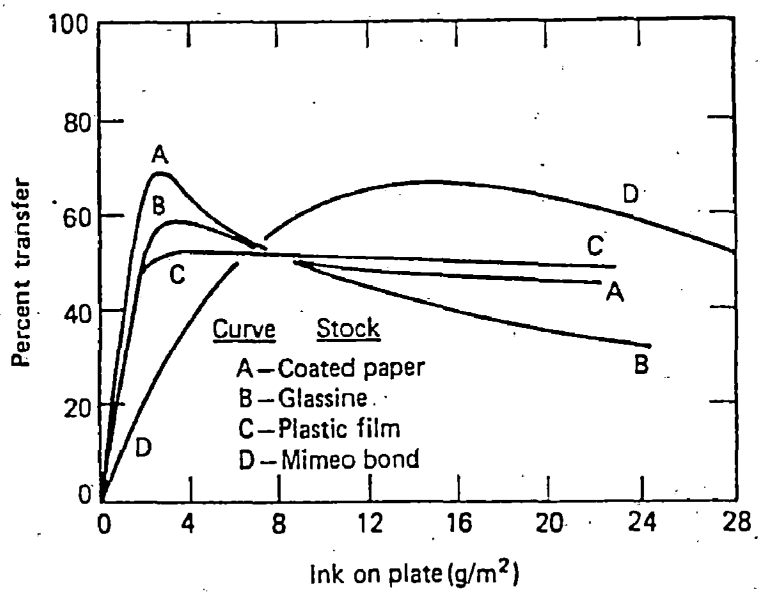
Brightness, whiteness, cleanliness and opacity.

The newsprints must have the optimum moisture level to improve the runnability. In particular , the newsprint exhibits improved stretch properties at the higher levels , which enables the sheet to better absorb shock energy without breaking[2].

The paper-ink behaviour is important and is influeneed by the characteristics of paper, the press and the printing ink. Several studies have been done to study the paper-ink behaviour.

1.2.5. Ink Transfer Parameters :-

An important approach to understanding and evaluating the influences of the paper surface on printing is through the study of the transfer of ink to paper during the printing impression. Best results are obtained with the minimum amount of ink and with the minimum pressure for the desired print density. There has been considerable study of the amount of the ink that transfers from the plate to the paper during the printing impression. This step is the very heart of the printing process. Inks, papers, and plates must be designed to perform properly because the transfer process determines to a great extent the quality of the print that will be obtained. The measurement of ink transfer is a very useful means of gaining insight into what is happening and how the materials are performing. Ink transfer can be measured experimentally by determining the amount of ink on the printing plate before and after impression. It has been reported that a good precision is attained by direct weighing of the ink on the plate. The results are commonly expressed as fraction of the ink originally on the plate that transfer to the paper. For a particular combination of materials and press conditions, there is a characteristic curve for percent transfer as a function of original ink film thickness on the plate. A representative group of curves taken from the work of Fetsko and Walker[9] for transfer to a variety of surfaces is shown in the following Figure.



Characteristic transfer curves for printing ink applied to four different surfaces. (Courtesy of American Ink Maker.)

In the early works on ink transfer in fifties, ink transfer curves were experimentally obtained for a variety of printing papers. Walker and Fetsko[10] proposed a very comprehensive theory of ink transfer in printing that has been widely used and studied.

Walker and Fetsko postulated that :

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

2. At the end of the impression, the remaining "free" ink splits between the separating printing plate and paper surface. A constant percentage of this "free" ink is transferred to the paper. This is generally less than 50 percent and depends on the materials and printing conditions used.

These concepts can be expressed as an equation :

$$y = b + f(x-b) \qquad (1)$$

Where

y = ink transferred per unit area, g/m^2

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

x = ink originally present on the plate, g/m^2

$x-b$ = nonimmobilized or "free" ink film

f = fraction of free ink transferred to paper

This equation is readily applied to measured data in its transposed form :

$$y = b(1-f) + fx \qquad (2)$$

A plot of y versus x should be a straight line. Experimental data show that a straight line relationship is obtained only for smooth surfaces and for large values of initial ink film thickness. This plot is not as linear for rougher, more absorbent surfaces such as newsprint.

At very low ink-film thickness there is insufficient ink on the plate for complete contact with the paper surface. Morever, the ink available on the plate is less than the amount of ink that can be immobilized.

For application in the low ink film thickness region and to uncoated papers, the Walker-Fetsko equation is modified into the following form :

$$y = (1-e^{-kx})[b(1-e^{-x/b})(1-f)+fx] \ldots\ldots\ldots\ldots(3)$$

where

k = a constant expressing the smoothness of paper

The first term $1-e^{-kx}$ represents the fraction of the paper surface contacted by the ink. It is zero when x is zero and increases to approach unity as the ink film increases. For smoother paper k is larger, and this fraction approaches 1.0 much more rapidly. The expression $1-e^{-x/b}$ corrects b, the amount of ink that can be immobilizzed by the paper surface, for low-film thickness where that much ink may not be available. Both of these exponential factors approach 1.0 at medium to high ink films and thus reduce this equation to the simpler form of Eq.1. Using equation (3) and the values of b and f from the simple equation, the value of the paper smoothness constant k can be calculated from data at low-ink-film thickness[1].

Schaeffer and co-workers [4]studied, the dependnce of the ink transfer parameters (b, f and k) for a variety of inks and papers over a range of printing pressures and speeds. Increasing impression was found to result in incresed total transfer whereas increased printing speed showed a decreased in the total transfer[4]. Bery[11] pointed out that b tends to increase with increase in printing speed. He proposed a modified equation to explain this increase based on the theory that paper has greater resistance to flattening , and hence the valleys remain large, as the printing speed is increased. Work with the ink transfer constants k and b has shown that k is indeed a very meaningful characterization of the printing smoothness of paper and b of its ink receptivity.

1.2.6 Absorbency and Ink Receptivity of Printing papers:

These are another set of important properties of printing papers because they have a strong effect on this successful transfer of the ink film to the paper surface. For good printing results the paper should quickly receive the ink from the contacting printing plate and immobilize it. Moreover, the ink should quickly dry on the surface of the paper without too much penetration of pigment into the paper. The phenomenon is referred as good ink holdout. Usually high-holdout sheets are smoother, require less ink for coverage, and have high print density and gloss. Very high ink holdouts can also create problems in some printing tibs, must notably the problem of set off. Set off means that the wet ink film on the sheet surface contacts and pratially transfers to the next sheet in the press delivery stock.

Ink recieptivity and ink absorption differ primarily in the magnitude of time involved. Ink receptivity is the property that causes paper to accept the printing ink at the instant of contact between the paper and the ink. It is a surface phenomenon determined by the ease with which the ink wets the paper. The ink receptivity is considered good when the paper accepts the ink readily and uniformly over the whole surface. Ink receptivity is a function of both the paper and the ink.

The effects of printing speed and impression pressure on total ink transfer is that, increasing impression increased the total transfer whereas, increasing printing speed decreased the total transfer. The most convenient way of summarizing the effects of printing conditions in the transfer process is to describe individually the observed changes in the transfer parameters[4].

At ink film thickness lower than that required for complete coverage, the transfer equation utilizes an exponential distribution (e^{-kx}) to characterize the increase in area of contact between the ink film on the plate and the paper as the ink film thickness on the plate is increased. The exponential distribution (e^{-kx}) considers the smoothness parameter of paper. Increasing the printing pressure increases the smoothness of paper whereas, printing speed has relatively little influence [4].

In the high ink film thickness points the ink transfer is subdivided into two factors as : the ink immobilized during dwell time, b, and the split of the free ink film .f. The parameter k has very insignificant effect[4].

Walker and Fetsko found that b increased with increased impression and decreased with increased printing speed.

Fetsko found with the IGT printability tester an increase in b with increasing printing speed at the lower of two printing pressures employed.Increasing the pressure caused no significant change in b at the faster speed but did cause b to decrease at the slower speed.

The depth of penetration during dwell time will increase to a maximum with increasing impression and then approach zero as the pressure approaches to the pressure under which the porous structure collapses completely, b is identical to the depth of penetration of ink or pigment.

Walker and Fetsko found out that f decreased significantly as the printing speed was increased .According to the findings of Nielsen at the higher impression levels f decreased with increasing speed, whereas, at lower impressions, f increased with increasing printing speed. f increases with increasing impression pressure. With changing printing conditions the b and f appear to be inversely related i.e. increases in b are accompnied by decreases in f. To summarize, increasing the impression pressure increases total transfer, whereas, increasing printing speed decreases the total transfer.

1.2.7 Evalution of Prints :

(i) Print density

It is the optical contrast between a printed and an unprinted surface. For newsprint, this contrast is usually measured from a solid print and is dependant on the brightness of the paper. The density of a print can be raised by increasing the amount of ink on the printing plate[2]. Mathematically PD is determined as [5]

$$PD = \log \frac{R_\infty}{R_P}$$

where,

R_∞ = Reflectance of a paper backed with a pile of same paper

R_P = Mean reflectance of the print , PD = Print density

(ii) Print through

The undesirable effect of the print being visible through the reverse side of the paper is called print through (or show-through). It depends on the opacity and porous structure of the paper. A higher ink application to improve print density has an adverse effect of increasing show through. In extreme cases, the ink will migrate to the reverse surface, causing strike-through[2].

It is mathematically expressed as [6]

PT PTst

$$\log(R'_\infty / R_{pr}) = \log(R'_\infty / R_x)$$

PTp

$$+\log(R_x / R'_{pp})$$

PT_v

$$+ \log(R'_{pp} / R_{pr})$$

where PT = Total print through.

R'_∞= Reflectance of the unprinted sheet on the reverse of the paper backed with an infinite pile of the same paper.

$$R_x = \frac{\left[(R_o + R_p) - R_o R_p \left(R'_\infty + \frac{1}{R'_\infty}\right)\right]}{\left(1 - R_o R_p\right)}$$

R_x = The reflectance of the unprinted sheet backed with a sheet of the same paper printed with known amount of ink and known optical density.

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

R_{pr} = Reflectance of the reverse of the print.

PT_{St} = Direct show-through (this is the unprinted opacity componene, i.e. without ink penetration into the sheet) It is the least print show-through value possible for a given paper .

Pt_P = Show through due to ink penetration

R'_{PP} = Reflectance on the reverse side of the print into which pigment has penetrated and which has been extracted for vehicle oil.

PT_V = Loss of opacity due to vehicle oil penetration.

(iii)Proportion of area covered

When a paper is printed with a low ink- film thickness on the printing plate, the ink is transferred mainly to those surface elements of the of the paper that are in contact with the ink under the printing pressure. Due to the pressure ink also reaches some elements that are actually lower than the contact plane.The fraction of the surface covered by the ink can be used as a good measure of printing smoothness .For smoother papers, the proportion of covered area, is nearer to unity , but decreases with increasing roughness.An easy way to determine the fractional contact area is by measuring reflectance of the printed area. A surface element can be regared as being covered by ink if it reflects light to the same extent as a continuous layer of pigment so thick that a further increase in the thickness of the layer does not affect the reflectance factor.It may then be assumed that the amount of light reflected by a printed strip is the sum total of the light reflected by the unprinted surface elements and the surface elements covered by the ink. Mathematically it is expressed as

$$R_p = aR_i + (1-a)R_\infty$$

$$a = \frac{R_\infty - R_p}{R_\infty - R_i}$$

Where, a = fraction of the paper surface covered by the ink..

R_i = The reflectance of continuous layer of ink and

R_∞ and R_p are the reflectance factors of unprinted paper and printed paper respectively.

The assumption here is that each surface element of a solid print has a reflectance equal either to that of a continuous pigment layer or to that of the unprinted paper.The accuracy of measurement of coverage area is, however, dependent to some extent on the optical properties (scattering coefficient) and the roughness of the paper.

The reflectance of a printed area is an integrated value of the reflectances of all the surface elements. Light entering the paper in areas not covered by pigment is scattered so that part of the light is observed in adjacent pigment covered areas. As a consequence, a small unprinted spot of a print reflects less of the incident light than does an area of the same size surrounded by unprinted paper. The size distribution of the uncovered spots influence the reflectance of the print, so that the reflectance is smaller if the uncovered area is composed of a large number of small spots than if it is composed of lower and larger one[5].

The influence of these phenomena in the optically covered area can be described by the scattering coefficient(s) of the paper.

The optically covered area related to surface roughness and scattering coefficient as[5] :

$a = B_0 + B_1 G + B_2 S$

Where, a = optically covered area

G = Surface roughness of the paper $[(ml/min)^{1/3}]$

s = scattering coefficient of the paper (m^2/g)

B_o, B_1 and B_2 = coefficients

For felt side of paper :

$a = 0.990 - 0.0100G - 0.898S$

Wire side of paper

$a = 0.968 - 0.0128\ G - 0.345S$

The influence of the roughness value is stronger than the influence of the scattering coefficient.

paper.doc/pc-a/IInd

EXPERIMENTAL WORK

2.1. PAPER SAMPLES :-

Five different indegeneously manufactured newsprint samples were selected for the present study. Three of these samples were of standard newsprint grade coded as SNP.1, SNP2, SNP3 and one was a pink newsprint grade coded as PNP and other was a glazed newsprint coded as GNP. Strip from these samples was cut in the size of 55mm x 300mm

2.2. APPRATUS :-

The printing experiments were carried out using an IGT printability tester (Model AIC_25). The printing disc used was of 64mm diameter and 50mm width (soft roll).

2.3. PRINTING INK :-

The Ink used for these experiments was a standard black offset ink supplied by IGT. The ink was of the non-drying, oil-based type containing carbon black as pigment.

2.4. PRINTING METHOD :- The printing experiments were conducted in the laboratory maintained at standard atmospheric condition (Temp = $27^0c \pm 1^0C$; RH = 65% ± 5%). A sufficient amount of Ink was initially applied on the IGT inking unit and was allowed to run so that the ink was thoroughly distributed on different rolls of the unit. The printing conditions in the printability tester were simulated to that of an offset printing. A printing disc with a rubber covering was used for the experiment. No backing was used on the printing sector of the IGT printability tester.

The printing disc was inked in the IGT inking unit. The printing disc was weighed before and after inking using an analytical balance with a least count of 0.1mg. Then the inked disc was fixed to the IGT printability tester. The paper strips were printed was done maintaining the following printing conditions.

Printing Force (N)	Printing speed(m/s)
200	1
200	2.3
400	1
400	2.3

The weight of the disc was taken again after printing. From these weights it was possible to determine the amount of the ink on the printing disc before and after the printing. This also enabled to determine the amount of ink transferred to the paper during the printing. Let the amount of ink initially applied on the printing disc be x g/m^2 and that transferred to the paper surface was denoted as y g/m^2. The printing disc was cleaned after each printing using cyclohexane solvent. The procedure was repeated for printing other strips of paper. For each grade of paper, a series of strips was printed with varying amounts of ink on the printing disc x. This was easily achieved by applying a large amount of ink to the inking unit only once. As the strips were printed, the amount of ink available in the inking unit gradually decreased. The initial amount of ink applied to the inking unit was so adjusted that a series of paper strips could be printed with the amount of ink on the printed disc varying from about 45 g/m^2 to about 0.5 g/m^2.

2.5. (a) PHYSICAL PROPERTIES OF PAPERS :-

The papers studied were evaluated for the following properties.

Properties		**Testing Methods**
(1) Grammage	:	TAPPI T410 om-93
(2) Caliper	:	TAPPI T411 om-89

(3) Apparent density : TAPPI T220 sp-96

(4) Surface Roughness by parker print surf Tester TAPPI T555 pm-94

(5) Surface Roughness by Bendtsen smoothness TAPPI T538 om-96

(6) Water absorbency by Cobb Method TAPPI T411 om-90

(7) Porosity by Bendtsen air leak method TAPPI T547 pm-88

(8) Fines content determination (fines to coarse fraction):

Bauer Mc-Nett analysis :- TAPPI 233 os-75

10g of paper sample was taken and turn into small pieces. Those were soaked in water overnight. The soaked paper samples were disintegrated, till the dispersion was complete. Normally 40,000 revolutions were found sufficient for complete disintegration. The fines content (passing through 200 mesh seive) were estimated using Bauer Mc-Nett calssifier. Each sample was classified into five classes as +28 mesh, +60mesh, +100mesh, +200 mesh, and -200mesh.

2.5. (b) OPTICAL PROPERTIES :-

Unprinted paper:-

(1)Brightness : TAPPI T452 om-92

(2)Opacity : TAPPI T425 om-91

(3)Specific Scattering coefficient :SCAN C:27:69

R_o = Reflectance factor of a single sheet of paper backed by a black cavity.

R_∞ = Intrinsic luminous reflectance factor of paper (Reflectance factor of an infinite pile of paper)

Printed paper strips:-

R_p = Mean reflectance factor of the print.

R_{pr}= Mean reflectance factor of the reverse side of the print.

R_x= The reflectance of the unprinted sheet backed with a sheet of the same paper printed with known amount of ink and known optical density.

All the reflectance values were measured using Technibrite Micro TB IC reflectometer, using the y-filter having dominant Wavelength of 557 nm.

RESULTS AND DISCUSSION

Results of printing experiments are given in Table-1 and Table-2
Properties of newsprints are given in Table-3.

3.1. EFFECTS OF PRINTING CONDITIONS ON INK TRANSFER :-

The amount of ink transferred to the paper, y, is plotted as a function of the amount of ink on the printing disc,x, at different printing conditions in Figure 1 to 4. The general behaviour of x-y relationship appears to be nearly same for all the samples

Fig. 5 shows the behaviour of y as a function of, x for SNP.1. Increasing the impression pressure and decreasing the printing speed, increased the total transfer in the high ink film thickness region where complete coverage was obtained

Similar behaviour was observed for all other newsprint samples.

3.2. DETERMINATION OF INK TRANSFER PARAMETERS :-

The ink transfer parameters were calculated as described in Appendix A. The experimental data were fitted to the Walker-Fetsko equation given as

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

The various terms in the equation are described in chapter -I.

The values of constants f, b and k were determined using the technique suggested by Walker[3].

b = Ink receptivity of paper and is defined as the ink immobilization capacity of paper. It is obtained during compression of paper.

k = The smoothness of paper during actual printing or printing smoothness.

f = The split of the free ink during decompression.

The values of f, b and k depend on the printing conditions. The technique suggested by W.C. Walker is as follows:

Linear approximation :-

The Walker-fetsko equation approached a much simpler form as $y = b(1-f) + fx$, for large values of x. for large values of x, a plot of y vs x gave a straight line with a slope of f and an intercept equal to b (1-f).

Substituting the values of b_1 and f_1 in equation-1, the values of k_1 were calculated from low ink-film data points. The average values of $k_1$was taken. By inserting the values of f_1, b_1 and k_1 in equation-1 the values of y were calculated for the corresponding x values. The errors in y or the difference from the data were determined and averaged over all the points. The average error so obtained was substantial. To minimize the average error the second approximation was done.

Second approximation :-

The calculated y values were plotted vs corresponding x values used for the straight line in the first approximation and a straight line was drawn through them.

b and f values were evaluated from the slope and intercept of the line and designated as b_c and f_c respectively.

The values of b and f determined from the second approximation were as:

$$b_2 = \frac{b_1^2}{b_c} \text{ and } f_2 = f_1 - \frac{(b_2 - b_1)(x-y)}{(x-b_2)^2}$$

x and y correspond to the highest ink film thickness data pint. By inserting b_2 and f_2 values in equation -3 to low ink- film thickness points, k values were calculated.

The average value of k was taken and designated as k_2.

Similarly substituting b_2, f_2 and k_2 values to equ-I the values of y were calculated for the corresponding x values. The errors in y values were determined and averaged over all the points. The reduction in average error was observed, which lead to third approximation.

Third Approximation :-

In third approximation the b and f values were calculated as follows:

$$b_3 = b + \frac{b_1^2(b_1-b_c)}{b_c^2}$$

$$f_3 = f_1 \div \frac{(b_3-b_1)(x-y)}{(x-b_3)^2}$$

Similar procedure was followed for calculating k_3 value and y values. The average error in y was also determined similarly. The average error in y was reduced.

The values of b, f and k obtained after third approximation are close to the actual values. The values of these constants one given in Table-4.

3.2.1. The effects of printing conditions on ink transfer parameter :-

The effects of printing conditions on ink transfer parameters are shown in figures-6 to 17.

3.2.1.a. Effect of printing forces :-

* b increased with increasing impression. It might be due to the increase in compression of the stock, so that the ink penetration increases. At high impression pressure the paper stock becomes more porous thereby increasing the

ink immobilization capacity of paper.

* f seems to decrease with force.
* k. the printing smoothness factor increases with the force. It is due to the flattening of the paper surface at higher impression pressure.

3.2.1.b. Effect of printing speed :-

* b decreases as speed is increased, perhaps the amount of ink immobilized by the paper decreases as the dwell time is reduced.
* f is reduced by increasing speed. It is due to the lesser surface compressibility of paper at higher speeds.
* k is almost independent of speed.

The normal range of values obtained in the present study is the same as reported in litrature.

3.3 PRINT DENSITY :-

Print density is an important aspect of print quality. It is defined as the optical contrast between a printed and unprinted surface.

In the present study the print density values of all the printed strips were determined using:

PD = log (R_∞/R_p)

The values of R_∞ and R_p can be measured using either a densitometer or a reflectometer. In the present study these values were measured using a Technibrite Micro TB 1c reflectometer, through the y-filter.

Print density as a function of x for different paper samples has been shown in figures 18 to 21. The Print density values increase with increase in x.

For all the printing conditions GNP gave the maximum print density and SNP3 had the minimum value. The print density values observed in the decreasing order were as GNP, PNP, SNP1, SNP3 and SNP2. Since the print density very strongly depend upon the intrinsic reflectance factor of the paper, so these values were essentially in the same order as can be seen from the Table-3.

Since all the papers studied in this group were of the same grade (news print), thus the effect of R_∞ is most significant on the print density. There is very little difference in x-y relationship of the papers studied.

Fig-22 shows a plot of x, for PD = 1.0 as a function of the intrinsic reflectance factor (R_∞). The ink required (x g/m^2) to obtain an optical density of 1.0 decreases with the increase in intrinsic reflectance factor.

3.4. PRINT-THROUGH PROPENSITY :-

Print through is the general name given to the phenomenon that a print on one side of a paper is partially visible on the reverse side of the sheet. This in corporates phenomenon variously known as show through, strike through etc. International agreement as to how print through should be evaluated appears to be lacking, but a widely used value of PT is determined as a logarithmic function analogous to the print density as:

Print density (PD) = $\log(R_\infty/Rp)$

Print through (PT) = $\log(R_\infty/Rp)$reverse

where R_∞ is the intrinsic reflectance factor of the paper and R_p is the reflectance factor of the printed portion. For print through both the values of R_∞ and R_p are measured on the reverse side of the paper with an opaque pad of the paper as background.

The print through is a particularly vital property when a paper is printed on both sides, when the reader wishes to be able to read what is printed on one side of the paper without being distubed by what is printed on the reverse.

Opacity of the paper is considered to be an important property in controlling the print through. However a plot between the print through and the opacity (fig-27) of the paper samples studied suggests that print through is not very well correlated with the opacity. It is generally recognized that the total print through incorporates the following three additive components(6).

1. Direct show through, PT_{st}: This is the unprinted opacity component, i.e. without ink penetratom into the sheet . At a given optical density, direct show-through depends on the original opacity of the paper. It is the least print show-through value possible for a given paper.
2. The pigment penetration, PT_p.
3. Loss of opacity due to vehicle oil penetration, PTv.

Thus the total print through (PT) can be expressed as

$$PT = PT_{st}$$

$$\log(R_\infty / R_P) = \log(R_\infty / R_x)$$

$$PT_P$$

$$+ \log (R_x/R_{PP'})$$

$$PT_V$$

$$+ \log (R_{PP'}/R_{Prev})$$

Larsson and Trollsas[8] proposed an elegant method of determining R_x by placing a single sheet of paper over the print and measuring the reflectance factor with an opaque pad of the paper as background and determined $R_{PP'}$ by measuring the reflectance factor on the reverse of print after extraction of the vehicle with a suitable solvent, normally petroleum ether. However Pauler and Bristow[7] suggested that R_x may be calculated for a homogeneous paper by direct application of the Kubelka-Munk theory :

$$R_x = [(R_O + R_P) - R_O R_P (R_\infty + 1/R_\infty)_{rev}]/(1 - R_O R_P)$$

In the present work the total print through has been divided into two components as:

$$\underset{PT}{\log(R_\infty / R_P)_{rev}} = \underset{PT_{st}}{\log(R_\infty / R_x)} + \underset{PT_{PP}}{\log(R_x/R_P)_{rev}}$$

The last term includes the effect due to ink penetration and vehicle separation. The values and PT, PT_{st} and PT_{PP} at print density (PD) = 1 are given in Table-5 at 200N force and 1m/sec speed.

Fig-28 shows show through component (PD=1) of print through as a function of opacity at 200 N printing force and 1m/sec speed. There appers to be a good relationship between the two. The show through decreases as the opacity is increased as was expected. Similar trends were also obtained for all other printing condions.

For the papers studied the porosity has a major contribution to the penetration of ink to the paper. Fig-29 shows a plot of the pigment penetration component of the print through (PD=1) as a function of porosity at 200 N printing force and 1m/sec speed. The pigment penetration increases with increase in porosity except for GNP where the print through is considerably higher in relation to porosity. Similar trends were also observed in all other printing condns. This may possibly due to a greater extent of vehicle separation Due to this large pigment penetration component the newsprint sample SNP2 gives much higher print through and poor print density values.

A Bauer Mc-Nett classification of the samples is given in Table-6. There appears to be a little correlationship between the total print through or the pigment penetration component of print through and any of the size fractions.

Fig-23 to 26 show print through as a function of χ (g/m²). Print through generally increases as the amount of χ is increased.

3.5. PROPORTION OF AREA COVERED BY INK :-

The smoothmess of paper plays a significant role in determining the optical coverage of a solid print. The ink required to obtain a coverage of 0.5 and 0.95 and the values of smoothness obtained in different testers are given in Table-7 at 200N force and 1m/sec speed.

Fig-29 and 30 show the ink required (x g/m^2) as a function of Bendtsen roughness for A = 0.5 and A = 0.95 respectively at printing force of 200 N and speed of 1 m/sec. It is evident, that the ink requirement increases with the increase in roughness value, with one exception. It may be due to experimental error.

The ink requirement for A = 0.95, for all the samples remained almost the same, due to the high ink-film thickness on the paper surface. It seems that the ink requirement for A = 0.5, to be a good measure for evaluation of covered area. Similar trends were observed under all other printing condition.

Fig-31 shows a plot of printing smoothness, k (dynamic smoothness during printing) as a function of Bendtsen Roughness. The k value decreases with increase in roughness. Fig 32-35 show optically covered area (A) as a function of y. It increases with increase in amount of y. For a given amount of ink the covered area increases with increase in printing force, whereas it decreases with increase in printing speed.

Fig-36 shows a plot of print density as a function of covered area. It was observed that for a given optically covered area the print density decreased with decreasing intrinsic reflectance factor of the paper. So to keep the print density constant, the covered area must be increased when the reflectance factor of the paper decreases.

CONCLUSION

In the present work ink transfer behaviour in offset printing for five Indian Newsprint samples has been studied. Of these 5 Newsprint samples three are standard newsprints made by different manufacturers, one is a pink newsprint meant for printing financial newspapers and one is a glazed newsprint for printing weekly inserts. The printing experiments have been conducted on a Laboratory Printability Tester (IGT model AIC_25) using standard non-drying oil type offset ink. The printing discs were rubber covered and hard metal surface backed the paper. Large data have been accumulated to give relationship between the amount of ink initially present on the printing disc and the amount of ink transferred to paper during printing. The data have been fitted to the famous Fetsko and Walker equation and the ink transfer parameters, namely b, f, and k have been determined. The prints have been evaluated for their print density and print through.

A comparison of Indian Newsprints with the newsprints manufactured in North American shows a marked difference in their printing behaviour even though they have nearly identical runnability properties.

For example to achieve a print density of 1.0 on an average 4 g/m^2 ink is required on the printing disc for North American newsprints, whereas for Indian Newsprint it was in the range of 10g/m^2 to 20 g/m^2 similarly, the show - through due to pigment penetration was in the range of 0.03 to 0.09 for Indian newsprints, which is double to that of N.American newsprints.

The show-through of Indian Newsprint is not necessarly related to the opacity. A large contribution to this is due to the pigment penetration.

REFERENCES

1. Bruno H. Michael & Walker, W.C., "Printing", Pulp and Paper Chemistry and Chemical Technology, Vol.IV, Edited by J.P. Casey, 1983.
2. Smook G.A. "Introduction to Paper End Uses", Handbook for Pulp and Paper Technologists, 1989.
3. Walker W.C., "Determination of Ink Transfer Parameters", TAPPI 64(5) : 71(1981).
4. Schaeffer W.D., Fisch A.B. and Zettlemoyer A.C., "Transfer and Penetration Aspects of Ink Receptivity", TAPPI 46(6) : 359 (1963).
5. Larsson. Lars. O. and Sunnerberg. G., "Optically covered area of Solid Prints related to paper properties", TAPPI 59(8) : 96(1976).
6. De Grace J.H., "The Print-Through Propensity of Newsprint", JPPS 19(5) : J 208(1993).
7. Bristow, J.A., "Print-Through and Ink Penetration - a Mathematical Treatment", Advances in Printing Science and Technology, W.H. Banks, Ed., Pentech Press, 19 : 137-145 (1988).
8. Larsson, L.O., Trollsas, P.O. Svensk Papperstidning 75(1972) 8 : 317.
9. Fetsko,J.M. and Walker, W.C.,Am.Ink Maker,33(11):38(1955).
10. Walker, W.C. and Fetsko J.M., Am. Ink Maker,33(12):38(1955).
11. Bery, Y.,TAPPI 62(8):89(1979).

APPENDIX - A

Method for evaluating parameters can be judged on the basis of how nearly they give the original values. Any differences must be due to method of working with the data and not to experimental errors.

Linear approximation :

Walker and Fetsko proposed following equation for determining the ink transfer parameters

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

Equation-1 approaches a much simpler linear form for large values of x. As x increases, the exponentials approach zero and drop one to give the following linear equation[3].

$$y = b(1-f) + fx. \qquad (2)$$

Thus, for large values of x, a plot of y vs x should give a straight line with a slope of f and an intercept equal to b(1-f). This technique has been widely used to evalute b and f from experimental data.

Solving Equation (1) for k gives

$$K = -\frac{1}{x}\ln\left[1-\frac{y}{b(1-e^{-x/b})(1-f)+fx}\right] \qquad (3)$$

The value of k is calculated from low ink-film data by inserting the values of b and f.

The plot of y vs x for the news print shows a distinct carvature over the full range. Common practice with such curves has been to draw the best straight line through the highest ink film points where the simplifying assumptions of Equation (1) are most nearly satisfied. The approximate values of b and f are determined from the plot. This first approximation of the constants is completed by using the approximate values for b and f and solving for k by applying eq. (2) to the low ink film points. The values of k increase steadily and in the high ink film points become indeterminate. This shows a basic misfit between the equation and data. So the average value of k over the low film thickness is considered.

The values of y are calculated by inserting the approximated values of the constants and the original value of x in Eq. (1). The errors in y as the difference from the data are determined. These errors are substantial and would lead to the conclusion that this equation does not fit the data well. So, it is very important to find more accurate method for determining the constants and fitting the transfer equation to such data.

Second approximation :

One way to get better solution for the transfer parameters is to make a second approximation correcting for the error illustrated above. The steps of second approximation are:-

1. Using the first approximation values for constants, b, f and k in eq. (1)y values are calculated for the corresponding values of x for the data points used for the straight line in the first approximation.

2. These calculated y values are plotted against the corresponding x values to draw a straight line through them similar to the line drawn in first approximation .

3. b and f are evaluated from the slope and intercept of this line and designated as b_c and f_c.

4. Comparison of b_c with b should show the error in drawing a straight line in this way with these data. A second approximation to the true values of b can be determined from the equation :

$$b_2 = \frac{b_1^2}{b_c} \qquad (4)$$

5. The corresponding correction for f_1 can be determined best by differentiating the linear transfer eq^n 2 for f with respect to b for the constants y and x.

$$df/db = y\text{-}x/(x\text{-}b)^2 \qquad (5)$$

Equation 5 is applied to the highest ink-film data point. f_2 is obtained as :

$$f_2 = f_1 - \frac{(b_2 - b_1)(x - y)}{(x - b_2)^2} \qquad (6)$$

6. b_2 and f_2 are applied to eq^n 3 in the low ink-film points to solve for k. The average value of k is obtained and designated as k_2

These second approximation value for the parameter should be closer to the true values and should make the equation fit the data significantly better.

Third approximation :

One difficulty with the second approximation solution is the amount of curvature, and hence the error decreases as b decreases. The error determined for the second approximation involves use of lower values of b and hence the calculated corrction is too small. Thus an improvement can made by assuming the correction to be proportional to b. This leads to third approximation to b :

$$b_3 = b_1 + \frac{b_1^2 (b_1 - b_e)}{b_e^2} \qquad ...(7)$$

The errors are reduced. This shows a significant improvement and suggests that an even greater empirical correction can be done.

TABLE-1

S. No.	a	b	c	X(g/m²)	Y(g/m²)
Force,200N,Speed 1m/s					
1B	269.7165	270.1094	269.9989	38.3329	10.7808
5B	269.7169	270.0134	269.9349	28.9277	7.65877
9B	269.7171	269.939	269.8684	21.6495	6.88802
34B	269.7325	269.9451	269.8745	20.7421	6.88802
30B	269.7207	269.8284	269.78	10.5076	4.7221
38B	269.7013	269.8035	269.7575	9.97104	4.48794
23B	269.7408	269.8072	269.7782	6.47825	2.82936
26B	269.7206	269.7854	269.7624	6.32215	2.24397
13B	269.7132	269.7519	269.7412	3.77573	1.04393
18B	269.713	269.74	269.7342	2.63423	0.56587
71B	269.7124	269.72	269.7196	0.74149	0.03903
73B	269.7315	269.7366	269.7364	0.49758	0.01951
34C	269.7097	270.0502	269.9494	33.2205	9.83445
2C	269.7179	269.9628	269.882	23.8934	7.88317
6C	269.7171	269.8878	269.8264	16.6542	5.99043
22C	269.7332	269.8984	269.8382	16.1176	5.87335
10C	269.7166	269.837	269.7915	11.7467	4.43916
14C	269.7164	269.7957	269.764	7.73683	3.09278
18C	269.7141	269.7686	269.7471	5.31724	2.09763
23C	269.7404	269.7867	269.77	4.51721	1.62932
39C	269.7	269.7363	269.7222	3.54157	1.37565
32C	269.7191	269.7324	269.7292	1.2976	0.3122
71C	269.73	269.738	269.7373	0.78051	0.06829
72C	269.7308	269.7363	269.736	0.5366	0.02927
1D	269.7089	270.0075	269.925	29.1326	8.04903
5D	269.7107	269.9589	269.8832	24.2154	7.38559
9D	269.715	269.8889	269.8206	16.9664	6.66362
29D	269.7211	269.8711	269.8125	14.6346	5.71725
13D	269.7114	269.8423	269.7903	12.7711	5.07333
17D	269.7104	269.804	269.7657	9.13199	3.7367
21D	269.7101	269.7766	269.75	6.48801	2.5952
36D	269.7075	269.7558	269.7393	4.71234	1.60981
25D	269.7096	269.7566	269.7404	4.58551	1.58054
30D	269.7009	269.7334	269.7244	3.17083	0.87808
34D	269.7197	269.7429	269.739	2.26348	0.3805
71D	269.7117	269.7203	269.7201	0.83905	0.01951
72D	269.7133	269.7206	269.7204	0.71222	0.01951
5E	269.7092	270.168	270.0724	44.7624	9.32712
9E	269.7099	269.9615	269.8859	24.5471	7.37584
13E	269.7092	269.8983	269.8336	18.4494	6.31239
33E	269.7085	269.8067	269.7648	9.58078	4.08793
17E	269.7309	269.7996	269.7715	6.70265	2.74155

21E	269.7069	269.747	269.7331	3.91232	1.35614
29E	269.6992	269.7316	269.7216	3.16107	0.97564
25E	269.7386	269.7707	269.7615	3.1318	0.89759
71E	269.7118	269.7344	269.7294	2.20495	0.48782
72E	269.7292	269.7392	269.7386	0.97564	0.05854
1G	269.7313	269.7373	269.7371	0.58538	0.01951
5G	269.7007	269.981	269.8766	27.3472	10.1857
9G	269.7025	269.9235	269.8507	21.5616	7.10266
13G	269.701	269.842	269.787	13.7565	5.36602
17G	269.7013	269.7859	269.7505	8.25391	3.45377
21G	269.7006	269.7476	269.7305	4.58551	1.66834
71G	269.7001	269.7222	269.7175	2.15616	0.45855
72G	269.7112	269.7214	269.7206	0.99515	0.07805
Force-4	269.7301	269.7368	269.7361	0.65368	0.06829
6B	269.7261	270.1346	270.0376	39.8549	9.46371
10B	269.7268	270.0159	269.9274	28.2058	8.63441
36B	269.7267	269.9359	269.8604	20.4104	7.36608
29B	269.7336	269.9196	269.8457	18.1469	7.20998
24B	269.7088	269.8433	269.7858	13.1224	5.60993
33B	269.7406	269.7969	269.774	5.49285	2.23422
14B	269.72	269.7752	269.7483	5.38553	2.62447
17B	269.7228	269.7652	269.7496	4.13671	1.522
74B	269.7223	269.7513	269.7432	2.82936	0.79027
36C	269.7133	269.7235	269.7226	0.99515	0.08781
1C	269.7096	269.9976	269.9064	28.0984	8.89784
5C	269.7259	269.9668	269.8808	23.5032	8.3905
28C	269.7248	269.9103	269.8424	18.0981	6.6246
9C	269.7333	269.8729	269.8172	13.6199	5.43431
13C	269.7243	269.8576	269.8038	13.0053	5.24894
17C	269.7239	269.8026	269.7685	7.67829	3.32693
25C	269.7234	269.7809	269.7554	5.60993	2.48788
21C	269.7388	269.7776	269.7612	3.78548	1.60005
30C	269.7222	269.7429	269.7356	2.01957	0.71222
74C	269.719	269.7355	269.7308	1.60981	0.45855
75C	269.7312	269.7416	269.7392	1.01467	0.23415
	269.7312	269.738	269.737	0.66344	0.09756
2D					
6D	269.7195	270.0689	269.9721	34.0889	9.4442
10D	269.721	269.9596	269.8692	23.2788	8.81979
14D	269.7221	269.8914	269.8163	16.5176	7.32706
18D	269.7216	269.8418	269.7828	11.7272	5.75628
22D	269.7215	269.8079	269.7664	8.42953	4.04891
26D	269.7206	269.7802	269.7533	5.81481	2.62447

32D	269.7205	269.7644	269.7479	4.28306	1.60981
35D	269.6998	269.7265	269.7181	2.60496	0.81954
74D	269.7195	269.739	269.7352	1.9025	0.37074
2E	269.7125	269.7213	269.7207	0.85856	0.05854
6E	269.7202	270.2103	270.104	47.8161	10.3711
10E	269.721	270.0158	269.9281	28.7619	8.55636
14E	269.7213	269.9315	269.8584	20.508	7.13193
35E	269.721	269.8117	269.7685	8.84905	4.21476
18E	269.7305	269.7889	269.7617	5.69774	2.65374
22E	269.72	269.7661	269.7458	4.4977	1.98055
31E	269.6994	269.7265	269.7166	2.64398	0.96588
26E	269.7388	269.7654	269.7565	2.5952	0.86832
74E	269.6988	269.7175	269.7125	1.82445	0.48782
2G	269.7315	269.7393	269.7382	0.761	0.10732
6G	269.7139	270.036	269.9474	31.4254	8.64417
10G	269.7152	269.9356	269.8572	21.5031	7.64902
14G	269.7144	269.8519	269.7921	13.415	5.83433
18G	269.7143	269.797	269.7518	8.06854	4.40989
22G	269.7142	269.7592	269.7403	4.39038	1.84396
74G	269.7139	269.7361	269.7309	2.16592	0.50733
Force-2	269.7128	269.7198	269.7191	0.68295	0.06829
35B					
11B	269.7338	269.9335	269.8801	19.4835	5.20992
27B	269.7189	269.906	269.8548	18.2542	4.99528
39B	269.7084	269.8248	269.7881	11.3564	3.5806
22B	269.7142	269.8121	269.777	9.55152	3.4245
25B	269.7406	269.8058	269.785	6.36117	2.02933
16B	269.7085	269.7728	269.7557	6.27337	1.66834
20B	269.7131	269.7462	269.7394	3.22937	0.66344
31B	269.7129	269.7352	269.7314	2.17568	0.37074
72B	269.7192	269.7319	269.7295	1.23906	0.23415
4C	269.7135	269.7196	269.7194	0.59514	0.01951
41C	269.7174	269.9185	269.8674	19.6201	4.98552
27C	269.7146	269.8776	269.8338	15.9029	4.2733
8C	269.734	269.8849	269.8405	14.7224	4.33184
12C	269.7159	269.8611	269.8193	14.1663	4.07818
	269.7158	269.8157	269.7841	9.74664	3.08302
16C		Continued......			
42C	269.7143	269.7799	269.7594	6.4002	2.00006
20C	269.7008	269.7631	269.7442	6.07824	1.84396
24C	269.7143	269.7594	269.7447	4.40014	1.43419
37C	269.739	269.781	269.7688	4.09769	1.19028
38C	269.7125	269.7271	269.724	1.42443	0.30245
73C	269.6991	269.7121	269.7091	1.26833	0.29269

3D	269.7135	269.721	269.7207	0.73173	0.02927
7D	269.7099	269.9903	269.9311	27.3569	5.77579
11D	269.7104	269.913	269.8549	19.7665	5.66847
15D	269.7112	269.868	269.8179	15.298	4.88796
19D	269.7106	269.8218	269.7844	10.8491	3.64889
23D	269.7101	269.7891	269.762	7.70756	2.64398
27D	269.7093	269.7662	269.7478	5.55139	1.79518
31D	269.7095	269.7489	269.7383	3.84402	1.03418
38D	269.7137	269.7467	269.7396	3.21961	0.6927
73D	269.707	269.7262	269.7226	1.87323	0.35123
3E	269.7311	269.7375	269.7374	0.62441	0.00976
7E	269.71	270.1112	270.045	39.1427	6.45874
11E	269.71	269.9242	269.8707	20.8982	5.21967
15E	269.7089	269.8711	269.8241	15.8249	4.58551
34E	269.7088	269.7896	269.761	7.88317	2.79033
19E	269.7309	269.7936	269.7712	6.11726	2.18543
30E	269.7071	269.7406	269.7309	3.26839	0.94637
23E	269.7385	269.7691	269.7622	2.98546	0.67319
27E	269.712	269.7403	269.7336	2.76106	0.65368
73E	269.7118	269.7298	269.7271	1.75615	0.26342
3G	269.7312	269.7353	269.7349	0.40001	0.03903
7G	269.7027	269.9565	269.8867	24.7617	6.80997
11G	269.702	269.8923	269.84	18.5664	5.1026
15G	269.702	269.821	269.781	11.6101	3.90256
19G	269.701	269.7731	269.7486	7.03436	2.39032
23G	269.7001	269.7404	269.7297	3.93183	1.04393
73G	269.7	269.7189	269.7159	1.84396	0.29269
Force -	269.7132	269.719	269.7188	0.56587	0.01951
4B					
8B	269.7264	270.0619	269.9915	32.7327	6.86851
12B	269.7265	269.9697	269.9059	23.7276	6.22458
37B	269.7265	269.9004	269.8445	16.9664	5.45383
28B	269.7341	269.9064	269.8407	16.8103	6.40995
32B	269.7213	269.8488	269.8023	12.4394	4.53673
21B	269.7075	269.7651	269.7445	5.61969	2.00982
15B	269.7404	269.7927	269.7752	5.1026	1.70737
	269.7228	269.7567	269.7467	3.30742	0.97564
19B					
76B	269.7229	269.747	269.7416	2.35129	0.52685
35C	269.731	269.7358	269.7354	0.46831	0.03903
3C	269.7218	270.0606	269.9781	33.0547	8.04903
40C	269.7252	269.9378	269.8803	20.7421	5.60993
7C	269.7021	269.8662	269.8166	16.0103	4.83917
29C	269.7271	269.8828	269.8342	15.1907	4.74161

11C	269.7333	269.8613	269.8189	12.4882	4.13671
15C	269.7245	269.8389	269.7999	11.1613	3.805
19C	269.7231	269.792	269.7667	6.72216	2.46837
26C	269.7234	269.7723	269.7528	4.77088	1.9025
31C	269.7386	269.7746	269.7627	3.5123	1.16101
33C	269.706	269.7194	269.7158	1.30736	0.35123
76C	269.7058	269.7172	269.7142	1.11223	0.29269
4D	269.731	269.7367	269.7362	0.55611	0.04878
8D	269.7204	270.0007	269.9303	27.3472	6.86851
12D	269.7208	269.9274	269.8603	20.1567	6.54654
16D	269.7219	269.8638	269.81	13.8443	5.24894
20D	269.7214	269.8241	269.7819	10.0198	4.1172
24D	269.721	269.7928	269.7618	7.0051	3.02448
28D	269.7204	269.7727	269.7537	5.1026	1.85372
33D	269.7207	269.7575	269.7458	3.59036	1.1415
37D	269.7137	269.7409	269.7334	2.65374	0.73173
75D	269.7063	269.7225	269.7194	1.58054	0.30245
4E	269.7127	269.7177	269.7176	0.48782	0.00976
8E	269.7214	270.1215	270.0472	39.0354	7.24901
12E	269.7213	269.9693	269.9069	24.1959	6.08799
16E	269.7214	269.8991	269.8437	17.3371	5.40505
20E	269.7211	269.799	269.7671	7.60024	3.11229
32E	269.72	269.7588	269.7453	3.78548	1.31711
24E	269.7378	269.7618	269.7553	2.34154	0.63417
28E	269.6993	269.721	269.7145	2.11714	0.63417
75E	269.6987	269.7151	269.7114	1.60005	0.36099
4G	269.7127	269.7175	269.7174	0.46831	0.00976
8G	269.7155	269.9756	269.8844	25.3764	8.89784
12G	269.7154	269.905	269.8445	18.4981	5.90262
16G	269.7143	269.8301	269.7856	11.2979	4.3416
20G	269.7145	269.7835	269.7552	6.73192	2.76106
24G	269.7185	269.756	269.7439	3.65865	1.18052
75G	269.7125	269.728	269.7257	1.51224	0.2244
	269.7129	269.7186	269.7183	0.55611	0.02927
B=SNP1		X=(b-a)/A			
C=GNP		Y=(b-c)/A			
D=SNP2					
E=PNP					
G=SNP3					

TABLE-2

Samples	a.Rp	a.Rpr	Area	P.D	Rx	P.T.	P.T.st	PTpp	
200,1m/s									
1B	4.38	46.304	0.992	1.120	54.20	0.096	0.028	0.068	
5B	4.584	46.766	0.988	1.100	54.21	0.092	0.028	0.064	
9B	4.882	46.268	0.983	1.070	54.23	0.097	0.028	0.069	
34B	5.642	42.562	0.968	1.010	54.26	0.133	0.027	0.105	
30B	7.094	47.272	0.941	0.911	54.33	0.087	0.027	0.060	
38B	6.588	47.29	0.951	0.943	54.31	0.087	0.027	0.060	
23B	9.462	48.29	0.897	0.786	54.45	0.078	0.026	0.052	
26B	13.208	49.002	0.828	0.641	54.64	0.072	0.024	0.047	
13B	19.6	51.364	0.709	0.470	54.99	0.051	0.022	0.030	
18B	28.146	52.07	0.550	0.310	55.50	0.045	0.018	0.028	
71B	45.06	53.58	0.236	0.110	56.69	0.033	0.008	0.024	
73B	48.5	53.76	0.170	0.078	56.96	0.031	0.006	0.025	
34C	4.57	53.75	0.977	1.193	69.08	0.123	0.014	0.109	
2C	5.08	56.66	0.970	1.150	69.09	0.100	0.014	0.086	
6C	4.78	62.07	0.974	1.170	69.08	0.060	0.014	0.046	
22C	7.22	57.6	0.939	0.990	69.13	0.093	0.014	0.079	
10C	4.96	62.51	0.972	1.160	69.09	0.057	0.014	0.043	
14C	7.36	63.68	0.937	0.986	69.13	0.049	0.014	0.036	
18C	11.37	64.69	0.878	0.797	69.21	0.042	0.013	0.029	
23C	16.56	62.23	0.802	0.634	69.31	0.059	0.013	0.047	
39C	15.22	64.95	0.822	0.671	69.28	0.041	0.013	0.028	
32C	32.1	64.89	0.574	0.347	69.69	0.041	0.010	0.031	
71C	51.27	68.02	0.294	0.143	70.32	0.021	0.006	0.014	
72C	58.56	68	0.187	0.086	70.64	0.021	0.004	0.017	
1D	5.34	36.73	0.997	0.988	50.15	0.151	0.016	0.135	
5D	5.82	37.02	0.987	0.951	50.17	0.147	0.015	0.132	
9D	6.03	37.59	0.983	0.936	50.18	0.141	0.015	0.125	
29D	5.62	42.02	0.991	0.966	50.16	0.092	0.015	0.077	
13D	6.86	40.42	0.965	0.880	50.20	0.109	0.015	0.094	
17D	7.97	42.89	0.941	0.814	50.23	0.083	0.015	0.069	
21D	11.02	43.96	0.876	0.674	50.33	0.073	0.014	0.059	
36D	13.7	46.01	0.819	0.579	50.41	0.053	0.013	0.040	
25D	15.64	45.98	0.777	0.521	50.48	0.053	0.013	0.041	
30D	18.78	47.1	0.710	0.442	50.58	0.043	0.012	0.031	
34D	28.08	48.06	0.511	0.267	50.92	0.034	0.009	0.025	

71D	41.24	49	0.230	0.117	51.46	0.026	0.004	0.021	
72D	43.78	49.2	0.175	0.091	51.58	0.024	0.003	0.021	
1E	4.2	47.28	0.991	1.170	57.23	0.118	0.035	0.083	
5E	4.6	49	0.984	1.130	57.25	0.102	0.035	0.068	
9E	5.03	48.97	0.977	1.090	57.27	0.103	0.035	0.068	
13E	6.44	51.03	0.952	0.984	57.35	0.085	0.034	0.051	
33E	9.73	50.73	0.896	0.800	57.54	0.087	0.033	0.055	
17E	15.94	53.01	0.790	0.590	57.92	0.068	0.030	0.038	
21E	**20.98**	**53.58**	**0.703**	**0.471**	**58.25**	0.064	0.027	0.036	
29E	18.39	52.79	0.748	0.528	58.08	0.070	0.029	0.041	
25E	27.14	53.34	0.598	0.359	58.69	0.066	0.024	0.041	
71E	**44.95**	**55.98**	**0.293**	**0.147**	60.17	0.045	0.013	0.031	
72E	48.06	56.22	0.239	0.118	60.48	0.043	0.011	0.032	
1G	5.67	43.51	0.974	0.995	55.54	0.110	0.004	0.106	
5G	6.15	47.29	0.965	0.959	55.54	0.073	0.004	0.070	
9G	6.21	49.81	0.964	0.955	55.54	0.051	0.004	0.047	
13G	8.1	50.84	0.927	0.840	55.55	0.042	0.004	0.039	
17G	**13.47**	**46.43**	**0.823**	**0.620**	**55.59**	**0.081**	**0.003**	**0.078**	
21G	24.31	47.9	0.614	0.360	55.68	0.068	0.003	0.065	
71G	39.36	55	0.322	0.153	55.82	0.008	0.002	0.006	
72G	41.4	55.12	0.283	0.131	55.84	0.007	0.001	0.006	
200,2.3m/s									
35B	7.458	45.842	0.935	0.889	54.35	0.101	0.027	0.074	
11B	7.672	48.112	0.931	0.877	54.36	0.080	0.027	0.053	
27B	8.998	48.804	0.906	0.808	54.43	0.073	0.026	0.047	
39B	10.32	47.914	0.882	0.748	54.49	0.081	0.026	0.056	
22B	14.132	49.88	0.811	0.612	54.69	0.064	0.024	0.040	
25B	14.69	50.61	0.800	0.595	54.72	0.058	0.024	0.034	
16B	26.25	52.26	0.586	0.343	55.38	0.044	0.019	0.025	
20B	30.76	52.35	0.502	0.274	55.66	0.043	0.016	0.027	
31B	41.32	52.93	0.306	0.146	56.40	0.038	0.011	0.028	
72B	49.06	53.6	0.162	0.073	57.01	0.033	0.006	0.027	
4C	5.83	62.93	0.959	1.088	69.10	0.054	0.014	0.041	
41C	9.89	60.9	0.900	0.858	69.18	0.069	0.013	0.055	
27C	8.94	59.99	0.913	0.902	69.16	0.075	0.013	0.062	
8C	12.2	61.42	0.866	0.767	69.22	0.065	0.013	0.052	
12C	8.73	63.98	0.917	0.912	69.15	0.047	0.014	0.034	

16C	13.37	64.42	0.849	0.727	69.25	0.044	0.013	0.031	
42C	20.23	62.76	0.748	0.547	69.39	0.056	0.012	0.044	
20C	13.66	64.48	0.844	0.717	69.25	0.044	0.013	0.031	
24C	21.24	63.21	0.733	0.526	69.41	0.053	0.012	0.041	
37C	38.77	65.6	0.477	0.265	69.88	0.036	0.009	0.027	
38C	37.91	65.71	0.489	0.275	69.86	0.036	0.009	0.027	
73C	58.34	67.64	0.190	0.087	70.63	0.023	0.004	0.019	
3D	7.88	39.78	0.943	0.819	50.23	0.116	0.015	0.101	
7D	7.67	38.87	0.948	0.831	50.22	0.126	0.015	0.111	
11D	8.22	40.65	0.936	0.800	50.24	0.107	0.015	0.092	
15D	9.88	42.24	0.900	0.721	50.29	0.090	0.014	0.076	
19D	11.77	43.77	0.860	0.645	50.35	0.075	0.014	0.061	
23D	14.61	45.49	0.799	0.551	50.44	0.058	0.013	0.045	
27D	19.79	46.22	0.688	0.419	50.62	0.051	0.012	0.039	
31D	23.45	47.28	0.610	0.346	50.75	0.041	0.010	0.031	
38D	30.45	48.11	0.460	0.232	51.01	0.034	0.008	0.025	
73D	44.3	49.16	0.164	0.086	51.60	0.024	0.003	0.021	
3E	7.51	49.16	0.934	0.917	57.41	0.101	0.034	0.067	
7E	6.78	49.73	0.947	0.901	57.37	0.096	0.034	0.062	
11E	7.4	50.38	0.936	0.882	57.41	0.090	0.034	0.057	
15E	10.67	51.34	0.880	0.765	57.60	0.082	0.032	0.050	
34E	11.18	50.99	0.871	0.744	57.63	0.085	0.032	0.053	
19E	19.68	53.34	0.726	0.499	58.16	0.066	0.028	0.038	
30E	26.14	52.92	0.615	0.375	58.61	0.069	0.025	0.044	
23E	23.9	54.02	0.653	0.414	58.45	0.060	0.026	0.034	
27E	35.26	54.41	0.459	0.245	59.32	0.057	0.019	0.038	
73E	53.42	56.24	0.148	0.072	61.03	0.043	0.007	0.036	
3G	6.98	49.19	0.949	0.904	55.55	0.056	0.004	0.053	
7G	7.89	49.34	0.931	0.906	55.55	0.055	0.004	0.051	
11G	8.89	50.84	0.912	0.799	55.56	0.042	0.004	0.039	
15G	12.03	51.57	0.851	0.668	55.58	0.036	0.003	0.033	
19G	17.6	47.27	0.743	0.502	55.62	0.074	0.003	0.071	
23G	27.81	47.97	0.546	0.304	55.71	0.067	0.002	0.065	
73G	48.96	54.94	0.136	0.058	55.92	0.008	0.001	0.008	
400,1m/s								0.000	
2B	4.26	45.21	0.994	1.132	54.20	0.107	0.028	0.079	
6B	4.63	44.67	0.987	1.096	54.21	0.112	0.028	0.084	

10B	4.71	45.09	0.986	1.099	54.22	0.108	0.028	0.080	
36B	5.4	44.16	0.973	1.029	54.25	0.117	0.027	0.089	
29B	4.7	47.52	0.986	1.090	54.22	0.085	0.028	0.057	
24B	9.66	49.88	0.894	0.777	54.46	0.064	0.026	0.038	
33B	6.89	49.24	0.945	0.924	54.32	0.070	0.027	0.043	
14B	13.41	51.15	0.824	0.634	54.65	0.053	0.024	0.029	
17B	20.27	51.09	0.697	0.455	55.03	0.054	0.021	0.032	
74B	38.94	52.64	0.350	0.173	56.22	0.041	0.012	0.029	
36C	3.03	57.17	1.000	1.372	69.05	0.096	0.014	0.082	
1C	4.15	56.27	0.984	1.235	69.07	0.103	0.014	0.089	
5C	3.69	61.27	0.990	1.286	69.06	0.066	0.014	0.052	
28C	4.91	59.9	0.972	1.162	69.08	0.076	0.014	0.062	
9C	4.61	60.67	0.977	1.190	69.08	0.070	0.014	0.056	
13C	3.92	63.52	0.987	1.260	69.07	0.050	0.014	0.036	
17C	4.57	63.88	0.977	1.193	69.08	0.048	0.014	0.034	
25C	10.05	62.75	0.897	0.851	69.18	0.056	0.013	0.042	
21C	19.35	63.67	0.761	0.567	69.37	0.049	0.012	0.037	
30C	23.93	64.37	0.694	0.474	69.48	0.045	0.011	0.033	
74C	36.64	67.36	0.510	0.289	69.82	0.025	0.009	0.016	
75C	44.94	67.38	0.386	0.201	70.08	0.025	0.008	0.017	
2D	5.63	35.7	0.991	0.965	50.16	0.163	0.015	0.148	
6D	5.53	34.69	0.993	0.973	50.16	0.176	0.015	0.160	
10D	6.2	36.39	0.979	0.923	50.18	0.155	0.015	0.140	
14D	5.92	38.64	0.985	0.943	50.17	0.129	0.015	0.113	
18D	6.92	41.55	0.964	0.876	50.20	0.097	0.015	0.082	
22D	8.78	42.71	0.924	0.772	50.26	0.085	0.015	0.071	
26D	11.29	45.27	0.870	0.663	50.34	0.060	0.014	0.046	
32D	16.95	46.82	0.749	0.487	50.52	0.045	0.012	0.033	
35D	24.43	47.84	0.589	0.328	50.78	0.036	0.010	0.026	
74D	37.1	49.16	0.318	0.163	51.28	0.024	0.006	0.018	
2E	3.66	46.75	1.000	1.229	57.20	0.123	0.035	0.088	
6E	4.18	47.37	0.991	1.172	57.22	0.117	0.035	0.082	
10E	4.3	48.51	0.989	1.159	57.23	0.107	0.035	0.072	
14E	5.25	50.5	0.973	1.073	57.28	0.089	0.035	0.055	
35E	7.62	50.84	0.932	0.911	57.42	0.086	0.034	0.053	
18E	8.82	52.32	0.912	0.847	57.49	0.074	0.033	0.041	
22E	15.24	53.38	0.802	0.610	57.88	0.065	0.030	0.035	

31E	15.6	52.46	0.795	0.600	57.90	0.073	0.030	0.043	
26E	22.6	53.45	0.676	0.439	58.36	0.065	0.027	0.019	
74E	41.6	55.9	0.350	0.180	59.86	0.045	0.016	0.055	
2G	4.58	47.66	0.995	1.087	55.53	0.070	0.004	0.066	
6G	4.93	48.01	0.989	1.055	55.53	0.067	0.004	0.063	
10G	5.18	48.97	0.984	1.034	55.53	0.058	0.004	0.055	
14G	6.08	47.39	0.966	0.964	55.54	0.073	0.004	0.069	
18G	11.58	52.13	0.860	0.685	55.58	0.031	0.003	0.028	
22G	19.12	47.2	0.714	0.467	55.63	0.074	0.003	0.071	
74G	41.4	55.12	0.283	0.131	55.84	0.007	0.001	0.006	
400,2.3m/s									
4B	4.76	47.13	0.985	1.084	54.22	0.089	0.028	0.061	
8B	5.28	47.18	0.975	1.039	54.25	0.088	0.027	0.061	
12B	5.03	47.84	0.980	1.060	54.23	0.082	0.028	0.054	
37B	5.79	43.57	0.966	1.000	54.27	0.123	0.027	0.095	
28B	5.43	48.66	0.972	1.027	54.25	0.075	0.027	0.047	
32B	11.29	49.1	0.864	0.709	54.54	0.071	0.025	0.046	
21B	12.88	50.66	0.834	0.652	54.62	0.057	0.024	0.033	
15B	17.54	51.85	0.747	0.518	54.87	0.047	0.022	0.025	
19B	23.79	52.28	0.631	0.385	55.23	0.044	0.020	0.024	
76B	46.64	52.98	0.210	0.095	56.81	0.038	0.007	0.030	
35C	4.32	57.16	0.981	1.218	69.07	0.096	0.014	0.082	
3C	3.42	62.16	0.994	1.319	69.06	0.060	0.014	0.046	
40C	4.7	59.74	0.976	1.181	69.08	0.077	0.014	0.063	
7C	4.07	63.37	0.985	1.244	69.07	0.051	0.014	0.037	
29C	6.15	60.99	0.954	1.060	69.11	0.068	0.014	0.054	
11C	4.72	63.49	0.975	1.179	69.08	0.051	0.014	0.037	
15C	7.9	62.78	0.929	0.955	69.14	0.056	0.014	0.042	
19C	7.52	64.48	0.934	0.977	69.13	0.044	0.014	0.030	
26C	14.51	62.64	0.832	0.692	69.27	0.056	0.013	0.044	
31C	30.15	63.8	0.603	0.374	69.63	0.049	0.011	0.038	
33C	28.14	65.26	0.632	0.404	69.58	0.039	0.011	0.028	
76C	54.04	67.72	0.250	0.121	70.44	0.023	0.006	0.017	
4D	6.21	38.09	0.979	0.922	50.18	0.135	0.015	0.120	
8D	6.85	38.19	0.965	0.880	50.20	0.134	0.015	0.119	
12D	6.37	39.79	0.975	0.912	50.19	0.116	0.015	0.101	
16D	7.75	41.62	0.946	0.826	50.23	0.097	0.015	0.082	

20D	8.18	44.04	0.937	0.803	50.24	0.072	0.015	0.057	
24D	11.69	43.77	0.862	0.648	50.35	0.075	0.014	0.061	
28D	15.73	46.61	0.775	0.519	50.48	0.047	0.013	0.035	
33D	18.14	47.07	0.724	0.457	50.56	0.043	0.012	0.031	
37D	27.64	47.95	0.521	0.274	50.90	0.035	0.009	0.026	
75D	43.1	49.16	0.190	0.098	51.55	0.024	0.004	0.021	
4E	4.58	49	0.984	1.131	57.25	0.102	0.035	0.068	
8E	4.82	49.64	0.980	1.110	57.26	0.097	0.035	0.062	
12E	5.12	50.51	0.975	1.083	57.28	0.089	0.035	0.055	
16E	6.45	51.94	0.952	0.983	57.35	0.077	0.034	0.043	
36E	8.83	51.48	0.911	0.847	57.49	0.081	0.033	0.048	
20E	12.17	53.09	0.854	0.707	57.69	0.068	0.032	0.036	
32E	19.29	53.11	0.732	0.507	58.14	0.067	0.028	0.039	
24E	20.19	53.99	0.717	0.488	58.20	0.060	0.028	0.033	
28E	28.46	53.8	0.575	0.338	58.78	0.062	0.023	0.038	
75E	49.32	56.08	0.218	0.106	60.60	0.044	0.010	0.034	
4G	5.59	44.07	0.976	1.000	55.54	0.104	0.004	0.100	
8G	5.6	49.11	0.976	1.000	55.54	0.057	0.004	0.053	
12G	6.15	50.25	0.965	0.959	55.54	0.047	0.004	0.043	
16G	8.64	51.05	0.917	0.812	55.56	0.040	0.004	0.037	
20G	16.18	52.19	0.771	0.539	55.61	0.031	0.003	0.028	
24G	31.72	47.54	0.470	0.247	55.74	0.071	0.002	0.069	
75G	45.8	54.32	0.198	0.087	55.89	0.013	0.001	0.012	

TABLE - 3 PROPERTIES OF UNPRINTED NEWSPRINT SAMPLES

SAMPLE NAME/ PROPERTIES	SNP. 1	GNP	SNP. 2	SNP. 3	PNP.
GRAMMAGE (g/m^2)	45	50	45	45	45
CALIPER (μm)	73	84	72	74	76
APPARENT DENSITY (g/cm^3)	0.6164	0.5952	0.625	0.6081	0.5921
BULK (cm^3/g)	1.622	1.68	1.6	1.6445	1.689
COBB NUMBER (g/m^2)	54	49	72.8	77	73.5
BENDTSEN SMOOTHNESS(ml/min.)	382/240	80/38.125	197.5/ 123.125	267.5/215	186/104.5
PARKER PRINT SURF ROUGHNESS (μm)	>6	3.1	5.13	>6	4.8
POROSITY (ml /min.)	387.5	26.3	490	428.6	345.5
SPECIFIC SCATTERING Coefficient , s (m^2/kg)	45	80	39	43	46.5
OPACITY	93.44	96.72	96.2	99.1	91.88
BRIGHTNESS	51.66	68.36	49.08	51.3	41.74
GLOSS	11.94	28.8	11.93	9.28	10.5
Ro	54	69	50	55.5	57
R∞	57.79	71.34	51.98	56.01	62.04

TABLE- 4 : VALUES OF INK TRANSFER PARAMETERS UNDER DIFFERENT PRINTING CONDITIONS

Samples / Printing conditions	SNP.1	GNP	SNP2	SNP3	PNP.
Force -200N, f	0.168	0.2243	0.0993	0.136	0.139
Speed-1m/s b (g/m^2)	5.176	3.094	5.77	5.4	4.2
k (m^2/g)	0.116	0.202	0.12	0.149	0.135
Force-400N f	0.054	0.23	0.07	0.114	0.1095
Speed-1m/s b (g/m^2)	7.78	3.247	7.43	5.725	5.94
k (m^2/g)	0.129	0.268	0.16	0.16851	0.206
Force-200N f	0.164	0.1365	0.0185	0.208	0.0331
Speed-2.3m/s b (g/m^2)	2.53	2.615	5.278	3.55	5.262
k (m^2/g)	0.153	0.2125	0.1224	0.1202	0.127
Force-400N f	0.0782	0.1686	0.05	0.1855	0.08086
Speed-2.3m/s b (g/m^2)	4.9	4.11	5.998	4.11	4.525
k (m^2/g)	0.161	0.1426	0.1513	0.1426	0.186

TABLE-5

Samples	Bendtsen porosity (ml/min)	Opacity (%)	X (g/m^2) for PD=1	PT for PD=1	PTst for PD=1	PTpp for PD=1
SNP1	387.5	93.44	15.6	0.067	.0273	0.03968
GNP	26.3	96.72	8.4	.062	.0137	.0483
SNP2	490	96.2	28	.103	.01556	.0875
SNP3	428.6	99.1	24.4	.072	.0037	.0683
PNP	345.5	91.88	10.8	.06	.0342	.026

TABLE- 6 : BAUER Mc-NETT CLASSIFICATION OF DIFFERENT NEWS PRINT SAMPLES

NEWS PRINT SAMPLES	FIBRE FRACTION , PERCENT				
	+ 28	+60	+100	+200	-200 (fines)
SNP.1.	36.7	23.3	11.0	6.4	22.6
GNP	28.3	21.6	7.4	7.3	35.4
SNP2	42.7	17.0	9.9	5.6	24.8
SNP3	33.8	20.16	13.21	6.53	26.3
PNP.	27.76	29.2	14.0	7.7	21.34

\+ Indicates retained on the sieve.

\- Indicates passed through the sieve.

TABLE-7

SAMPLES	x (g/m^2) for A=0.5	X (g/m^2) for A=0.95	k (m^2/g) Printing smoothnes	Bendtsen Roughness (ml/min)	Parker Print Surf Roughness (µm)
SNP1	4.0	10	.116	382 / 240	>6
GNP	2.4	9.6	0.202	80 / 38.125	3.1
SNP2	3.8	9.6	0.12	197.5 / 123.125	5.13
SNP3	3	10	0.149	215 / 267.5	>6
PNP	3	9.2	0.135	186.0 / 104	4.8

Fig.1: Y as a function of X

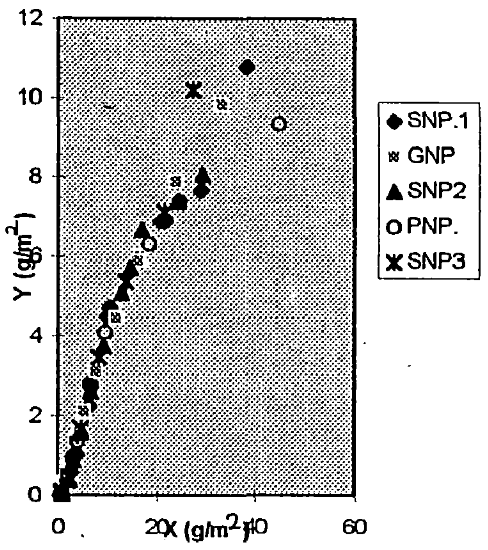


Fig.2 Y as a function of X at 400N force & 1m/s speed

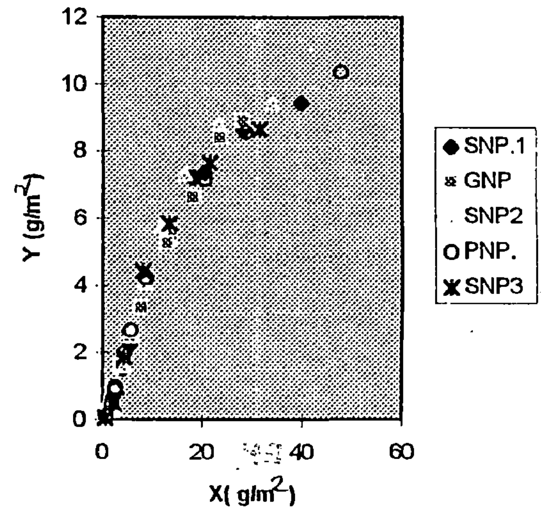


Fig.3 : Y as a function of X,force-200N & speed-2.3m/s

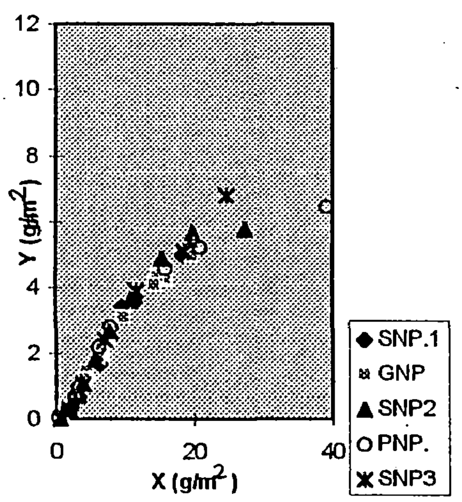
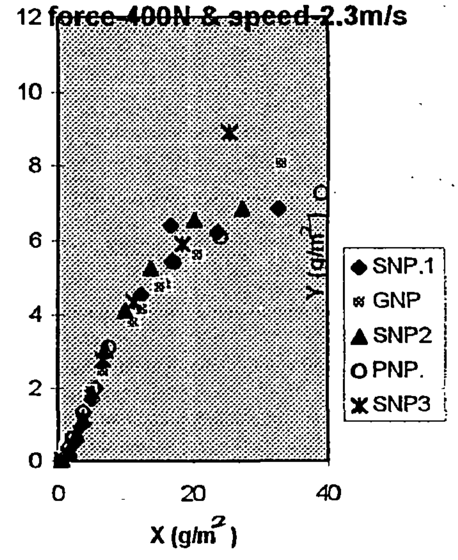


Fig.4 : Y as a function of X, force-400N & speed-2.3m/s



247923

Fig.5: Y as a function of X under different printing condition for SNP.1

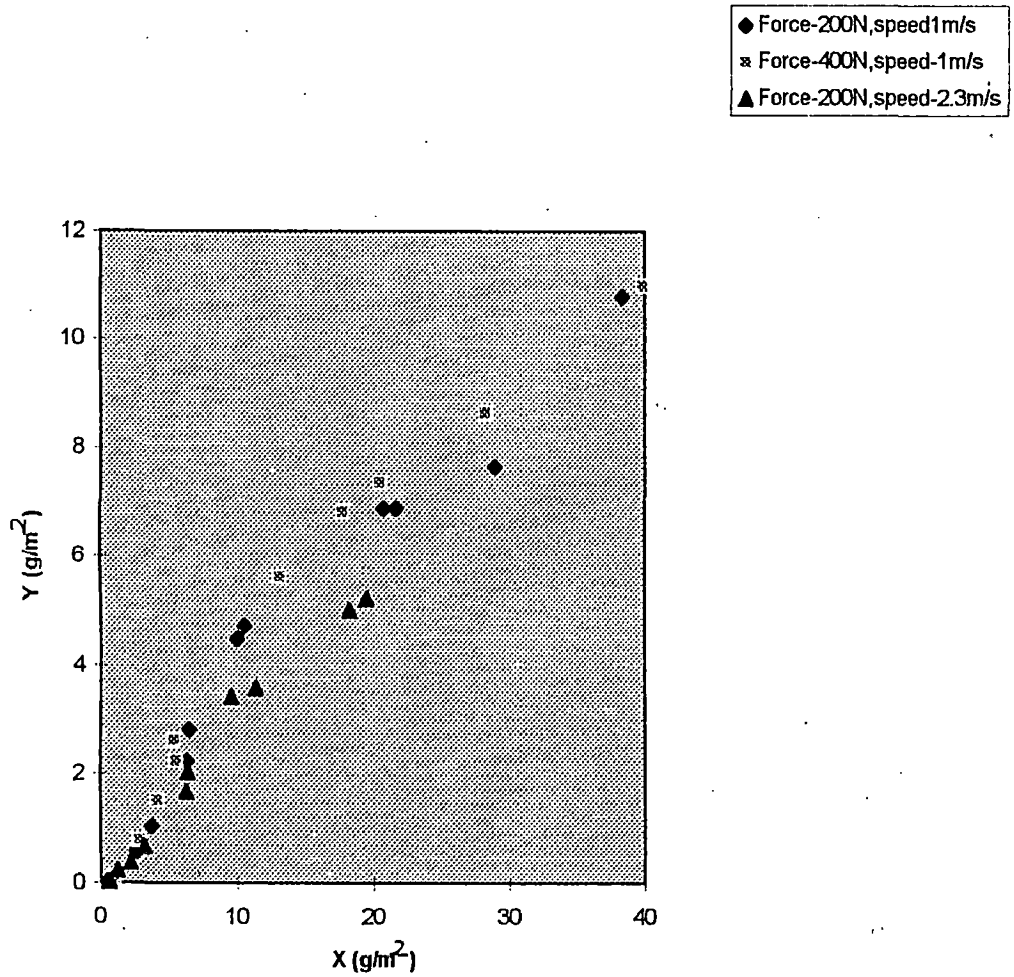


Fig.-6 : b as a function of force at 1m/s speed

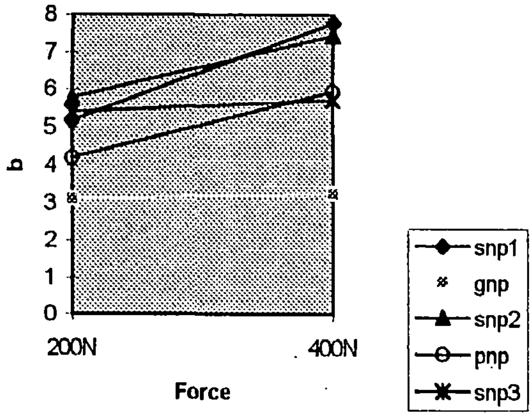


Fig.9 : b as a function of force at 2.3m/s speed

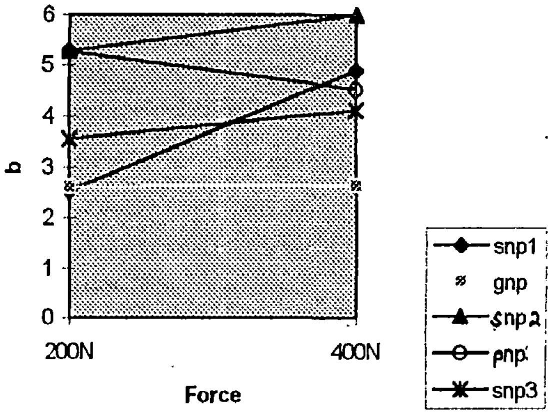


Fig.7 :f as a function of force at 1m/s speed

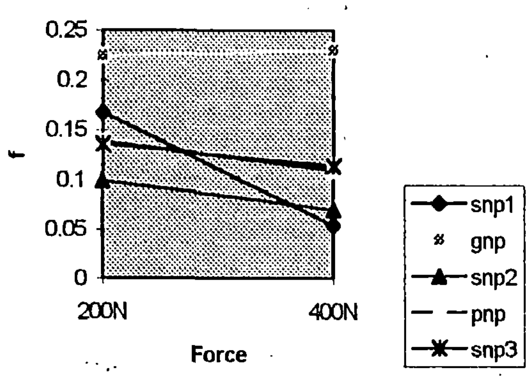


Fig.10 : f as a function of force at 2.3 m/s speed

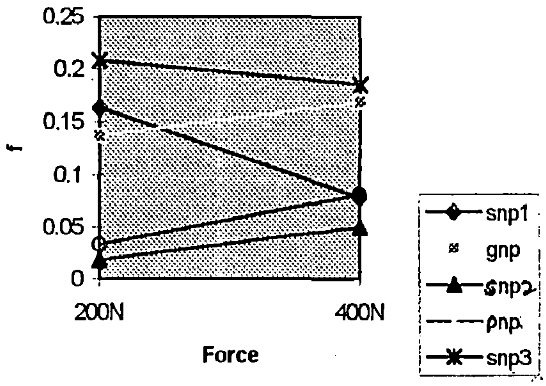


Fig.8 : k as a function of force at 1m/s speed

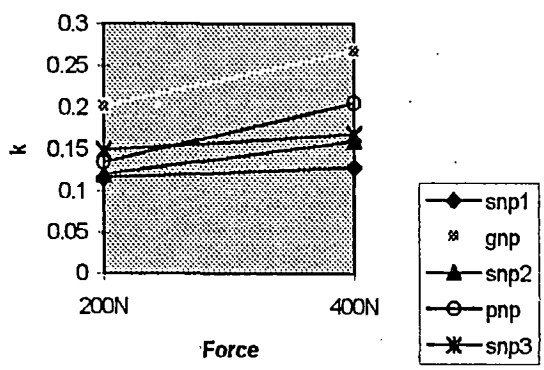


Fig.11: k as a function of force at 2.3 m/s speed

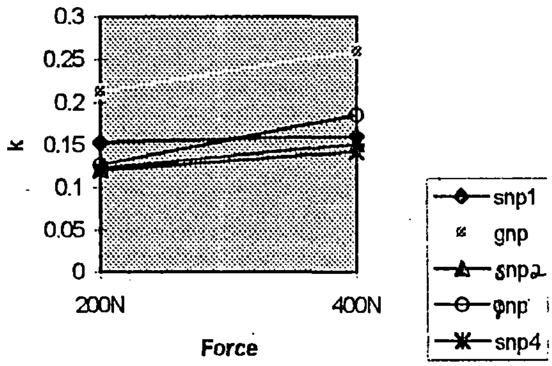


Fig.12: b as a function of speed at 200N printing force

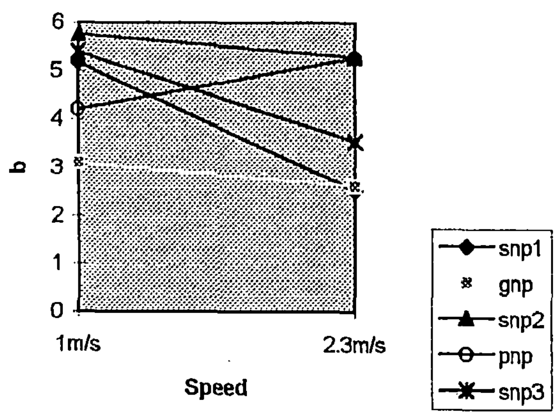


Fig.13: b as a function of speed at 400N printing force

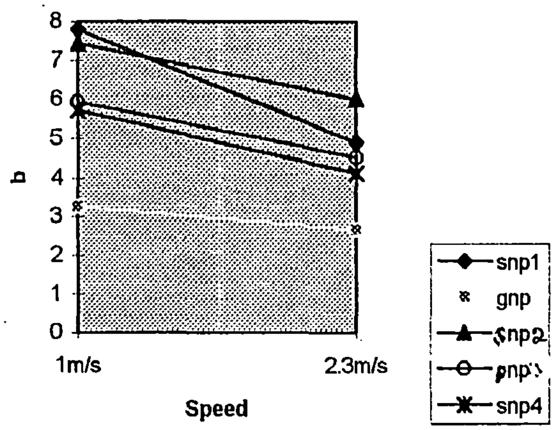


Fig.14: f as a function of speed at 200N printing force

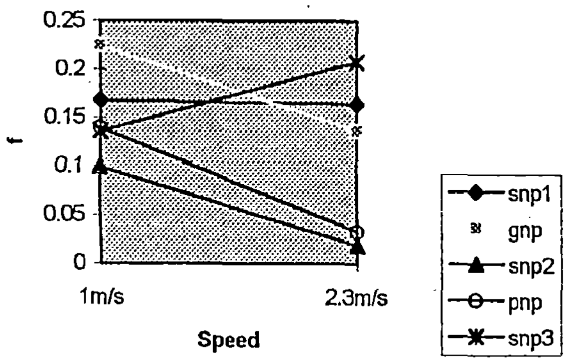


Fig.15: f as a function of speed at 400N printing force

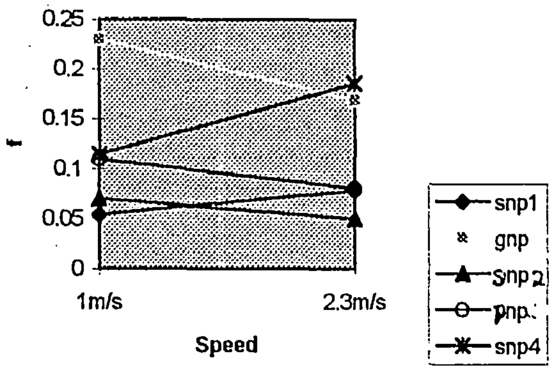


Fig.16: k as a function of speed at 200N printing force

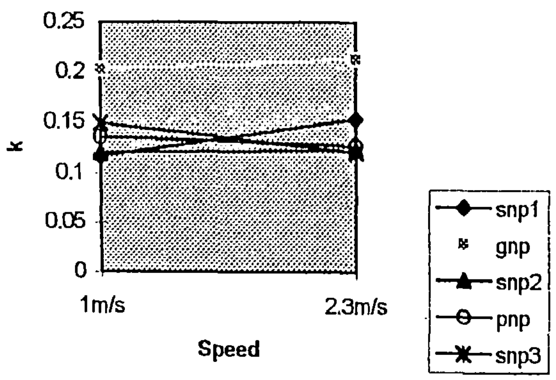


Fig.17: k as a function of speed at 400N printing force

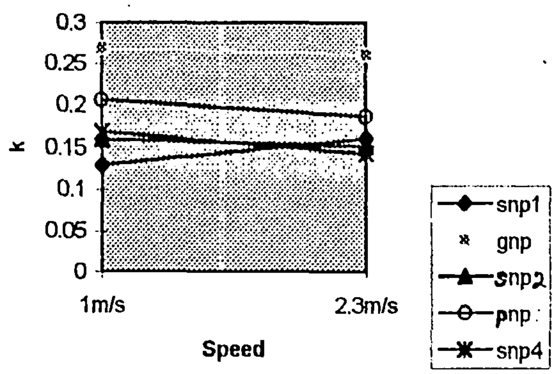


Fig.-18 :Plot for Print density (P.D.) vs X ,force-200 & speed-1 m/s

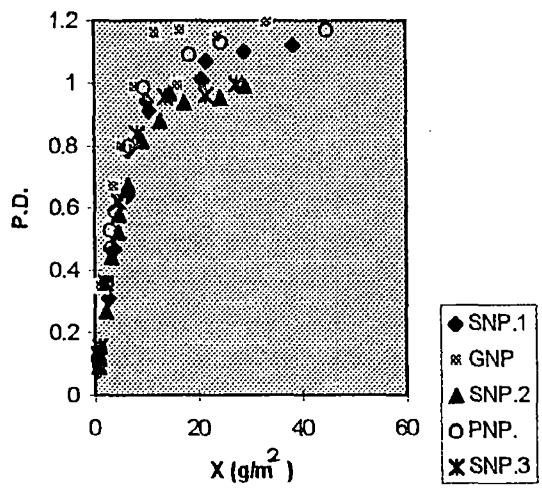


Fig.-19 : Plot for P.D. vs X

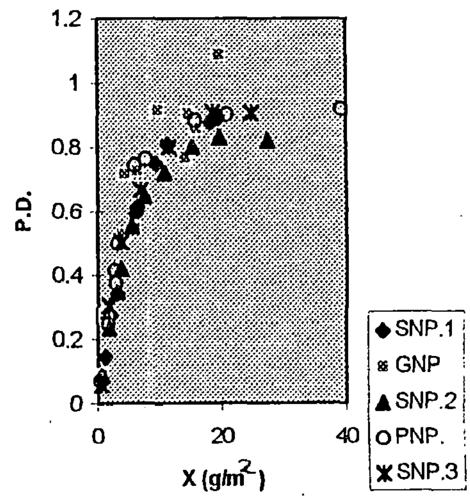


Fig.20 :Plot for P.D. vs X, force-400N & speed-1m/s

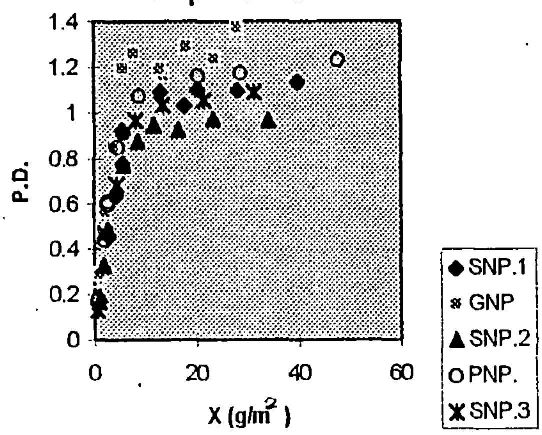


Fig.-21 : Plot for P.D. vs X ,force-400N & speed-2.3m/s

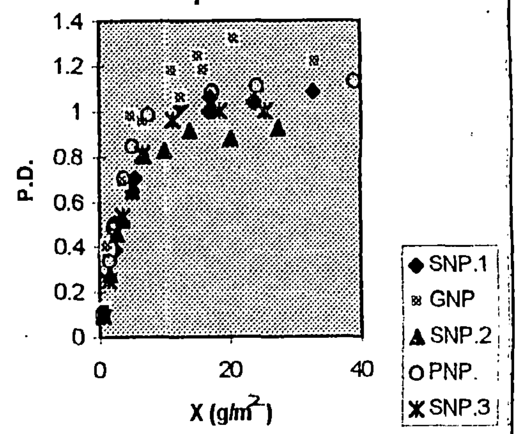


Fig.22: X as a function of R_{∞} Force=200N & speed=1m/s for PD=1

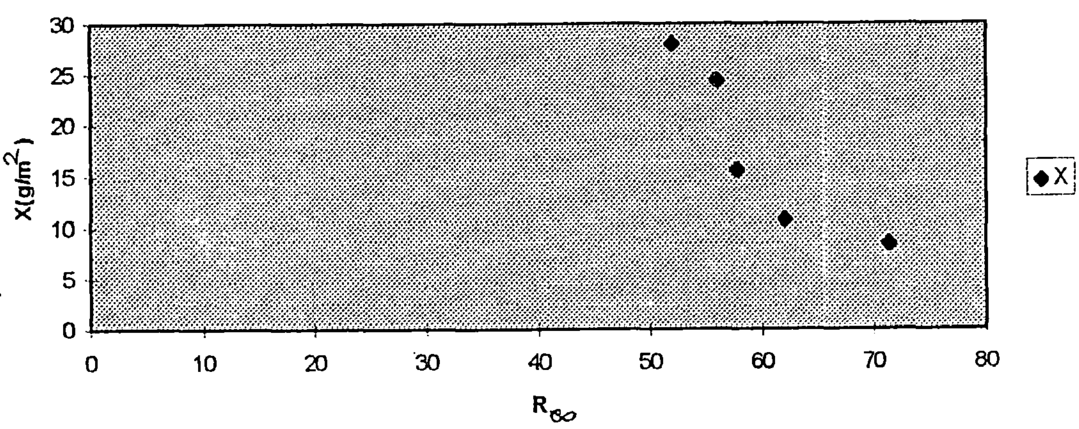


Fig.26: Total Print through (P.T.) as a function of X,force-200N & speed-1m/s

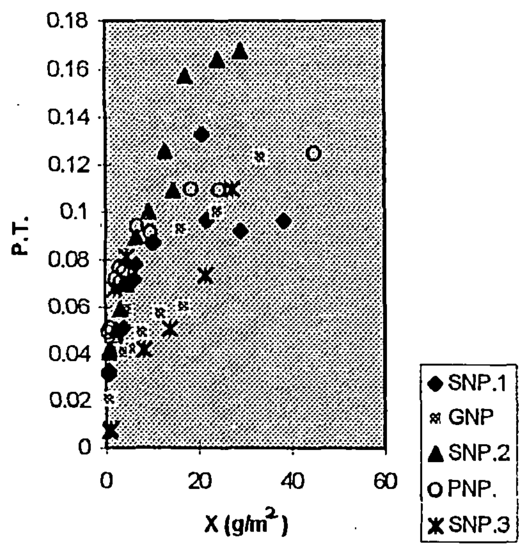


Fig.23: Total P.T. as a function of X ,force-200N & speed-2.3m/s

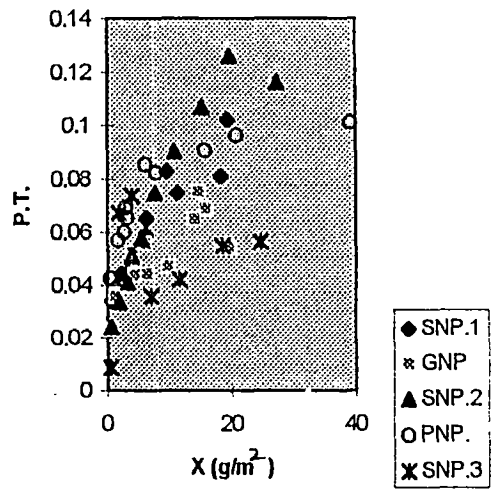


Fig.24: Total P.T. as a function of X, force-400N & speed-1m/s

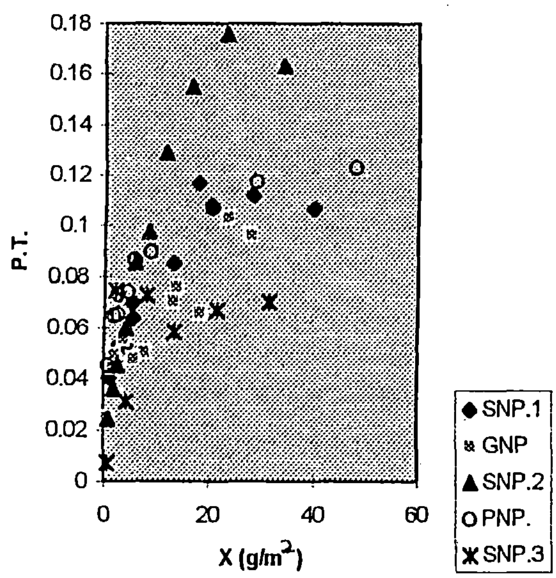


Fig.25: Total P.T. as a function of X, force-400N & sped-2.3m/s

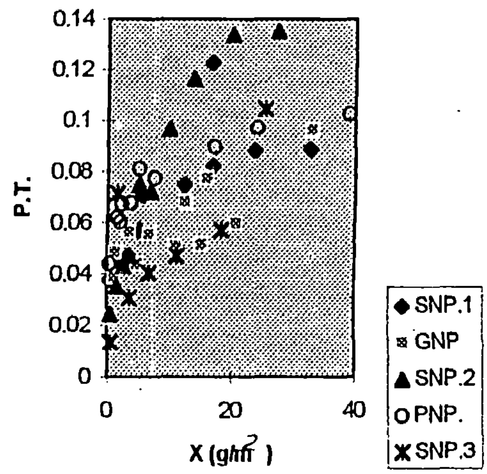


Fig.27: Plot of PT, PTst at PD=1 as a function of Opacity at 200N force & 1m/s speed

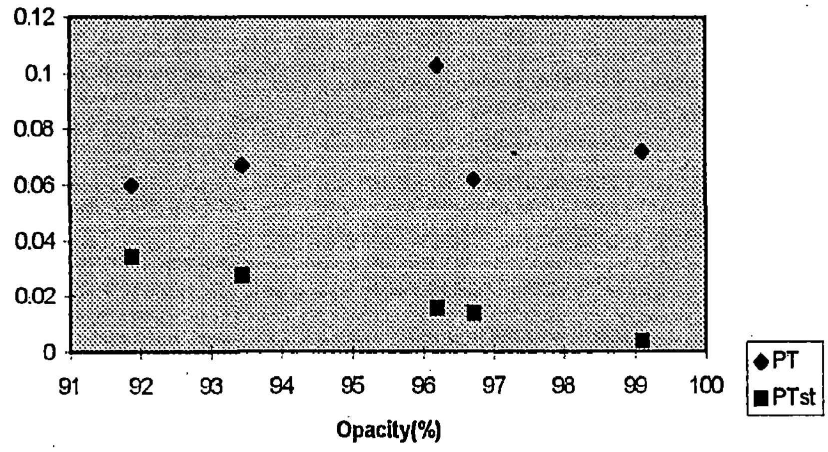


Fig.28: Plot of PTpp at PD=1 as a function of Porosity at 200N force & 1m/s speed

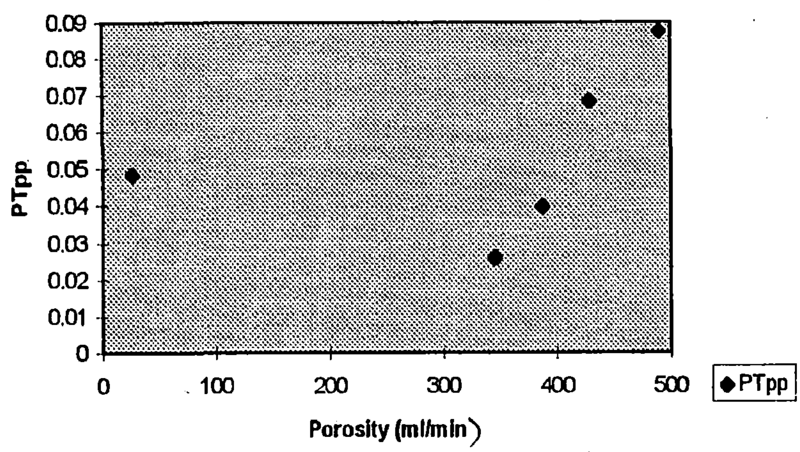


Fig.29: X as a function of Bendtsen roughness for A=0.5at 200N force & 1m/s

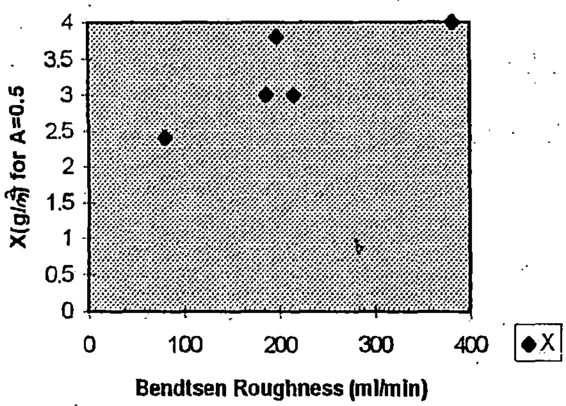


Fig.30: X as a function of Bendtsen Roughness forA=0.95 at200N & 1m/s

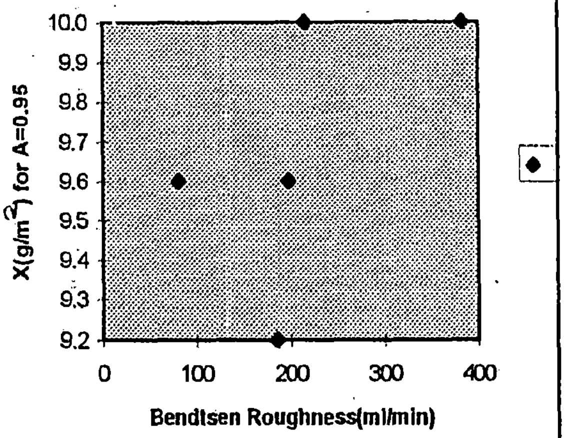


Fig.31: Plot of k(printing smoothness) as a function of Bendtsen Roughness

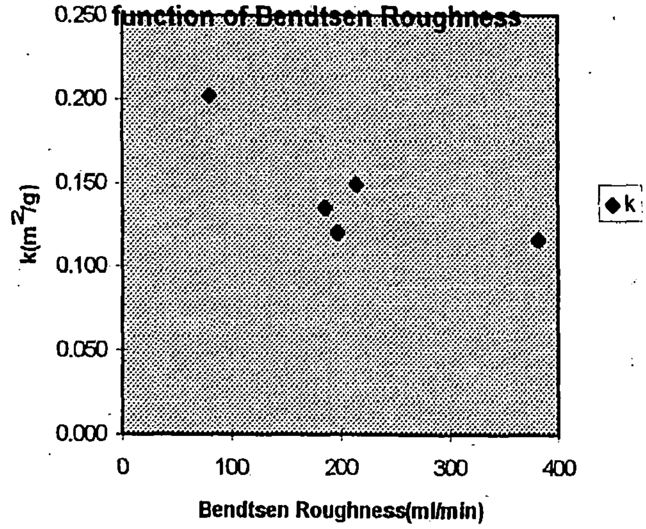


Fig.32: A as a function of Y at 200N & 1m/s

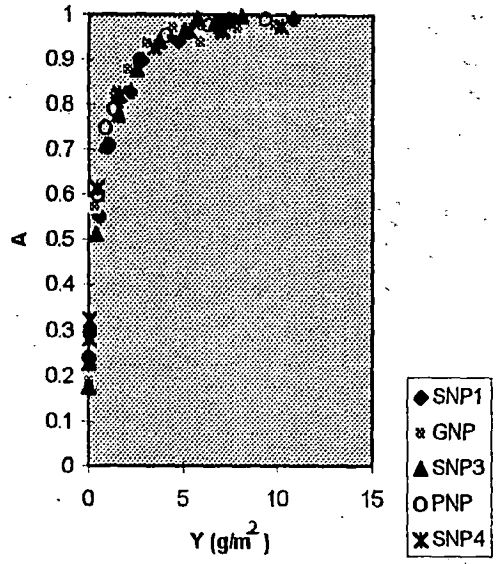


Fig.33: A as a function of Y at 200N & 2.3m/s

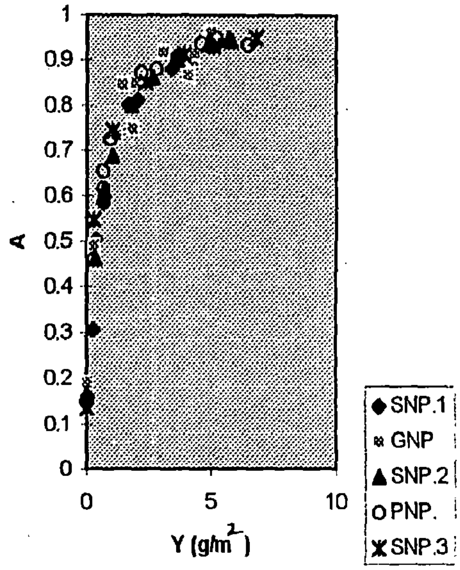


Fig.34: A as a funtion of Y at 400N & 1m/s

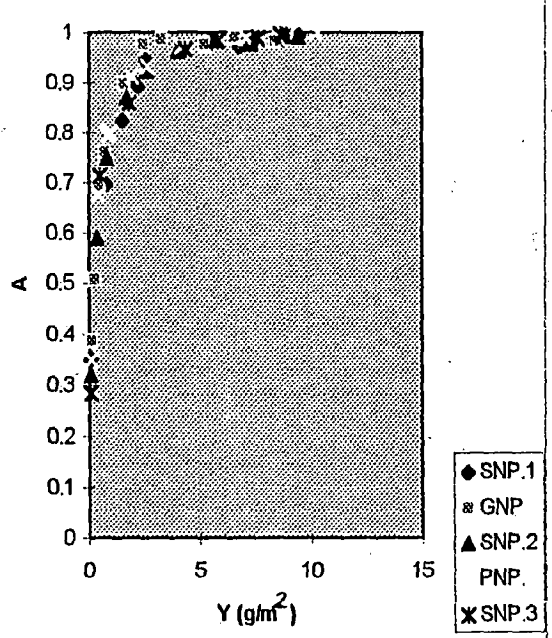
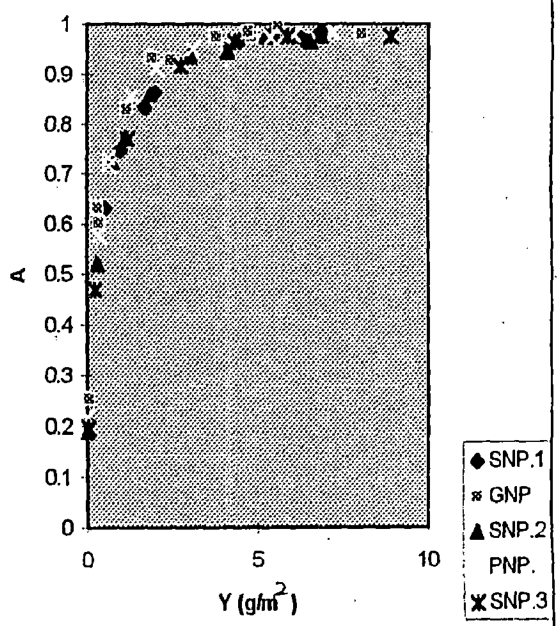


fig.35: A as a function of Y at 400N & 2.3m/s



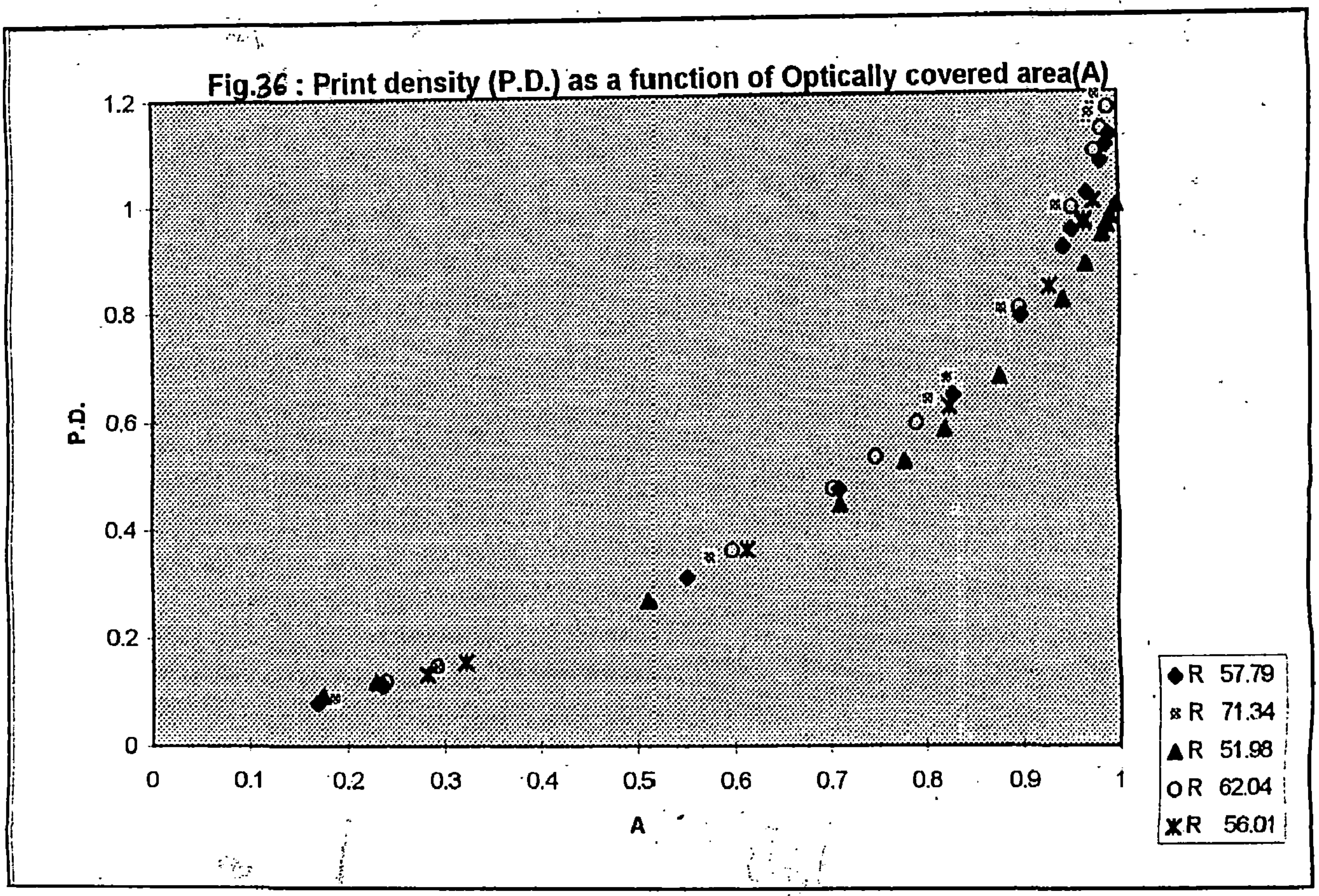


Fig.36 : Print density (P.D.) as a function of Optically covered area(A)
P.D.
1.2
1
0.8
0.6
0.4
0.2
0
0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1
A
R 57.79
R 71.34
R 51.98
R 62.04
R 56.01