Printability and paper properties

SINGH S.P.* and RAO N.J.*

ABSTRACT

There are three major components in any printing process; paper, ink and printing press. This review paper analyses the various paper properties which influence the print quality. Most of the printing performance parameters discussed here depend, besides paper properties, on the characteristics of the ink, the printing speed and other press variables. The present discussion highlights only the paper properties since it is most important to the papermaker.

INTRODUCTION

Most of the paper produced today is printed by one method or the other. The printer's primary task is to make a true reproduction of original image on the paper surface economically. To control the quality of the final printed matter a number of variables are available in the printing press, the ink, and the paper. The present day customer's/reader's expectations are sometimes not met inspite of the great flexibility the printer has. The printing press, the ink, and the paper must then all be studied to fiind the reasons for the poor performance. The effect of paper is most important to the papermaker who has to control various properties of paper during its manufacture to suit the specific requirements of the intended printing method. Knowledge of printability of paper is also essential to protect the papermaker against any undue criticism of the paper when the printing press or the ink is actually at fault.

PRINTING PROCESSES

Different printing processes impose varying demands on paper. Therefore, when discussing properties of printing paper, it is essential to mention the printing process in which the paper in question is to be printed. Brief review of the salient features of various printing processes has been presented in the following paragraphs.

This review does not covers the non-impact printing processes such as laser, electrostatic, ink jet and thermal printing. The domestic market of paper for these processes, though growing fast, is small at present

Letterpress Printing

In the letterpress printing process the image portions of the printing plate are raised above the plane of non image areas. When the ink is applied on these printing plates with the help of rollers, only the image portions come in contact with the inked rollers and receive ink. This ink bearing plate is then pressed against paper surface to produce a print Letterpress is one of the oldest form of printing but it is gradually being replaced by other printing processes.

Letterpress inks are viscous tacky systems which usually cure by oxidation. The major exception is news inks in which the vehicle is generally a mineral oil drying of which is accomplished by apsorption.

Lithographic Offset Printing

In lithographic printing the image and non-image areas both lie on the surface of the plate in the same

*Institute of Paper Technology
SAHARANPUR

plane. The plate is created by a combination of photo mechanical and photo chemical processes which make the printing area ink receptive and the non-printing area water receptive. In the printing process the plate is wet first with water and then immediately by ink. In commercial practice most lithographic printing is accomplished by an offset process, that is, by transferring the image from the plate to an intermediate roll or blanket and from there to the paper being printed.

Lithographic inks are viscous inks with varnish systems similar to letterpress varnishes. They differ in that the ink films applied are thinner than letterpress and therefore, they require higher pigment content. Also the lithographic inks must be able to run in the presence of water since water is added to create the non-image areas of the plate.

Gravure Printing

The gravure or "Intaglio" printing process is different from others in that the design to be printed is etched or engraved in to and below the surface of the printing cylinder. The printing image consists of millions of tiny recessed cells per square metre. These cells vary in depth andwidth so that they may accurately meter the proper amount of ink to each tonal gradation of the image. It consists of a gravure cylinder on which the design to be reproduced is etched. The cylinder rotates partially immersed in an ink reservoir, a doctor blade removes excess ink from the surface of the cylinder, an impression roller brings the paper in contact with the gravure cylinder for printing to take place.

Gravure inks are low viscosity inks to be quickly accepted by the paper and dry by solvent evaporation.

PAPER PROPERTIES

The properties of printing papers are divided into two main groups; runnability and printability. Runnability means the combined effect of properties that ensure smooth feeding of paper through the press at the desired speed. Printability is a general term referring to all the propertiesof p per thata contribute to good quality of the printed matter.

The present discussion highlights the effect of various paper properties on its runnability and printability. Although the reader is assumed to be conversant with the terms used to express printability, a brief glossary has been given at the end for ready reference.

Figure—1 shows the main properties which govern the printing quality of papers The uniformity of properties is placed at the centre of this diagram. It is essential to recognize the importance of uniformity of paper properties because it is easier to adjust the operation of a printing press to a paper of lower but uniform quality than to a paper with severe fluctuations of characteristic values even when the average values are high. The paper properties are shown inside the circle and the parameters used to characterized the runnability and the printability have been shown outside the circle boundary.

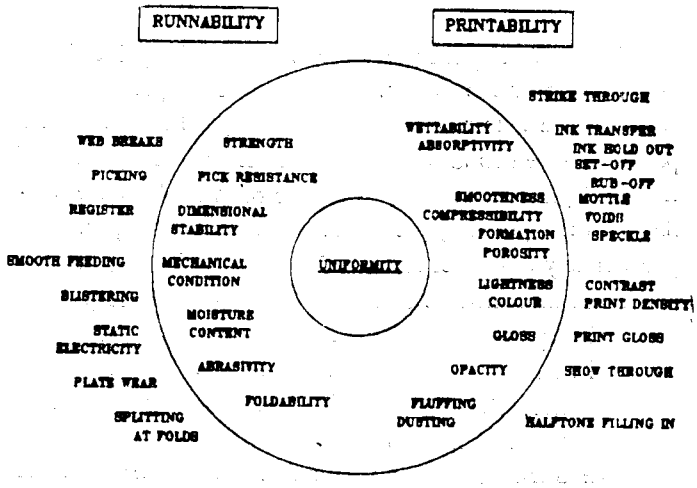


FIGURE-1 PROPERTIES GOVERNING RUNNABILITY AND PRINTABILITY OF PAPER

The paper properties listed towards left in the circle are more strongly related to the runnability and those listed towards right are more strongly related to the printability of paper.

RUNNABILITY PROPERTIES

Strength Properties

Weak paper means frequent web breaks during printing and consequently frequent press stoppages and lost time and money. The most vital strength needs are

high tear and tensile strengths to resist the stresses in operation on the press.

The paper should also have adequate internal bond strength to avoid delamination of the fibrous structure leading to blistering during rapid drying of the printed sheets in heat-set process.

The best approach to obtain necessary strength is in the choice of the pulp itself because nearly all the steps that can be taken to improve the strength during papermaking lower the printability properties. If long chemical fibers are included to enhance tearing strength, smoothness is decreased. If the chemical fibers are beaten to improve tensile strength the absorbency, opacity, and resiliency are adversely affected. It is best to add only enough long fibers to the furnish to obtain the necessary tear strength. To obtain the desired bursting and tensile strength it is preferable to use measures which preserve the original pulp strength rather than to develop strength by fibrillating. Usually some compromise between strength and print quality must be made.

Surface Strength (or Pick Resistance)

Considerable tension is applied when the paper and inked forme are separated in a printing process. Portions of paper surface are pulled up by the ink film when the paper surface does not have adequate strength and stretch. This is called picking. Pick resistance is of increasing importance in the higher gloss printing or/ and lithographic printing where inks of high tack are used. The higher press speeds further aggravate picking.

Surface sizing of paper usually improves pick resistance of paper, but it lowers printing quality of paper, since it reduces compressibility and flexibility of paper.

Wet-pick resistance of paper should be separately studied since it can be significantly lower than that of dry paper, especially for coated papers. Wet-pick resistance is of crucial importance in multicolour offset printing in which the second and subsequent colours are applied to paper which has been exposed to moisture.

Dimensional Stability

Dimensional stability, sometimes referred to as hygroexpansivity, is the ability of paper to retain its dimensions and its shape despite changes in its moisture or under the influence of, for example, variation of the physical and mechanical stresses during printing. The paper should have sufficient dimensional stability with the change in humidity during printing to ensure good register in multicolour printing.

Mechanical Condition

Rolls of paper must be true for proper unwinding and feeding of paper through high speed roll-fed presses. Rolls should be wound such that it is possible to unwind them with uniform tension between press sections which is necessary for good register. Sheets used in sheet-fed printing presses must be flat.

Paper defects such as wiremarks, haircuts, fiber cuts, poor splices, slime holes, and the likes are responsible for a large number of breaks. Content of shives in pulp play an appreciable role in the initiation of breaks. Problems can arise from caliper and moisture variation, curl, or mechanical damage. Curl causes trouble by interfering with the action of feeder mechanism and register guides.

Moisture Content

Proper moisture control is very important in printing papers. Lack of moisture control results in curl and dimensional instability of the paper on the press, causing distortion of the printing image and improper positioning of the paper. Ink drying times become longer at higher moisture content.

Poor moisture control of paper results in blistering. To avoid blistering, coated papers made for heat-set letterpress or offset printing are made with a lower moisture content than those made for other ink-drying systems. There is, however, a lower limit to which moisture content can be reduced without endangering other paper properties like folding endurance.

A runnability problem related to the poor moisture control is due to static electric charge that can build-up on the paper as it runs through the press. A very dry paper has a high electrical resistance, and thus cannot conduct the charge away as it is formed. The static charge may cause the following difficulties:

— Fine specks or foreign matter, e.g. paper dust, are attracted by the paper surface and are held there.

— The paper surfaces stick together causing difficulties in feeding and register. It also tends to set-off the printed sheets.

Besides grounding the paper, the static electricity can be minimized by keeping the press room relative humidity high. Warming of paper also helps to reduce static electricity.

Abrasiveness

The abrasivity of paper surface causes the printing plate to wear out fast. Impurities in the filler material contribute to the abrasivness significantly.

Foldability

The folding properties of coated papers play an important role in the runnability of paper at both press folder and subsequent bindery operations. The most stringent condition for foldability is imposed in multicolour heat-set printing. The printed paper is exposed to the heat shock from burners radiating at 1000-1400°C. The paper web temperature rises (approx. 220°C) and cools between successive printings and becomes dry. While in this moisture free conditions, the printed paper is folded into signatures, paper with poor foldability will split at the folds. It has been realized that ordinary tensile and double fold tests do not predict the splitting properties of coated papers for such applications.

PRINTABILITY PROPERTIES

Wettability and Absorbency

Wettability and absorbency control the mechanism of ink transfer from the printing form to the paper.

Wettability is the measure of ink receptivity that causes paper to accept ink instantaneously at the contact between the paper and the ink. It is measured as the contact angle of a drop of liquid on paper and it changes as a function of time. The surface of uncoated papers is composed of cellulose fibers which have high wettability. It is retarded when the fiber surface is coated with a substance with low surface energy, for example in coated papers, or while transferring last inks in multicolor printing.

The further movement of the ink deep into the paper structure depends on the absorbency of the paper. Ink absorbency differs from the ink receptivity primarily in the magnitude of time involved. Absorbency concerns mainly with the drying of the printed ink film. An appropriate value of absorbency is very essential for the final print quality. A very high absorbency, usually associated with rough paper surface, tends to drain the ink vehicle into the sheet and leaves a dull and rough ink film on the print. Sometimes the oil vehicle is absorbed but does not carry the ink in with it. If the ink pigment dries out without sufficient vehicle it becomes chalky and tends to fall off.

On the other hand, low absorbency which is usually associated with smooth paper surface results in high ink holdout on the surface producing denser, cleaner, smoother and glossier ink film on the prints. In these cases lesser ink is required for coverage and more saturated colors are produced. Cast coated papers are exception to the above generalization, which are very smooth and glossy and also very absorbent. They give low gloss prints with most inks.

Although high ink holdout is often associated with good print quality it can lead to set-off in the printed paper. Excessive ink holdout can also make trapping much more difficult in multi-color work.

Uniformity of absorbency is very important in the printing of large solid areas, lack of which can produce very blotchy, undesirable gloss patterns in the print. In halftone printing nonuniformity in absorbency can give density variations.

The absorbency requirements of paper are also altered by changes in the ink characteristics. Quick-set inks, which set within a few seconds, are made from two-phase vehicles. For setting to take place, the thin mineral oil phase must be rapidly absorbed by the paper leaving the thick colloidal phase to gel on the surface. If the thin oil cannot drain away rapidly, then setting is retarded and the presence of mineral oil film on the surface may cause a second color to fail to trap, producing a 'ghosting' effect. Thus, with quick-set inks good print-gloss can be produced on papers of higher absorbency that would have given matte results with conventional inks.

Smoothness and Surface Compressibility

The Smoothness determines how well the paper surface attains full contact with the ink film. Inadequate contact between the paper surface and ink results in an image that is broken or incomplete. Generally rough papers require more ink in printing causing excessive show through and poor halftone dot formation. Another option in printing rough papers is the use of increased printing pressure but that causes mottling and punching of prints.

An essential feature of paper is that it is compressible both in the bulk and in the surface. Surface compressibility of paper refers to the reduction in roughness under application of pressure on the surface. It differs from the bulk compressibility which is defined based on the reduction in the thickness of the sheet. The print quality is dependent on the surface roughness in combination with the surface compressibility. A soft compressible paper even though rough will print better than a hard paper that is fairly smooth. Surface sizing reduces surface compressibility and flexibility.

The high surface smoothness should be achieved through measures like proper choice of pulp, appropriate refining of pulp, right choice of fillers and good formation of sheet rather than calendering the sheet very hard. When a sheet is heavily supercalendered to try to obtain necessary smoothness, the wiremarks tend to show up prominently in the prints due to variation in the absorptivity.

Formation

After smoothness, formation has wide ranging effects on evenness of both solid and halftone prints, particulary on calendered papers. Formation can be measured in the form of local variations of either grammage, thickness, density, or transparency, the latter being the most common method. The variation of paper density is most dangerous because it manifests itself with local variations of smoothness and absorptivity which is highly detrimental to the quality of prints. Denser spots tend to refuse ink in the printing and the prints give mottled apperance. Variation in density arise when a paper of poor formation is calendered to achieve a uniform thickness; variations of thickness turn into variations of density.

Offset printing is more tolerant of the effect of variation in paper formation, since it prints from a resilient rubber blanket.

Often formation is compromised with other paper properties like strength and economic considerations. Longer fibers needed for good strength contribute to a wilder formation. Additional refining, which tends to improve formation, is limited by other conditions such as dimensional stability and paper machine operation. Slow running paper machines with their wire shake produce excellent formation.

Density and Porosity

Roughly, the paper with high porosity has high compressibility and softness, but there is no general correlation between properties if papers of same kind are compared. Finely ground pulp, high filler content and supercalendering give papers a low softness.

Density is generally calculated from the grammage and the caliper of the paper. It roughly expresses the porosity of paper structure. Density and porosity affect setting and drying of ink. As average quantities, however, they may be misleading if the size distribution and location of the pores in the thickness direction of the paper are very complex.

Linting

Linting is a term normally used to describe both dusting and fluffing. Fluffing is paper fiber becoming detached during printing. The dusting is caused by clay or other mineral matter inadequately retained in the sheet.

Chalking or dusting properties of the coatings are important in the prevention of the build-up on the printing plates, rollers, folders, and other press components.

Lightness and Colour

Colour is quantitatively expressed in terms of three attributes, lightness, saturation, and hue. These can be measured with a spectrophotometer or filter photometer and interpreted as points in the CIE coordinate system. Lightness is normally measured as the luminance factor (FMY/C filterin ELRFPHO). Light ness has a strong positive effect on the print density in

solid areas and the range of density in half-tone areas. If the ink layer does not cover the paper fully, i.e. there are light tones in the picture areas, or speckled solid areas on rough papers-the uncovered fraction of the paper surface contributes its own colour to the colour of the print. The consequence is the reduction of density, an increase in the lightness and a decrease in the saturation of the colour of the print.

Opacity

Opacity of paper significantly contributes to the print through. Print through is defined as the contrast between printed and unprinted areas when seen from the reverse side.

$PT = \log_{10}$(paper, reverse side/^{R}print, reverse side)
Where R is reflectance factor of paper with paper backing.

Print through is one of the more controversial terms used to describe prints. It represents the combined effect of three factors.

- Show through due to lack of opacity of paper.
- Strike through due to the penetration of ink pigment into paper.
- Separation of the ink vehicle in the paper which reduces opacity.

In cases where the effect of vehicle pigment separation is slight, print through is mainly determined by the opacity of paper. For example, in smooth coated papers the printing is achieved with the ink film thickness as small as 1 to 2 μm and the seperation of the vehicle and pigment is slight. In such cases the print through is mainly determined by the opacity of the paper. On uncoated paper the required ink film thickness may be 3 to 4 μm. Therefore, in addition to opacity, adsorption properties of paper also have an effect on the amount of oil and pigment penetrating the paper thus affecting the print through value.

Consequently a significant condition for smooth and dense coated paper is that they are sufficiently opaque. Uncoated papars should have, in addition to sufficient opacity, a surface with pores of equal size as small as possible to prevent the penetration of pigment at the moment of printing.

Of all the pulps available to the papermaker groundwood is by far the most opaque. By raising the groundwood content of the sheet it is possible to produce a more opaque paper. But if this measure is impractical it will then be necessary to fill the sheet with pigment or to go for coating of the paper.

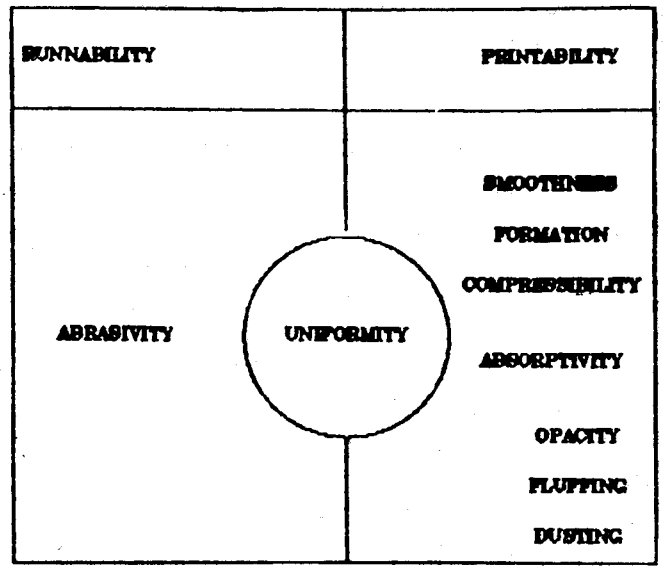
Gloss

The gloss of print is mainly affected by the smoothness and absorptivity of paper and above all by the amount and kind of the ink binder and its retention in the printed ink layer. Gloss of the base paper has little relationship with the print gloss but it is important due to the presence of the unprinted areas. The more the large unprinted ares exist the more the gloss of paper must be taken into account.

PROPERTIES DEMANDED BY VARIOUS PRINTING PROCESSES

Requirement for Letterpress Printing

The paper properties of greater significance in a letterpress printing have been highlighted in Figure-2. The demand is high on most printability properties. Smoothness, formation, compressibility, absorbency, lightness, opacity, linting and dusting behaviour of paper play a vital role in the final print quality. The general requirement for good ink transfer are high oil absorbency, high light scattering coefficient and good smoothness of the paper.

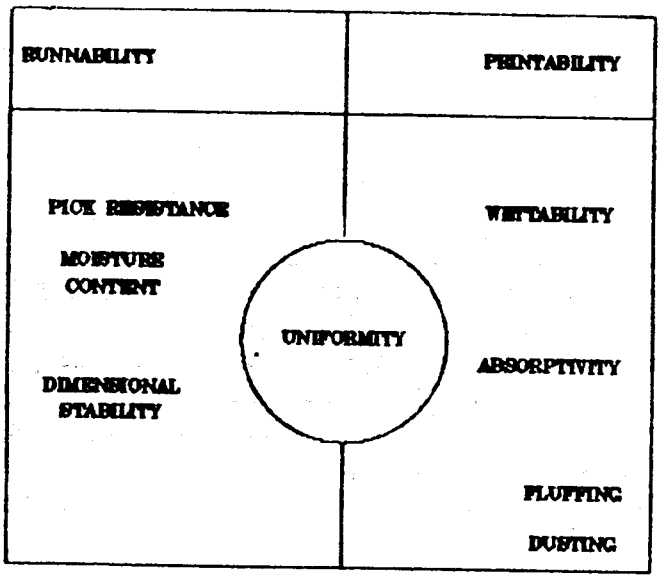


Figure—2 Important Properties for Letterpress Printing

On the runnability side the high abrasiveness of paper will result in excessive printing plate wear.

Requirement for Lithographic Offset Printing

In offset printing processes, the emphasis is more on runnability properties of paper (Figure-3). Due to the presence of a soft deformable offset roll in this process, the smoothness, formation and the compressibility of the paper are not so critical.



Figure—3 Important Properties for Offset Printing

Since the inks used in this process are more tacky, a good pick resistance (both dry and wet) is necessary for offset papers.

Good dimensional stability is essential for this process since it is associated with changes in moisture content of the paper. Hard sized paper is better sinceit is less prone to the effect of press moisture.

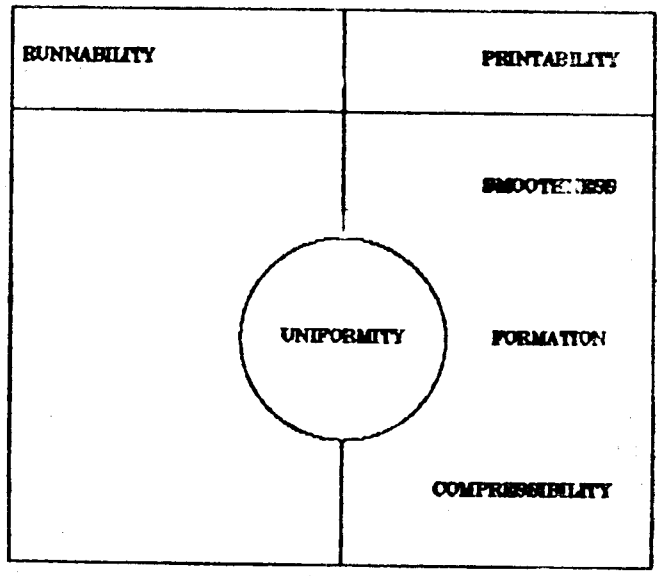
Requirement for Gravure Printing

For gravure printing the most important paper properties are smoothness, compressibility, and good formation of paper (Figure-4). In fact the process demand the ultimate in surface smoothness for the achievement of adequate contact and satisfactory ink transfer.

GLOSSARY OF TERMS

Binder The component of the ink film which holds the pigment to the printed surface.

Blanket The intermediate roll in the offset process which receives the image from the printing plate and transfers it to the paper.



Figure—4 Important Properties for Gravure Printing

Blistering Blistering is the raising of blisters on the paper surface by local internal rupture of the sheet in the image areas. Too high a moisture content, too close a paper surface and/or too less an internal bond strength or resistance to delamination are mainly responsible for blistering. Due to rapid heating in heat-set dryers, the vapour is generated in the paper more rapidly than it can escape and the resulting pressure build-up delaminates the sheet especially in heavily inked areas.

Cast-coated Paper The coating is allowed to harden or set when the paper is in contact with a highly polished chrome casting surface. Cast coated papers have, in general, a high gloss.

Chalking of Prints The condition where ink on paper is slow in drying and rubs off after days or even weeks. Chalking is frequent in coated papers.

Contrast Contrast between solid areas and 70-80% half-tone areas.

Curl Distortion of the unrestrained sheet which tends to roll into the form of a cylinder. This is due to difference in stress-strain characteristics through the thickness of the sheet. The curl side is the concave side of the sheet.

Density Range Difference in print density between the solid and the lightest possible tone.

Dot The individual element of a halftone printing forme.

Drying of Ink The conversion of an ink film to a solid state. This can be accomplished by any of the following means, either singly or in combination—oxidation, evaporation, polymerization, penetration, gelation and precipitation.

Drying Oils Oils which possess the property of hardening to a tough film by oxidation and polymerization.

Feathering A ragged or feather edge which shows at the edge of type or cuts. It may be caused by poor ink distribution, bad impression, excessive ink or ink not suitable for the paper.

Filling up (or Filling in) A condition in the printing of half-tones where the ink fills areas between the dots and produces a solid rather than a sharp halftone print. This may also occur in the printing of type matter.

Flexography A typographic form of printing using rubber plates and relatively thin bodied resin solvent inks. Formerly known as aniline printing.

Fluff Debris from paper which gathers on the rolls or doctors of a paper machine or on the rolls of a printing press.

Fluffing The release from a paper during the printing process, of fluff dust.

Forme (Form) Printing plate or roller which contain the image.

Fountain The ink reservoir on a printing press. In lithography it is also the reservoir for the dampening solution use to prevent the non-printing areas of the plate from receiving the ink.

Ghosting Presence of a faint image of a design, appearing in areas which are not intended to receive that portion of the image.

Gravure Method of printing where the ink is placed in cells below the plate surface. Gravure inks are of low viscosity based on volatile solvent for quick drying.

Halftone A printed image composed of dots of varying frequency (number per unit area), size or density producing tonal gradations.

Heat-set Inks Letterpress and lithographic inks which dry under the action of heat by evaporation of their high boiling solvent.

Highlights The light or open area of a halftone print.

Impression The printing pressure necessary for ink transfer. Also refers to a single print.

Ink Printing ink consists of three main ingredients; vehicle, pigment and additives. The vehicles, or fluid ingredients, act as carrier for the pigment and as binder to affix the pigment to the printed surface. The pigments or solid ingredients are the colouring matters of the ink. Additives are number of supplementary agents such as waxes, lubricants, driers, reducing oils, antioxidant, gums, starches and surface active agents added to modify various characteristics of ink.

Length of Ink The property of ink whereby the ink can be stretched-out into a long thread without breaking. Long inks have good flow in the fountain.

Mileage The surface area covered by a given quantity of ink or coating material.

Mottle An uneven appearance in solid prints manifested by small dark and light areas. (See print evenness).

Offset An indirect form of printing in which the ink is transferred to an intermediate roll from which it is transferred to the paper.

Pearling (Flow Mottle) Uneven distribution of ink.

Pigment Fine solid particles used to give colour to printing inks. They are substantially insoluble in the vehicle and in water.

Print Density Print density refers to the contrast between the printed and unprinted areas. These contrasts can be determined from reflectance measurements on the printed and unprinted areas on the paper. The print density is defined as the logarithmic ratio of reflectance

$$D = \log_{10} (R_{paper}/R_{print})$$

Where R is reflectance factor measured with paper backing.

High print density is a desirable property of print. In halftone images range of print density is more important which means the difference in print density between the solid and the lightest possible tone.

The other terms, viz, 'print blackness' and 'black ness contrast' are sometimes used to express print density. The print density depends on the characteristics of both ink and paper as well as on the quantity of ink transferred to the paper. For a given ink, print density depends on smoothness, absorbency and brightness of paper.

Print Through Print through is the general name given to the phenomenon that a print on one side of paper is partially visible on the other side of the sheet.

Print Uniformity (Evenness of Solid Prints) This characteristic is a critical aspect of print quality. Visually significant non uniformity are expressed by mottle and voids. Mottle can be described as low amplitude and low frequency variations in optical density. Voids fall on the other end of the frequency/amplitude spectrum which are perceivable gaps in the ink coverage characterized by sharp edges and high contrast. Mottle is generally associated with non-uniformity in formation of the paper while voids are associated with surface roughness or picking.

Picking Picking is pulling out of portions of paper surface by the ink film.

Register When an image is printed in parts, as in multiple colours, it is a requirement that all parts match exactly. When they do they are "in register", otherwise they are "out of register".

Rub off see set-off

Saturation Printing of coloured half-tones in the light or middle tones.

Set-off and Rub-off A criterion of good ink drying is that the ink on the printed surface sets in a short time after which it should not have a tendency to transfer to other surfaces which may come in its contact, whether these be other paper surfaces or parts of the press. In practice it is possible to distinguish between two types of transfer; that which takes place under direct shear-free contact and that which requires a rubbing action. The former type normally takes place only during a short interval immediately after printing whereas the latter type may occur over a considerably longer period. The ink transfer occurring in the first case is known as set-off phenomenon, whereas the smearing occurring as the result of a rubbing action is usually called rub-off.

Sharpness Optical sharpness of the edges of dots and lines.

Shortness of Ink That property of a printing ink which is characterized by a lack of flow. It is opposite of length of ink.

Show Through The transparency of printed sheet which permits printing to be seen from the other side of the sheet.

Signature In web printing and binding the name given to a printed sheet after it has been folded.

Solid Prints Areas on the print those should be fully covered by printing inks.

Speckles Small unprinted spots in the solid areas.

Strike Through The penetration of the vehicle of the printing ink through the sheet, so that it is apparent on the opposite side.

Tack of Ink Cohesion of an ink film which is responsible for its resistance to splitting between two rapidly separating surfaces.

Tone Reflected colour from the printed portions.

Trapping The ability of a printed ink film to properly accept a succeeding ink film.

Vechicle The liquid portion of an ink that holds and carries the pigment and provide workability, and drying properties, and binds the pigment to the paper after it has dried.

Voids See Print Evenness.

REFERENCES

Most of the terms given in glossary are taken from "Printing Ink handbook", National association of Printing ink Manufacturers, Inc., U.S.A. (1980).