Printability of paper

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ABSTRACT

Printability of paper is a broad general term encompassing all the properties of paper that contribute to good quality of printed matter. Printability can not be expressed as a single numerical value. Many different properties have to be evaluated, preferably under conditions similar to those existing during real printing, for obtaining reasonably accurate assessment of printability of paper. Printability demand on paper is also dependent on the intended printing process.

The commonly used terms to describe print quality and the printability demands on paper for different printing processes have been discussed in this presentation. The presentation has been very general in nature. The material for this presentation has been collected from many books, journal articles, and personal discussions. The contribution of all the authors is gratefully acknowledged, even though it is not possible to recall by name at this stage.

THE PRINTABILITY

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. Table-1 lists some of these variables. In spite of the great flexibility available, the printer is sometimes unable to meet the present day customer's/reader's expectations. The printing press, the ink, and the paper must then all be studied to find 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.

Table-1 Variables in paper, ink, and the printing press that control the quality of printed output

Paper	Ink	Printing press
• Smoothness	1. Tack	• Type of printing
• Strength – surface, tensile, tear	2. Drying mechanism	• Speed
• Cleanliness	3. Vehicle	• Printing pressure
• Brightness	4. Pigmentation	• Temperature
• Opacity	5. Rheology	• Time delay between successive impressions
• Gloss	6. Color	• Type and amount of dampening solution in offset printing.
• Moisture		
• Dimensional stability		
• Abrasivity		
• pH		

Printability is a broad general term used to express all the properties of paper that contribute to good quality of printed matter. Thus, printability cannot be expressed in terms of a single quantity. The questions like, "How much is the printability of a given paper?" have no definite answers.

Quality of a printed matter is a complex concept that cannot be expressed in simple quantitative terms. The ultimate judge of the print quality is the eye and the mind of the viewer. The viewer evaluates simultaneously the content (physical aspects) as well as the intent (psychological aspects) of the image.

Numerous instrumental methods developed so far for evaluating different aspects of print quality have been helpful in comparing only the physical

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properties of the printed image with that of the original or intended image. Many current researches are focused on developing methodologies to evaluate the sociological and behavioral aspects of printed media usage.

TERMS USED TO DESCRIBE PRINT QUALITY

Before we attempt to measure printability we need a means to describe print quality. As stated previously, printability is more in the domain of subjective evaluation, yet many print quality parameters can be determined from instrumental measurements and those can form the basis of control. Brief definitions of some of the more commonly used terms are presented here.Properties of the finished dry prints can be broadly categorized into three groups:

1. Optical - related to the appearance of the printed surface such as print density, Color, gloss, and uniformity of appearance.
2. Mechanical - having to do primarily with durability of printed surface under mechanical stresses such as rubbing and folding/creasing.
3. Chemical - such as the resistance to weather, moisture, light, heat, or specific chemicals, vapor/gas permeability, adhesion properties, and effect of the print on odor and flavor of foods.

The different aspects of only the optical properties of dry prints are briefly discussed in this presentation.

Optical Properties of Dry Prints

Print Density

A print is visible because of the differences in light reflected by the inked and uninked portions of the paper. This contrast between the printed and unprinted areas is termed as 'print density'. Other terms, like 'print blackness' and 'blackness contrast', are also used to express print density.

The print density is defined as the ratio of light absorbed by the print to the light absorbed by the unprinted paper. It can be measured directly using a densitometer. Print density can also be determined from reflectance measurements on printed and unprinted areas using a reflectance spectrophotometer. The print density is defined as the logarithmic ratio of reflectance

$$\text{Print density} = \log \frac{R\infty}{R\infty p} \qquad (1)$$

Where, R_∞ and $R_{\infty p}$ are the reflectance of unprinted and printed areas of paper measured with paper backing.

The logarithmic ratio presents the contrast more in conformity with the sensitivity of the human eye (Weber-Fechner Law).

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

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

The condition when a print on one side of the sheet is partly visible on its reverse side is called 'print-through'. Print-through is undesirable, particularly when a paper is printed on both sides, such as books, magazines, and other publication materials. The reader would like to read what is printed on one side without being disturbed by what is printed on the reverse.

Print through can be determined quantitatively, in a similar fashion as the print density, as the logarithmic ratio of reflectance of unprinted and printed areas when seen from the reverse side.

$$\text{Print through} = 100.\log \frac{R\infty,rev}{R\infty p,rev} \qquad (2)$$

Where, $R_{\infty,rev}$ and $R_{\infty p,rev}$ are the reflectance of unprinted and printed areas of paper measured with paper backing on the reverse side of the printed paper. The logarithmic ratio is usually multiplied by 100 so that simple whole number values can be reported.

In IGT print through test, the print through is calculated from whiteness of the printed portion from the reverse side as a percentage of the original whiteness of the paper.

The essential requirement to avoid any noticeable print-through is that the paper to be printed should have a high opacity. However, opacity alone is not a reliable guide to predict whether a paper, after printing, will have undesirable print-through or not. When a paper is printed, there is an interaction between the ink and the paper. A portion of the ink transferred to the paper during printing will penetrate into the sheet. The depth of the penetration will depend on the absorption characteristics of the paper, type of vehicle and mechanism of drying of the ink, and the conditions in the press. Depending upon the depth of ink penetration, the print-through effect will increase as the thickness of the paper that is available for hiding the print on reverse side is reduced. It may be remembered that the opacity of paper is dependent on the grammage, and hence the thickness, of the sheet.

Further, certain components of the ink penetrate the paper more than the others penetrate and add to the print-through effect.

Thus, the print through may be assumed a result of three contributing factors:

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

The show through is the print through component influenced by the opacity of the paper. However, the show-through is not identical with opacity or printing opacity (R_o/R); but they are related. The show-through for large amounts of ink on paper is a logarithmic function of the printing opacity.

$$\text{Show through} = 100 \times \log (R_o/R_\infty)$$

Often the terms print-through and show-through are used interchangeably. Strike through, is a term, applied to a situation where the ink or any component of it has physically penetrated all the way through the sheet.

The print through increases as a function of the amount of ink applied to the paper. In case of smooth coated papers the printing is achieved with the ink film thickness as small as 1 to 2 m and the separation 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 m. 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.

Roughly, for a constant opacity, papers made from low-yield chemical pulps have greater print-through than papers made from mechanical pulps. Increasing the amount of fillers in chemical pulps reduces print-through. Addition of fillers in mechanical pulps has little effect on print-through. Mineral oil based inks, or slow drying inks penetrate deeper into the paper and increase print-through.

Increased fines content can increase opacity, reduce roughness and reduce the depth of ink-pigment penetration into the sheet. However, increased fines could also result in greater print-through because the smaller pores are more likely coated with oil, with a resultant loss in light scattering and hence opacity. Such observations suggest that print-through of paper may be influenced by modifications in sheet structure.

Ink Holdout

When an ink film is applied to paper surface, it does not stay completely on the surface but penetrates to a degree dependent upon ink, paper properties, and printing conditions. The condition when a large portion of the applied ink dries on the surface is referred to as 'good ink hold out'.

Print Gloss

Print gloss is one of the important features of a printed surface because it strongly affects print density, imparting depth to the print, a sense of quality, high clarity, and higher image resolution.

Technically, an ideal printing surface should be matt (diffusely reflecting) but extremely smooth to bring out a glossy dark print. 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. The gloss of unprinted paper is not directly related with the print gloss. Often the high gloss of paper does not ensure a glossy print.

Gloss of the base paper is important due to the presence of the unprinted areas. The more the large unprinted areas exist the more the gloss of paper must be taken into account.

Color of Print

Like optical density, apparent print color is a function of the light reflectance characteristics of the combined paper-ink structure. Unlike print density color is a three dimensional entity. All three attributes of color - hue, chroma, and lightness of are affected by stock surface characteristics and the printing process parameters. There should be minimum color difference between the printed image and the original / intended image. Purity of the colored halftones in light and middle tones is referred to as 'saturation' of the print.

Usage of color printing is increasing for all types of printing jobs and is expected to rise from current levels of about 50% to about 80% in 2020. Short run printing jobs are expected to develop fastest.

Deployment of waterless offset printing process in combination with computer-to-press technology is vital for the growth of color printing. This technique can reproduce sharper and more saturated dots than conventional offset giving improved color reproduction, better resolution and print contrast. The potential of waterless offset in getting high-resolution pictures can be utilized by placing high requirements on the paper surface characteristics, both physically and chemically (1).

Print Uniformity

This characteristic is a critical aspect of print quality. In solid prints, visually significant non-uniformity includes mottle, speckle, and voids. For halftone prints, the non-uniformity is characterized by missing dots and speckle in highlights and middle tones, irregularity of dots in middle tones and shadows, and lack of optical sharpness of edges of dots and lines.

Mottle, Speckle and voids: Mottle can be described as variations in apparent optical densities of low amplitude and low frequency. Speckle and voids in solid areas of the print refer to a lack of coverage by the ink film. Speckle represents presence of many small unprinted spots, while voids are perceivable gaps in coverage characterized by sharp edges and high contrast. Voids are characterized by variations in optical density of high amplitude and high frequency.

Unevenness in printing is influenced by many parameters - type of ink, color sequence, type of printing press, speed, rubber blanket, damping water and the type of paper. Mottle is generally associated with non-uniformity in formation of paper while voids are associated with surface roughness or picking.

There can be three kinds of mottle:

1. **Back trap (print) mottle:** an uneven printing result, caused by uneven ink absorption of the paper.
2. **Water interference mottle:** an uneven printing result, caused by insufficient and uneven water absorption of the paper, followed by uneven ink absorption.
3. **Ink trap mottle:** an uneven printing result caused by a wrong trapping of the ink in tack and/or viscosity and is also influenced by an uneven absorption of the ink by the paper.

Gloss mottle: when the gloss of paper or print is examined visually, the eye sees gloss pattern or gloss mottle. The viewer is more strongly influenced by the intensity, size, and distribution of glossy spots on the paper than they are by the average levels that are measured.

Distortion of halftone dots: The halftone areas should have clean well-defined individual dots in prints. A good halftone print is said to have high printing snap. Dot gain refers to the undesirable condition when the printed halftone dots are larger than the size of the dots on the image carrier. Dot gain depends to a large extent on the characteristics of the ink and the pressure in the printing nip. On the part of the paper, the dot gain is greater on uncoated papers than on hard coated papers because of absorbent nature of the former grades. Similarly, the printing snap is better on coated paper than on uncoated paper.

Halftone filling-in: This refers to a condition in printing of halftones when ink fills areas between dots and produces a solid rather than a halftone print. The halftone filling-in influences the contrast between the solid areas and the shadows (70-80% halftone area) of the image, The less filling-in occurs in the shadows, the larger is the contrast.

Filling-in of halftones depends on the linting tendency of the paper. An accumulation of solid particles fibers, fiber debris, filler, and coating pigment on image carrier or the blanket occurs. Critical lint built-up is the level of accumulation when the accompanying problems such as smudging and filling in of halftones reach such a level that the printing must be stopped and blanket/printing plate cleaned. Linting is regarded a serious problem if the interval between press cleanings is less than 5000 impressions.

Scumming: During offset printing, paper is moistened by the rubber blanket. Due to the moistening, certain components of the coating may be dissolved and deposited on the blanket, from which they may be transferred to the printing plate, causing a discolouration in the non-image areas of the print. There may be two effects - tinting and scumming. Tinting occurs when the paper components are decreasing the interfacial tension between ink and water in such a way that an ink/water emulsion is formed. The scumming is the result of a decrease in the water-sensitivity of the offset plate, so that non-image areas accept ink. Scumming is more serious as it may ruin the plate during the press run.

Picking: Picking is pulling out of portions of paper surface by the ink film. The problem is most severe in lithographic printing where the inks used are tacky. Surface sizing of paper usually results in a stronger surface of paper surface.

Wet pick resistance of paper is of crucial importance in multicolor offset printing. The second and subsequent colors are applied to stock which has been exposed to the moisture. Pick resistance of the moistened paper can be significantly lower than that of dry paper, especially for coated papers.

Blistering: Blistering is the raising of blisters in the dryer by local internal rupture of the sheet in the image areas. Too high a moisture content, too close a paper surface and/or too close an internal bond strength or resistance to delamination are mainly responsible for blistering. Due to rapid heating in heat- set dryers, the vapor 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. Also the tendency to blister increases as the grammage of paper is increased since there will be an increase in the total amount of moisture and water vapor generated.

The film of printing ink also tends to seal the paper surface thus increasing the possibility of blistering. Blistering occurs most frequently on heavier weight coated sheets. For a given rate of heating it can be predicted with the aid of the Gurley porosity tests.

Register: In multicolor printing the relative position of the succeeding colors on the paper determines whether a clear sharp single-imaged print will be printed. When all parts of the image match exactly, they are in register. Register depends on the dimensional stability of the paper and the alignment and speed of the printing machine.

Set-off and Rub-off: A criterion of good ink drying is that the ink on the printed surface shall not for more than limited period after printing show a tendency to transfer to other surfaces with which the ink may come into contact. These contacting surfaces may be other paper surfaces or parts of the press. In practice it is possible to distinguish between two types of transfer: 1) set-off, which is the transfer that takes place under direct shear-free contact, and 2) rub-off, which requires a rubbing action between the surfaces. The set-off normally takes place only during a short interval immediately after printing whereas the rub-off may occur over a considerably longer period.

PRINTABILITY DEMAND OF PAPER

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 refers to all the properties of paper that contribute to good quality of the printed matter.

Figure-1 shows the main properties which govern the printing quality of papers. The uniformity of properties is placed at the center 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 characterize the runnability and the printability outside the circle boundary. The paper properties shown inside the circle can further be divided into two groups. Those listed at the left side are more strongly related to the runnability and those listed at the right side are more strongly related to the printability of paper. A qualitative relationship between paper properties and its performance parameters is shown in Table-2. A desired effect on various performance characteristics is also indicated in this table.

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. Content of shives in pulp play an appreciable role in the initiation of breaks. Paper defects such as wiremarks, haircuts, fiber cuts, poor splices, poorly wound rolls or glued cores, slime holes, and the likes are responsible for a large number of breaks. 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.

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.

Surface Strength (or Pick Resistance)

Considerable tension is applied when the paper and inked form are separated in a printing process. Portions of paper surface are pulled up by the ink film if the paper surface is not strong enough. The phenomenon is called as picking. To withstand these forces the paper must have a high z-direction strength and stretch. Adequate 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 aggravate picking.

Surface sizing usually improves surface strength of paper, but reduces its flexibility and compressibility, and thereby reduces printing quality of paper, especially for gravure and letterpress printing. This is very important when the subject matter contains large proportions of light and mid-tones and where the print quality demands are high and the absence of light tone speckle is of vital importance.

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 multicolor offset printing in which the second and subsequent colors 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 content 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 multicolor printing.

Abrasiveness

Papers containing high content of silica impurity wear out the printing plates.

Mechanical Condition of Paper

Rolls of paper must be true for proper unwinding and feeding of paper through high-speed roll-fed presses. Rolls should be wound well enough so 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 level or flat. 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 of Paper

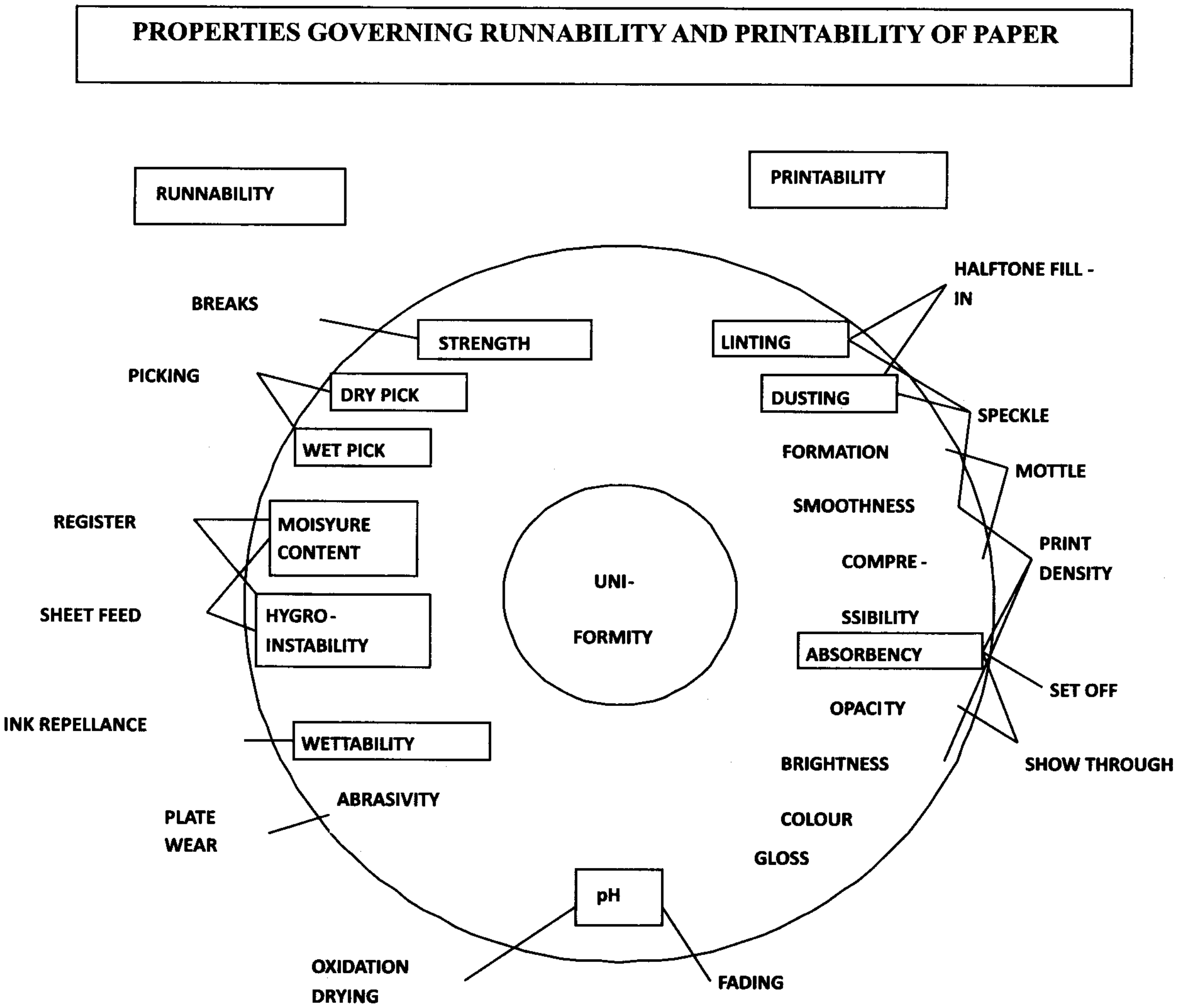

Figure-1 Runnability and printability properties

Proper control of moisture content and moisture uniformity is very important in printing papers. Moisture variations in paper result in curl and dimensional instability of the paper on the press, causing distortion of the printing image and improper positioning of the paper. Misregister can result from bad press conditions, as well as from faulty paper. But most cases of misregister on successive printing on an offset press can be traced to distortion of the paper. A change in the dimension of 0.02% during printing is enough to cause trouble.

Poor moisture control of paper results in blistering particularly on heat-set presses. Blistering is caused by too high a moisture content, too closed a paper surface and/or too low an internal bond strength or resistance to delamination. To avoid blistering coated papers made for heat-set letterpress or offset printing are made with lower moisture content than those made for other ink-drying systems. There is a lower limit to which moisture content can be reduced without endangering other paper properties like folding endurance. Ink drying times also become longer at higher moisture content and lower pH values.

Static Electric charges can build-up on the paper as it runs through the press. When the paper is very dry it has a high electrical resistance, and thus cannot conduct the charge away as it is formed. The static charge may cause the following difficulties:

- 1. Fine specks or foreign matter, e.g. paper dust, are attracted by the paper surface and are held there.
- 2.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.

pH of Paper

In combination with moisture content, pH of paper can have a marked effect on the time require for the drying of inks that harden by chemical oxidation and polymerization. A pH of 8.0 for the coating layer is about optimum from the standpoint of ink drying. A neutral or slightly acid coating tends to retard drying.

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 by the paper but it does not carry the ink into the paper 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 producing denser, cleaner, smoother and glossier ink film on the prints. In these cases, less 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 make trapping much more difficult in multicolor 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 non-uniformity in absorbency can give density variations.

The absorbency requirements of paper are also altered by changes in the ink characteristics. Quickset 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, setting is retarded and the presence of mineral oil film on the surface may cause a second color to fail to tarp, producing a 'ghosting' effect. Thus, with quickset 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 excessive printing pressure 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 has been defined as the change in surface roughness accompanying the application of pressure to true 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. Wiremarks tend to show up very prominently in gravure printing particularly in the light tones. When a sheet has been heavily supercalendered to try to obtain necessary smoothness, the wiremarks can sometimes be seen in the topside print.

Table-2 Effect of paper properties on print quality

	Properties of paper	Print quality: Solid areas: Density	Coverage	Evenness	Gloss	Print through	Set-off	Rub-off	Halftone areas: Density range	Evenness	Contrast	Saturation	Sharpness
Optical properties	Lightness	++				-	+	+	++		+	-	
	Opacity	+				--			+				
	Scattering coefficient	+				--			+		+		++
	Gloss	+			+								
	Color					-			-			-	
	Density	+	+	-	+	+	+	+		-	-		+
Structural properties	Porosity	-	-	+	-	-	-	-		+	+		-
	Smoothness	++	++		++	-	+	+	++	++	++	+	+
	Compressibility	+	+	+	-					+			
	Formation	+	+	++	+	-	-	-	+	++	+		
Absorption properties	Surface absorption			+	-	-	-	-		+	+	+	
	Wettability	+	+	+		+	-	-	+	+	+		
	The desired Effect	+	+	+	+	--	-	-	+	+	+	+	+

A three step scale is used. No sign has been given for no or a vague effect. A + or – indicates noticeable effect in the direction of sign. Strong effects have been shown by ++ or --

Formation of Paper

After smoothness, formation has wide ranging effects on evenness of both solid-prints and halftones and particularly on calendered papers. Formation can be measured in the form of local variations of grammage, thickness, density, or transparency, the latter being the most common method. The variation in paper density is most harmful 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 appearance. Variation in density arises when a paper of poor formation is calendered to achieve a uniform thickness. Variations of thickness turn into variations of density especially in a machine calendering process.

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.

Foldability of Paper

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 multicolor heat-set printing. The printed paper is exposed to the heat shock from burners radiating at 1000-1400 C. The paper web temperature rises to approximately 220 C in less than 1 second. It is then cooled prior to being printed a second time and subjected again to this severe heating and cooling. While in this moisture free condition, the printed paper is folded into signatures. It has been realized that ordinary tensile and double fold tests do not predict the splitting properties of coated papers for such applications.

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 the 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.

There are several laboratory methods for testing linting tendency of paper, but the laboratory conditions in these methods are significantly different from the actual printing conditions and none of the methods is generally accepted. Most reliable results can be obtained from pilot-scale press trials.

Lightness and Color

The color 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 filter in ELREPHO). Lightness 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 color to the color of the print. The consequence is the reduction of density, an increase in the lightness and a decrease in the saturation of the color of the print.

Opacity

Opacity of paper significantly contributes to the print through. In cases where the effect of vehicle pigment separation is slight, print through is mainly determined by the opacity of paper.

Mechanical pulps are more opaque than chemical pulps. Opacity of paper can be increased by raising the mechanical pulp content of the sheet, and/or increasing the filler/ coat weight.

Gloss

For many years the gloss, smoothness, and print fidelity were considered related. Low gloss, especially in coated papers, was felt to be indicative of a rough surface and correspondingly a surface having poor printability. The development of dull finish and matte-finish coated papers with equivalent and even superior smoothness and printing properties compared to papers of high gloss has reduced the importance of gloss of unprinted papers.

PAPER PROPERTIES REQUIRED FOR DIFFERENT PRINTING PROCESSES

Requirement for Lithography

The paper properties of greater significance in offset printing have been highlighted in Figure-2. Due to the presence of a soft deformable offset roll in this process, the smoothness, formation and the compressibility of the paper are less critical. On the other hand the requirement is more stringent on the runnability side. Since the inks used are tackier, the paper should have high surface strength. Because the paper is moistened during printing, properties like a certain minimum wet pick resistance, good dimensional stability, and uniform moisture content are very important. It is preferred to use a relatively hard sized paper that is less prone to the effect of press moisture. Ideally the moisture content in the paper should be in equilibrium with the environment of the press room. A low pH of paper surface can cause retarded ink drying, low print gloss, and in some cases the distortion of the printing image.

Requirement for Letterpress

For letterpress printing, the critical properties shift from the runnability side to the printability side. The properties, which play a vital role in the final print quality, are: smoothness, formation, compressibility, absorbency, lightness, opacity, linting and dusting behavior. The general requirement for good ink transfer is high oil absorbency, high light scattering coefficient and good smoothness of the paper. The high abrasiveness of paper will result in excessive printing plate wear.

Requirement for Gravure

In the gravure printing the requirement is more stringent for smoothness, formation and compressibility of paper. In fact the process demands ultimate in smoothness.

CONCLUSION

1. Quality of a printed matter is a complex concept. The viewer evaluates a printed matter simultaneously on the content (physical aspects) as well as the intent (psychological aspects) of the image.
2. Only the physical properties of the printed image can be evaluated by instrumental methods.
3. Properties of dry prints can be categorized into three groups: Optical - related to the appearance of the printed surface such as print density, color, gloss, and uniformity of appearance; Mechanical - having to do primarily with durability of printed surface under mechanical stresses such as rubbing and folding/creasing; Chemical - such as the resistance to weather, moisture, light, heat, or specific chemicals, vapor/gas permeability, adhesion properties, and effect of the print on odor and flavor of foods.
4. An acceptable printing paper should meet both the runnability and printability requirements. Runnability ensures smooth feeding of paper through the press at the desired speed, and printability ensures the desired printed output.
5. Different printing processes have different runnability and printability demands on paper.

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