Critical Analysis of Mottling and its Impact on Various Grades of Paper Substrates Printed under Conventional Sheet Fed Offset, Dry Toner & Liquid Toner Based Digital Print Engines

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Abstract

Mottle is one of the print quality factors which highly affect the final print in any printing system. Print mottle is without doubt one of the most important factors regarding visual impression of print quality in any printing system. It is usually the result of uneven ink layer or non-uniform ink absorption across the paper surface and it is more prominently visible in middle tone images or areas of uniform colour such as solids and continuous tone screen images. A mottled picture highly makes the picture smudgy and in most of the cases is not acceptable to the end user. It is required to print photographs with high sharpness and consistently from the very first print to the last print. Mottle pictures can also be observed visually and hence it needs utmost care and attention for enhancing the final print quality. Various types of mottles are generally resulted from the surface characteristics of the substrate, the setting and operation of the printing machines, and the behavior & characteristics of the printing ink.

Key words

Printing, printing press, paper, offset printing, dry toner based digital machine, liquid toner based digital machine, mottling.

1. Introduction

Printing means presentation. It is the presentation of ours ideas, thoughts, expression and knowledge to the people at large. The greatest invention of all time to the mankind is printing. It has created a platform to store information for future use and at the same time made it possible to be used by people of all region and all sections of society. Time Magazine, at the end of the millennium elected Johannes Gutenberg's work as the most crucial event of the millennium.

In general, printing is basically the reproduction of words, pictures, or designs on suitable printing substrates. Substrates are the surfaces on which printing is done. Mechanical method was used solely in past to produce the bulk of all printing, whereas modern printing systems relies mostly on photomechanical and chemical processes, lasers, scanners and digital electronics, nano technology, etc. Printing industry is a very unique, specialized and diversified industry and different printing processes are used to print a large variety of print products and thereby catering a wide array of people across the globe.

Media is one of the strongest pillars for any democratic country. It has certainly a bigger role to play for educating and uplifting the society. Print media, over the time became more durable, portable and affordable. It is one of the oldest media and still it dominates even though from time to time short term challenges are being imposed by other media. Over the years it has travelled a long path, be it the early writings, or the modern digital media. Introduction of internet has certainly changed the face of the conventional form of printing. Moreover, internet can be considered as the supplement to the print media and not its competitor. Research finding indicates that print media is growing worldwide.

Print media basically includes books, magazines, newspapers, brochures, posters, pamphlets and packaging printing. Print products can be classified into either commercial printing or periodicals. This classification is related to frequency of publication of the printed products. Catalogues, brochures, leaflets, business cards are generally produced occasionally and refers to commercial printing. Periodicals as the name implies appears periodically such as newspapers, journals and magazines. Other way of categorizing printed product is by splitting them into special product groups, like, book, magazine, newspaper, brochure, poster, folder and packaging.

Print mottle is without doubt one of the most important factors regarding visual impression of print quality in any printing system. It is usually the result of uneven ink layer or non-uniform ink absorption across the paper surface and it is more prominently visible in middle tone images or areas of uniform colour such as solids and continuous tone screen images. Mottle may be the result of differential ink gloss, density, or colour of the printed ink film. It is often described in terms of its more specific root cause by mottle type. Some of the very common printing mottles are; Printer's mottle, ink trap mottle, back-trap mottle, water interference mottle and paper surface mottle.

2. Literature Review

For over 500 years, letterpress printing system was the dominant printing system for the production of books and other related printed products. Major breakthrough was established at the end of the 18th century by Alois Senefelder, a German map inspector. He invented lithography process of printing in 1796. In the early days of lithography, a smooth piece of limestone was used (hence the name "lithography" is the ancient Greek word for stone). Today, offset lithography is referred as a planographic printing (because in this process of printing both the image areas and the non-image areas lie on the same plane i.e. there is no physical distinction between these areas) process that requires an image carrier in the form of a plate on which photo-chemically produced image and non-image areas are receptive to ink and water, respectively. Planographic process (both the image areas and the non-image areas are separated chemically) of printing is further classified into sheet fed offset and web fed offset presses and they are basically designed to feed the paper/substrate either in sheet/roll form into the printing machine for printing operation.

Traditional forms of printing are basically an analog form of printing technology. Analog is defined as a continuously varying event such as sound or pressure, while a digital signal (is either on or off) makes it a more predictable. Digital, unlike the traditional print processes (like letterpress, offset, flexography, gravure, screen printing) is a direct to output device process thus it does not employ a pre-press operation as would be associated with traditional commercial printing technologies.

Digital printing is also popularly known as Non-Impact Printing (NIP). There are numbers of NIP techniques available in the market and they are basically named after the physical or chemical principle they are based upon. Following technologies are commonly available under this category of printing; electrophotography, ionography, magnetography, ink jet, thermography, photography. Suitable methods are generally incorporated in the system to keep images looking the same colour despite where they are view or printed. This has certainly made it possible to reduce/minimize press turn-around time in comparison to the analog printing techniques. Digital printing systems offers quick response time and hence suits to most of the basic needs of the print buyers. Introduction of digital printing has certainly helped to offer variable data printing (which means personalization and customization is possible).

Unlike traditional methods, dry toner digital equipment works by projecting laser light onto a photo-receptor to produce a charged image. The toner electrostatically "jumps" from the toner source roll onto the photoreceptor, where the document image is created. The toner is then transferred to the paper to produce the finished document. Because the components do not contact each other, physical wear and image distortion are greatly reduced. So, with proper care, digital equipment has the potential to last considerably longer than its non-digital counterparts.

Liquid toner based digital printing machine (i.e. Hp Indigo presses) employs offset printing system successfully by incorporating an offset cylinder covered with a renewable rubbery blanket. The basic function of an offset blanket can be summarized as a pressure pad for making it sure that the inked image from the blanket surface gets transfer onto the substrate with even pressure. This is one of the major reasons behind accommodating a wide range of substrates by offset presses for giving this printing process an edge over other non-offset presses. As liquid toner digital presses employs offset printing system thereby enlarging the wider base of the substrates to be printed effectively by this printing presses.

Printer's mottle is the result of a misconfigured printing press that transfers an inconsistent or uneven layer of ink film on to the paper surface. It is generally caused by the printing press including insufficient printing pressure, contamination of the blanket, wrong printing sequence, and excess ink quantities applied on to the paper surface which leads to a muddy and mottled print image, cloudy structures may be generated due to faults in film and printing plate production.

Poor or inconsistent ink traps in various printing units which eventually transfers non-uniform ink layer on to the surface of the paper and/or previous ink films. This type of mottle is commonly known as the ink trap mottle. Trap requires one wet ink film to capture or trap subsequent ink films. Incorrect ink tack grading, wrong ink sequence, screens over solids, and paper absorbency are the basic causes behind the ink trap mottle.

3. Research Objective

Paper is the basic for any printing process and to take care of a wide range of needs and requirements of the print buyers and end-users, a wide range of papers are available in the market place. Different printing processes are in use for effecting different printing attributes and hence quality levels of these printing systems are also vary, while printing on various kinds/grades of papers. Different paper results into different print quality when printed by digital printing and conventional sheet fed offset printing.

Print mottle is one of the problems which affect the final print quality to a greater extent. It is required to print photographs with high sharpness and consistently from the very first print to the last print. Mottle pictures can be observed visually and hence it needs utmost care and attention. The objective of this research was to critical analysis of various mottles on uncoated, gloss coate, and matt coated papers which are used frequently by conventional sheet fed offset presses, dry toner based digital printing machines, and liquid toner based printing machines.

4. Research Methodology

Following presses were used for the study purpose; one Ricoh, one Xerox (dry toner based digital printing), and one Hp Indigo (liquid tonner based printing) under the digital printing presses category, and one four colour Heidelberg & one four colour Ryobi press. Sheet fed offset is one of the widely accepted forms of printing today, and this is true in both Indian and worldwide market scenario. Sheet fed offset is known for long run jobs with cost effectiveness coupled with high quality printing characteristics, and digital printing technologies have edge over the sheet fed offset printing in terms of short run printing jobs with cost efficiency, personalization, less burden on environment, low level of printing material wastage, and quick delivery time. Three basic requirement for effecting printing include; substrate, colouring substance (i.e. ink), and printing machine. Printing substrate has a major impact on the printing jobs as because it contributes 60-70% of the final cost of a print product.

For this research work three types of papers were selected one from uncoated source, one from coated gloss, and one from matt coated paper category for printing in the various printing machines identified for printing operations. Five different brands (A, B, C, D, and E) of papers (uncoated, coated gloss, and coated matt papers) were collected from various sources and these samples were then tested in a standard paper testing laboratory.

Various properties/tests of paper taken into account include; basis weight, thickness, brightness, CIE whiteness, yellowness, opacity, L*, a*, b*, gloss, tensile index, tear factor, burst factor,

roughness, porosity and Cobb. Out of the five brands, three paper samples one each category (uncoated, coated gloss, and coated matt papers) was selected having test value close to the standard values mentioned in ISO 12647-2 (The table 1 represent various testing results of the selected paper samples). The table shows various tests carried out and the standard procedures followed for various tests, deviation %, unit of measurement, and the test results of various samples. Then same grade of papers were collected from a single lot for printing operations in various printing machines.

Both the standard observer and laboratory test method (IGT, W58 PRINT MOTTLE) are followed in this work. Ten standard observers were selected from a group of 40 printing technology students as per the Farnsworth-Munsell 100 Hue Color Vision Test. Tables from 3 to 8 represent various data collected from the ten standard observers and table 9 shows the data collected from laboratory test of print mottle.

Mottling printing is usually done as constant print density trial (a study on the Environmental implications of offset technology in the Indian scenario and developing a sustainable strategy, Amrutharaj h. Krishnan (SP 09 MS DA 47)), since the print density level affects both the visual evaluation and measured values of mottling. Minimum of 2500 impressions per test is required to observe mottling in the sheet. The readings from the 2500th and 3000th printed sheet is taken in to account. The ten standard observers were given 20 printed sheets each (ten printed sheets at 2500th printing and ten from 3000th printing) for measuring the density (SID) of each colour and the readings were taken for measurement of deviation percentage. The various tables shown below shows % deviation for mottling of various grades of paper printed in different printing machines.

5. Data Collection & Analysis

Three types of paper; gloss coated, matte coated, and uncoated papers were printed on both front side and back side with the help of five types of printing presses. The 2500th and 3000th printed sheets were taken in to account for solid ink density measurement. All the four process colours, cyan, magenta, yellow, and black were taken in to consideration. The graphs shown below indicates the mottling factors of various grades of paper on various printing machines on both front side and back side printing.

Table1 Test results of paper samples

Sr. No.	Property	Standard Procedure	Deviation (%)	Unit	Sample 1 (Matt Paper)	Sample 2 (Gloss Paper)	Sample 3 (Uncoated)
1	Basis Weight	Tappi Test Method T 410	+/-3	g/m^2	128	124	114
2	Thickness	IS: 1060:1	+/-0.5	um	101	109	148
3	Brightness Side1/Side2	IS: 1060:2	+/-0.5	% ISO	88.5/88.1	88.3/88.0	89.2/88.6
4	CIE Whiteness Side1/Side2	T 562	+/-0.3	-	116.8/114.9	116.0/113.0	135.3/133.8
5	Yellowness Side1/Side2	T 1256	+/-0.5	-	-12.71/-12.05	-14.03/-13.48	-20.71/-20.29
6	Opacity	IS: 1060:1	+/-0.4	% ISO	96.2	97.9	95.3
7	L*	T 524	+/-0.5	-	93.9	92.8	92.9
8	a*	T 524	+/-0.5	-	1.76	1.16	3.89
9	b*	T 524	+/-0.5	-	-6.97	-7.30	-11.28
10	Gloss Side 1/Side 2	IS: 1060:1	+/-3	%	14/15	75/72	7/6
11	Tensile Index MD/CD	IS: 1060:1	+/-2	Nm/g	26.2/12.8	44.3/24.6	44.2/24.3
12	Tear Factor MD/CD	IS: 1060:1	+/-1	-	44.2/52.6	37.4/42.0	52.3/57.2
13	Burst Factor	IS: 1060:1	+/-2	-	9.5	18.3	18.3
14	Bendtsen Roughness Side1/ Side2	ISO 8894	+/-5	ml/min	11/12	9/11	158/267
15	Porosity	T 547	+/-20	sec/100 ml	2930	2540	38
16	$Cobb_{60}$	IS: 1060:1	+/-1	g/m^2	63.4	29.1	24.1

Table 2 Print mottle factor of uncoated paper (Front Side)

	M 1	M 2	S 1
Heidelberg	-1	1	0,60475
Ryobi	-1,5	0,5	0,655842
Ricoh	-1	1	0,761135
Xerox	-0,5	1	0,571632
Hp Indigo	-1	2	0,93704

While printing on uncoated paper (front side), print mottle factor in Heidelberg machine varies from -1% to +1%, Ryobi machine it varies from -1.5% to +0.5%, Ricoh machine it varies from -1% to +1%, Xerox machine it varies from -0.5% to +1%, and in Hp Indigo it varies from -1% to +2%, As the deviation %is below 10%, hence the mottling factor is negligible.

Table 3 Print mottle factor of uncoated paper (Back Side)

	M 1	M 2	S 1
Heidelberg	-0,5	0,5	0,598609
Ryobi	-1	1	0,697523
Ricoh	-2,5	1	0,810093
Xerox	-1	1,5	0,667341
Hp Indigo	-1	2	0,748931

While printing on uncoated paper (back side), print mottle factor in Heidelberg machine varies from -0.5% to +0.5%, Ryobi machine it varies from -1% to +1%, Ricoh machine it varies from -2.5% to +1%, Xerox machine it varies from -1% to +1.5%, and in Hp Indigo it varies from -1% to +2%, As the deviation %is below 10%, hence the mottling factor is negligible.

Table 4 Print mottle factor of gloss coated paper (Front Side)

	M 1	M 2	S 1
Heidelberg	-0.5	1	0.577211
Ryobi	-0.5	0.5	0.446496
Ricoh	-0.5	2	0.799038
Xerox	-1	1	0.684536
Hp Indigo	-2	0.5	0.695107

While printing on gloss coated paper (front side), print mottle factor in Heidelberg machine varies from -0.5% to +1%, Ryobi machine it varies from -0.5% to +0.5%, Ricoh machine it varies from -0.5% to +2%, Xerox machine it varies from -1% to +1%, and in Hp Indigo it varies from -2% to +0.5%, As the deviation %is below 10%, hence the mottling factor is negligible.

Table 5 Print mottle factor of gloss coated paper (Back Side)

	M	M	S
Heidelberg	1	2	1
Ryobi	-1.5	0.5	0.683951
Ricoh	-1	1.5	0.59794
Xerox	-1	1.5	0.815613
Hp	-1	2	0.868889
Indigo	-0.5	1.5	0.587121

While printing on gloss coated paper (back side), print mottle factor in Heidelberg machine varies from -1.5% to +0.5%, Ryobi machine it varies from -1% to +1.5%, Ricoh machine it varies from -1% to +2%, Xerox machine it varies from -1% to +2%, and in Hp Indigo it varies from -0.5% to +1.5%, As the deviation %is below 10%, hence the mottling factor is negligible.

Table 6 Print mottle factor of matt coated paper (Front Side)

	M	M	S
Heidelberg	1	2	1
Ryobi	-1.5	1	0.645373
Ricoh	-1.5	1	0.583425
Xerox	-1.5	1	0.861945
Hp	-1	1	0.647357
Indigo	-1.5	1.5	0.745654

While printing on matt coated paper (front side), print mottle factor in Heidelberg machine varies from -1.5% to +1%, Ryobi machine it varies from -1.5% to +1%, Ricoh machine it varies from -1.5% to +1%, Xerox machine it varies from -1% to +1%, and in Hp Indigo it varies from -1.5% to +1.5%, As the deviation %is below 10%, hence the mottling factor is negligible.

Table 7 Print mottle factor of matt coated paper (Back Side)

	M	M	S
Heidelberg	1	2	1
Ryobi	-1	1	0.669744
Ricoh	-1.5	2	0.735544
Xerox	-1	2	0.891466
Hp	-1	1.5	0.597001
Indigo	-1.5	1	0.686873

While printing on matt coated paper (back side), print mottle factor in Heidelberg machine varies from -1% to +1%, Ryobi machine it varies from -1.5% to +2%, Ricoh machine it varies from -1% to +2%, Xerox machine it varies from

-1% to +1.5%, and in Hp Indigo it varies from -1.5% to +1%, As the deviation % is below 10%, hence the mottling factor is negligible.

Table 8 Print mottle (IGT W: 49)

Printing side	Front side	Back side
Gloss coated paper	Not perceived	Not perceived
Matt coated paper	Not perceived	Not perceived
Uncoated paper	Perceived	Perceived

IGT W: 49 test result shows no sign of print mottle on coated paper (i.e. gloss & matt coated paper), and moreover the same is true for the top and bottom side of the substrate. Uncoated paper shows mottling and needs care and attention to avoid such possible problem.

6. Results & Discussions

Print mottle factor for all the substrates selected and used for this work shows the deviation % of less than 10, and the same is true for the five types of machines taken in to consideration for printing. This result shows that mottling is not observed in these types of paper in the above print engines used for printing. However, IGT test results show a slight variation that the constant print density measurement systems, and it is the uncoated paper, on which print mottle is perceived. While discussing the two methods employed for measurement and analysis of mottle, it is the gloss and matt coated paper, where mottle is not an issue.

Uncoated paper results into mottling than the coated papers as because of its different surface characteristics than the coated papers. Surface roughness of the uncoated paper is the major contributor towards mottling and by optimizing the surface of the paper suitably (preferably by choosing suitable fillers) possible mottling can be minimized to the limit, which can be acceptable for taking care of mottling on such type of papers. Suitable ink can be used for the uncoated paper, preferably not high viscous ink. The squeeze pressure between the printing cylinders in sheet fed offset printing also needs to be monitored for reducing possible mottling on uncoated papers. Some of the possible remedies of mottling in sheet fed offset include: prefer to use a slow setting ink system, change the sequence of inks in the press, and for package printing try to print text in the first unit and the solid in the last printing unit. In case of digital printing systems, the fusing of toners and proper selection of toner particles could be the possible remedies, especially in uncoated papers.

7. Conclusion

Print mottle affects seriously the quality of the pictures in the print and it is only the uncoated paper which contributes to print mottle in comparison to the gloss coated and matt coated papers and by possible modifications of the surface characteristics of uncoated papers it is very much possible that mottle can be taken care effectively. Proper selection of ink in relation to the surface characteristics of the paper, suitable adjustments in the press (i.e. squeeze pressure between the cylinders, ink sequence in the press) are also needs to be taken into account for managing print mottle in uncoated papers. Surface characteristics of the coated papers can also be optimized to offer a very smooth and even surface thereby reducing possible effects of mottling along with suitable identification & selection of printing ink to suit the surface characteristics of the substrate. By managing suitably these points, it is highly possible that the possible mottling during the printing cycle can be managed effectively and efficiently.

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