Section A-Research paper
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PRINTING INK DENSITY RELATED ISSUES IN DRY ELECTROPHOTOGRAPHIC (DEP) PRESSES & POSSIBLE SOLUTIONS IN RELATION TO THE SURFACE CHARACTERISTICS OF PRINTING PAPER FOR THE OPTIMIZATION OF SOLID INK DENSITY (SID)

Bijender[1], Anjan Kumar Baral [Ph. D. 2]

1. Research Scholar, Department of Printing Technology, Guru Jambheshwar University of Science & Technology, Hisar
2. Professor, Department of Printing Technology, Guru Jambheshwar University of Science & Technology, Hisar

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ABSTRACT

Keeping in view, the personalized print advantages and short run requirements of the print customers, dry electro-photographic (DEP) printing has become a popular printing method in the recent time in the printing industry. Paper industry is continuously improving itself to serve ever-changing printing requirements for fulfilling various printability and runnability related factors. One of the ways to improve the printability of paper is to apply a suitable coating layer onto the surface of uncoated paper for improve its surface characteristics so as to enhance level of the final print quality. This paper focuses on analysing the ink density related issues in DEP presses on various uncoated and coated paper stocks in relation to surface characteristics of these printing papers.

A master test chart was prepared with the help of texts, solids and line images along with colour control strip prepared with the help of presSIGN version 6.0. The chart was printed with the help of prominently used calibrated dry toner based digital printing machine on rough uncoated, finished uncoated, matte coated and gloss coated papers. The results indicated that coated range of papers exhibit better Solid Ink Density results compared to the uncoated stocks. With the correlation analysis it is found that the density related issues are highly correlated with the surface characteristics i.e., roughness and porosity of the cellulosic substrates.

Keywords: - Solid Ink Density, Rough Uncoated, Finished Uncoated, Matte Coated, Gloss Coated, Solid Areas

INTRODUCTION

Digital printing has brought about a revolution in the printing industry by enabling shorter print runs and personalized products. One popular form of digital printing process is electrophotography, wherein a latent image is created on a photoconductive drum and then transferred onto the substrate using dry toner (Leon, 2014). Paper is a complex material made from compressed cellulose fibers and typically obtained with a somewhat rough and porous surface from mills. The wide range of rough uncoated paper options poses a challenge in meeting customer expectations in the pressroom during printing. Uncoated papers have traditionally caused issues in printing jobs (Ataeefard, 2014).

The surface properties of paper, including smoothness, uniformity, roughness, formation, porosity, and permeability, all contribute to its printability and ultimately affect the quality of printed results. Understanding and optimizing these properties are essential for achieving optimal printing performance (Wilson, 1997). The optical properties of paper play a crucial role in determining the visual quality and overall appearance of printed images. Papers with specific optical characteristics, such as brightness, whiteness, gloss, opacity, and color, contribute to achieving the desired color reproduction and enhancing the appeal of the printed output (Wales, 2004).

To enhance various optical, surface, and printing properties, papers undergo different types of finishing treatments. One such process is paper coating, where a thin layer of coating mixture, known as coating color, is applied to the base paper. This coating improves paper gloss, brightness, ink receptivity, smoothness, and printability (Weigert, 2003). To achieve consistent printing and ensure good color reproduction in digital proofing systems, it is essential to have well-defined and controlled paper properties. By considering and optimizing the optical properties of paper, printers can enhance the visual impact and quality of their printed materials (Thompson, 1998).

REVIEW OF LITERATURE

This review of literature aims to explore the factors influencing solid ink density and the advancements in digital printing technologies to enhance print quality. One of the key parameters affecting print quality is the solid ink density, which refers to the amount of ink deposited on the substrate during the printing process. Density is a numeric logarithm term which represents the lightness and darkness of any printed colour. Solid ink density (SID) is the measurement of ink density at solid print areas (Thompson, 1998).

Achieving optimal solid ink density is crucial for producing vibrant colors and sharp images in dry electro-photographic (DEP) form of digital printing. Standards have been made for SID of Cyan, Magenta, Yellow and Black colours and printers need to take utmost care to match the colour with the help of controlling the density in the respective ink zones and focus should be to have minimum colour difference with the original with minimum SID values (Cofomegra; Adamcewicz, 1994 & Techkon, 2000).

It is important to consider the compatibility of the paper finish with the chosen printing technology, including dry toner systems. Some finishes may pose difficulties in terms of toner adhesion, image quality, and overall print performance. Careful evaluation and testing are necessary to determine the best combination of paper finish and printing technology for achieving optimal results (Evans, 2005). A study conducted in 2007 at the Printing Industry Center at the Rochester Institute of Technology aimed to explore the distinction in perceived value between prints produced using digital and offset printing equipment. The results indicated notable differences in how the prints were evaluated. Prints created on coated media using offset equipment were generally favored, whereas prints on uncoated media produced with digital printers were frequently assigned higher values (Farnand, 2009).

Kettunen and Kärenlampi (2018) examined the relationship between paper properties and runnability issues in dry toner electro-photographic printing. The authors found that paper roughness, stiffness, and moisture content significantly affect runnability. They recommend using papers with lower roughness, higher stiffness, and optimal moisture content for better runnability. Nakamoto et al. (2019) investigated the impact of fuser oil contamination on paper runnability in dry toner electro-photographic printing. The authors found that fuser oil contamination can also cause paper jams and misfeeds, leading to decreased productivity and increased waste. They recommend regular cleaning of the fuser unit and replacing the contaminated fuser oil to improve runnability.

Oshima et al. (2019) revealed the factors affecting toner adhesion to paper in dry toner electro-photographic printing, which can cause toner offset and paper jams. The authors found that toner adhesion is influenced by paper surface roughness, toner particle size, and fuser temperature. The author recommended using papers with smoother surfaces, smaller toner particle sizes, and appropriate fuser temperature settings to improve toner adhesion and runnability. Solid ink density is a critical factor in determining the print quality in dry electro-photographic form of the digital printing. The literature review highlights the importance of ink formulation, substrate characteristics, and printing process parameters in achieving optimal solid ink density.

RESEARCH OBJECTIVES

Dry toner based electrophotography printing is replacing the traditional offset printing process for shorter run jobs, print on demand and personalized prints. Coated and uncoated types of cellulosic substrates are widely used in dry toner based electrophotography printing systems. In dry toner based electrophotography the paper undergoes heating during the fusing stage and the substrate needs to be able to bear it without curl for better runnability and printability. Advancements in digital printing technologies, such as high-resolution printing processes, multilevel printing, and color management systems, offer the printers to enhance print quality. However, addressing existing challenges and exploring new research directions will be essential for the continued evolution of digital printing technologies.

There is strong requirement to examine the various substrate related quality problems arising in dry toner based electrophotography printing, so that necessary preventive actions may be taken while manufacturing the substrates categorized for digital printing. This paper focuses on analysing the ink density related issues in DEP presses on various uncoated and coated paper stocks in relation to the surface characteristics of printing papers and suggesting the ways to optimise the SID.

RESEARCH METHODOLOGY

Various types of papers were examined at the local market, and the papers with the specifications best matchable to ISO were selected for research work. The selected papers were having GSM 100 and belonged to different categories: rough uncoated, finished uncoated, matte coated, and gloss coated papers. The paper characteristics were measured in a calibrated paper testing laboratory and presented in Table 1.

To create a master test chart, Corel Draw Graphics Suite 2020 was utilized, incorporating elements such as lines, text, solids, images, and 234 colour gamut patches. The colour control features, including cyan, magenta, yellow, and black solids, 25%, 50%, 75% tint areas, slur patches, and RGB, were selected using PresSIGN Version 6. The 234 color gamut patches were chosen with the assistance of Fiery Colour Profiler Suite Version 7.2.

The printing process took place on calibrated Canon imagePRESS C8000 VP digital printing machine, calibrated with dry toner, available at Avantika Printers Private Ltd., New Delhi. The printing was carried out under standard pressroom conditions. A total of 200 sheets of various papers were printed, and after every 20 sheets, a sample was taken from each type of paper for testing purposes.

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Solid Ink Density (SID) was measured using the X-Rite (Exact) Spectro-densitometer found in the Quality Control Laboratory of the Department of Printing Technology at GJUS&T, Hisar, Haryana. To analyse the data and find correlation of SID with paper properties, Pearson's Coefficient of Correlation (r) was used. An r value close to -1 indicates a negative correlation, while an r value near +1 indicates a positive correlation between the variables.

DATA COLLECTION AND ANALYSIS

The paper testing result obtained from the certified paper testing laboratory is shown in Table.1. With the comparison of paper properties, it is found that porosity and roughness of rough uncoated paper was maximum with the values 603.5 ml/min and 160.75 ml/min respectively. Gloss value was found highest on the gloss coated paper with the gloss 77.98 % and 75.08 % on top and bottom side respectively.

Table.1. Various surface characteristics of different paper stocks

	GSM (g/m2)	Porosity (ml/min)	Roughness (ml/min)	Gloss-Top (% ISO)	Gloss-Bottom (% ISO)	Ash Content (%)
Rough Uncoated	99.33	603.50	160.75	34.13	36.13	6.00
Finished Uncoated	101.65	500.30	111.65	29.10	33.23	16.05
Matte Coated	101.08	145.50	50.41	35.10	34.80	24.43
Gloss Coated	101.73	130.92	10.24	77.98	75.08	25.97

Table 2 shown below represents the GRACOL standard densitometric reference values for Solid Ink Density. It specifies the recommended density values for different ink colours (Cyan, Magenta, Yellow, and Black) on various types of paper. The first column shows the various paper types i.e., rough uncoated, finished uncoated, matte coated and gloss coated paper stocks, used for the reference. Next columns represent the four primary ink colours used in printing: Cyan, Magenta, Yellow, and Black.

Table.2. GRACOL Standard Densitometric Reference Values for Solid Ink Density (Graphics Communication Association)

Paper Type	Cyan	Magenta	Yellow	Black
Rough Uncoated	1.00	1.12	0.95	1.25
Finished Uncoated	1.10	1.15	0.95	1.40
Matt Coated	1.30	1.40	1.00	1.60
Gloss Coated	1.40	1.50	1.05	1.70

As per standard, the recommended values for Cyan, Magenta, Yellow, and Black on Rough Uncoated paper are 1.00, 1.12, 0.95, and 1.25, respectively. For instance, the recommended values for Cyan, Magenta, Yellow, and Black on Finished Uncoated paper are 1.10, 1.15, 0.95, and 1.40, respectively. The recommended values for Cyan, Magenta, Yellow, and Black on Matt Coated paper are 1.30, 1.40, 1.00, and 1.60, respectively. In the case of gloss grade coated paper, the Cyan, Magenta, Yellow, and Black on Gloss Coated paper are 1.40, 1.50, 1.05, and 1.70, respectively. The tolerance for density was +/-0.07. These values serve as reference guidelines for achieving optimal print quality by ensuring the appropriate density of solid ink on different types of paper. Keeping in view the reference values of SID, the data was collected on DEP press.

Table.3. Comparison of average SID of DEP Press on Different Varieties of Papers

	Cyan	Magenta	Yellow	Black
Rough Uncoated	0.92	1.03	0.87	1.15
Finished Uncoated	1.01	1.06	0.87	1.29
Matt Coated	1.20	1.29	0.92	1.47
Gloss Coated	1.29	1.38	0.97	1.56

In the table 3 and figure 1 comparison of SID is carried out across different paper types and ink colours, providing insights into how the average SID values vary for each combination. It is found that on the Press-I, on the selected paper types, gloss coated paper stocks exhibited superior and highest density range i.e. 1.29, 1.38, 0.97 and 1.56 on cyan, magenta, yellow and black respectively which is highest compared to uncoated and matte coated paper stocks. Highest degree of finish is found responsible for the same. Rough uncoated paper stocks resulted into lowest density on all the process colours. Density range of all process colours was found in the range 6 % - 8 % less than the GRACOL reference SID values.

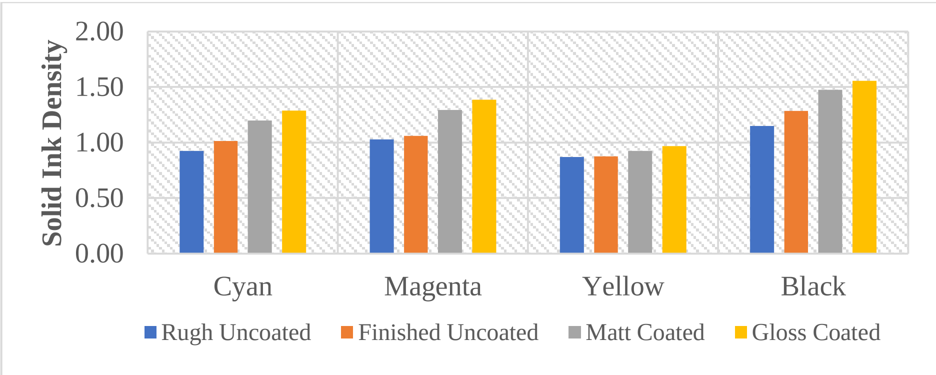

Fig.1. Impact of Substrate on Solid Ink Density of the Print

The SID trend is shown figure 1 in which it is quite visible that rough uncoated paper is having the lowest level of density among all the process colours. The possible reason behind this may be the highest level of roughness and porosity of uncoated paper. But in the case of coated papers, the coating fills up to pores present on the paper surface, which results into better surface finishes, which helps in imparting more better ink holdout and finally results into better solid ink density on the surface. Rough uncoated papers have exhibited density loss significantly due to the presence of pores and highest level of surface roughness on its surface.

RESULT AND DISCUSSION

The solid ink density is found more on gloss grade coated paper stocks compared to matte, and uncoated papers because of the presence of clay coating particles on the surface. Presence of Clay in the paper coating results into better paper finish compared to uncoated and matte grade coated stocks.

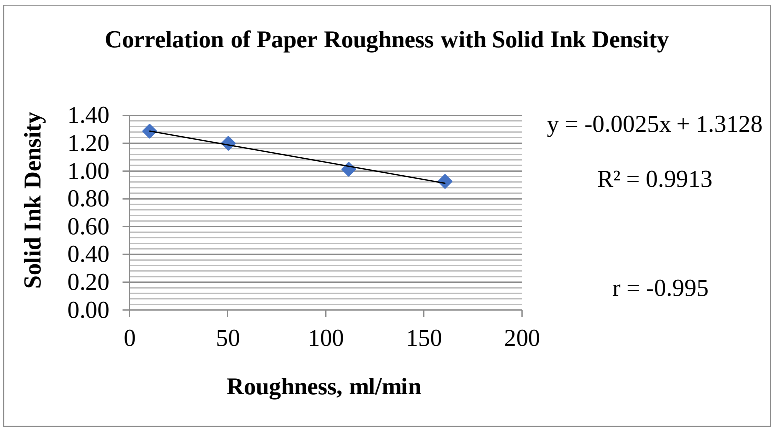

Figure. 2. Correlation of Paper Roughness with Solid Ink Density

With the correlation analysis of paper roughness with the SID (DEP, Press on Cyan Colour), Pearson Coefficient of Correlation (r) was found -0.995 (Figure 2), which is near to -1, which shows that solid ink density is highly negatively correlated with the roughness of the paper. In the same way, coefficient of correlation is found -0.979 for the correlation between paper roughness and SID for Cyan colour on DEP press (Figure 3). It shows that, more the roughness and porosity of the paper (which is in the case of uncoated paper stocks), less will be the SID. Similar trend was found on Magenta, Yellow and Black colours also, on all the six presses taken into consideration. Possible reasons behind these results are; on the surface of the uncoated paper stocks peaks and valleys and due to higher surface porosity, the ink settles down quickly and it essentially causes ink density loss than in the case of coated paper stocks.

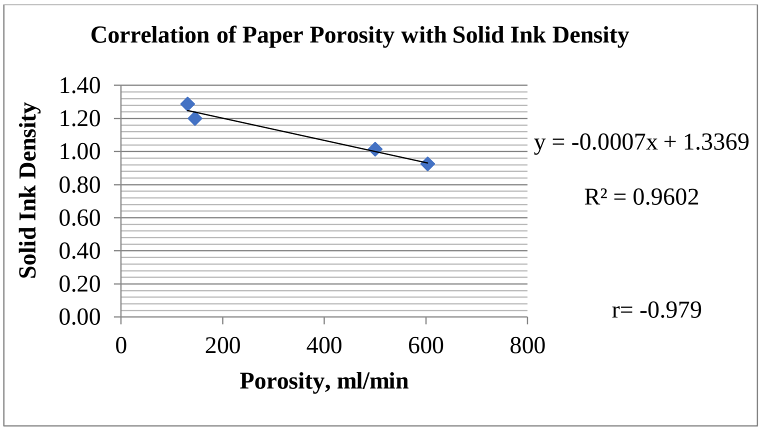

Figure. 3. Correlation of Paper Porosity with Solid Ink Density

To enhance to SID values especially on uncoated paper stocks, porosity and surface roughness of the paper is required to be improved by adding coating colour or sizing agent layer on it. The materials like CMC (Carboxy Methyl Cellulose), starch, latex, gelatine etc. are used as sizing agents for paper. For the purpose of coating, coating colour is applied on the surface of paper to fill the pores of the paper surface to compensate with the density loss in the case of uncoated paper stocks.

CONCLUSION

From the analysis of data presented in various tables and figures, it is quite evident that, paper surface characteristics, its morphological structure and degree of surface finish strongly affect the end user SID results of the four primaries. Effective control over the surface characteristics of the paper helps in achieving the target ink density results. In the case of solid ink density, the rough uncoated papers result into a significant density loss compared to the coated range of papers. In DEP while printing on all the selected presses, the SID values on cyan, magenta, yellow and black on rough uncoated, finished uncoated, matte coated and gloss coated papers was found 6% to 8%, which is less than the standard GRACOL SID reference values.

With the correlation analysis, it is found that both the roughness and porosity of the paper are negatively correlated to SID, which indicates that as much as the roughness and porosity is reduced by adding the coating colour, it will result into higher SID values. But, on the rough uncoated papers, the solid ink density loss is more, resulting into lack of resulting density, which can be certainly controlled by improving the surface characteristics of the substrates during the manufacturing process.

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