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Article

COMPARATIVE SID AND DOT GAIN ANALYSIS OF COATED AND NTR PAPERS USED IN LIQUID ELECTROPHOTOGRAPHY (LEP) PRINTING PROCESS

Bablu[1], Ankit Boora[2], Bijender Kaushik[3]

[1]Research Scholar, Department of Printing Technology, GJUS&T, Hisar, Haryana, India
[2]Assistant Professor, Department of Printing Technology, GJUS&T, Hisar, Haryana, India
[3]Assistant Professor, Department of Printing Technology, GJUS&T, Hisar, Haryana, India

Abstract: This paper provides a comparative evaluation of the print quality between coated and non-tearable (NTR) papers printed using the Liquid Electrophotography (LEP) process. The study aims to evaluate how different substrate characteristics influence print performance and image reproduction quality in LEP printing. Since coated gloss and non-tearable papers are widely used for commercial and specialty printing applications understanding their print behavior is important for selecting most suitable substrates for high-quality digital production. A master test chart will be printed on both substrates under controlled printing conditions using an LEP based digital printing system. The evaluation of print quality will be performed through objective measurement and comparative analysis of two print quality parameters including Solid Ink Density (SID) and Tone Value Increase (TVI). These parameters will be evaluated to determine color strength, tonal reproduction, color accuracy and overprint efficiency of both substrates. The measurements will be carried out under M-1 measurement conditions. The study aims to identify which substrate provides better print quality performance in terms of image sharpness, color consistency, tonal stability and print reproduction quality in the LEP process. The research will explore possible future improvements in substrate properties and digital printing materials to enhance print performance and optimize print quality for industrial and commercial applications.

Keywords: Liquid Electrophotography (LEP), Coated Paper, NTR Paper, Tone Value Increase (TVI), Solid Ink Density (SID).

1. INTRODUCTION

Printing has been one of the major inventions in the history of mankind. Printing refers to the reproduction of 'N' number copies similar to each other, close to original by using any mechanical and digital technologies [1]. In the earlier time, hand writing was used as a printed medium but with the invention taking impression has been faster and more efficient alternative to handwriting or drawing especially when printed materials requires to be produced on a larger scale [2]. In digital printing, a different approach is taken in which each image is assembled from a complex set of numbers and mathematical formulas. Images are captured from a matrix of dots generally referred to as pixels and this process is known as digitizing. The digitized image is then used for the digitally controlled deposition of ink, toner or exposure to electromagnetic energy such as light, through which images are reproduced. Digital printing is also popularly known as Non-Impact Printing (NIP). A number of NIP techniques are made available in the market and they are generally named after the physical or chemical principles on which they are based [3]. Electrophotography is also commonly known as "Xerography" and it is one of the oldest forms of the non-impact printing technologies. It was invented in the mid 1930's by Chester Carlson. Electrophotography is the most complex digital printing technology which basically consists of two critical materials and seven process steps. In this process an electrical image of the original is created on the photoconductive drum and covered with toner particles. When the copier paper passes over the photoconductive drum the toner is transferred to it [4].

Liquid Electrophotography (LEP) is a highly advanced digital printing technology that blends the principles of traditional electrophotography with the precision of liquid based inks. The toner particle size is in the 1-2 µm range. Because of the small particle size the ink provides high resolution, uniform gloss, sharp image edges and very thin ink films [4]. Since the basic material of the liquid electrophotography ink is a novel resin material rather than oily material curing is not dependent on the drying time of the ink film on the medium when it is in contact with the paper or other medium it can immediately cure and produce a clear printed images the edges do not blur and bleed. The biggest difference between Indigo ink and conventional ink is HP ElectroInk technology which directs the ink electronically using charged particles in the ink. Unlike conventional printing that uses a fixed plate, HP indigo digital presses use a light sensitive photoconductor that attracts ink in charged areas It is most widely recognized through HP Indigo presses which transformed modern commercial printing by offering offset like print quality but with the versatility of digital workflow. LEP stands at a unique intersection of chemistry, physics and printing science, enabling extremely fine image reproduction, smooth gradients, sharp text and a broad color gamut across various substrates. In simple words LEP is a digital printing process where charged liquid ink particles are attracted to an electrostatically created image on a photoconductor transferred to a blanket and then fused onto the substrate like paper, films, plastics or metallic sheets [5]. Unlike conventional toner-based laser printing that uses dry powder LEP uses liquid toner also called Electrolnk which consists of pigment particles dispersed in a carrier fluid. The liquid form allows the toner particles to be extremely small typically around one micron which is much finer than dry toner grains. This microscopic size contributes to its extremely high resolution, precise color reproduction and smooth surface finish. Traditional digital printing methods often struggle with non-porous materials like plastic films, metalized surfaces and synthetic papers. LEP on the other hand uses a heated blanket transfer mechanism that helps the liquid ink form a thin, uniform layer. This enables printing on porous as well as non-porous substrates, making the technology extremely valuable for luxury packaging, folding cartons, flexible packaging, shrink sleeves and high-end labels [6]

2. RESEARCH OBJECTIVES

Liquid Electrophotography (LEP) printing is widely used for high quality digital printing due to its ability to reproduce sharp images, smooth tones and stable colors. However, the print quality in LEP printing is greatly influenced by the type of substrate being used. Different substrates such as porous, semi-porous and non-porous surfaces show variations in toner adhesion, dot formation and surface finish. After considering these differences it becomes necessary to study how various substrates affect the overall print quality on LEP printing process.

1. To compare key print quality parameters such as Dot Gain (TVI) and Solid Ink Density (SID) on Coated and NTR printing substrates on LEP printing process.

2. Research Methodology

A quantitative experimental approach will be used to compare the print quality performance of Coated Paper and NTR Paper in the Liquid Electrophotography (LEP) Printing Process. Controlled printing trials will be conducted to evaluate and compare the print behavior of both substrates under print conditions. Solid Ink Density (SID) and Dot gain (TVI) where Selected parameters are tested on the average of 50 printed sheets at a time to maintain consistency of results and to allow reliability. To perform SID and TVI testing, a master test chart was used. The SID and TVI measurements were carried out using a densitometer and total fifty printed sheets were tested to ensure consistency and reliability of the results.

Data Collection and Analysis

The collected print quality data will be systematically analyzed to compare the performance pf Coated Paper and NTR Paper. Parameters such as SID and TVI Values will be measured and recorded for each color channel (CMYK). The average measured values will be represented using tables and graphical analysis to evaluate substrate performance.

Average SID comparison

Table.1. Average SID Comparison of between Coated and NTR Papers

Average	Cyan	Magenta	Yellow	Black
Coated Paper	1.37	1.43	1.25	1.91
NTR Paper	1.40	1.48	1.32	2.01

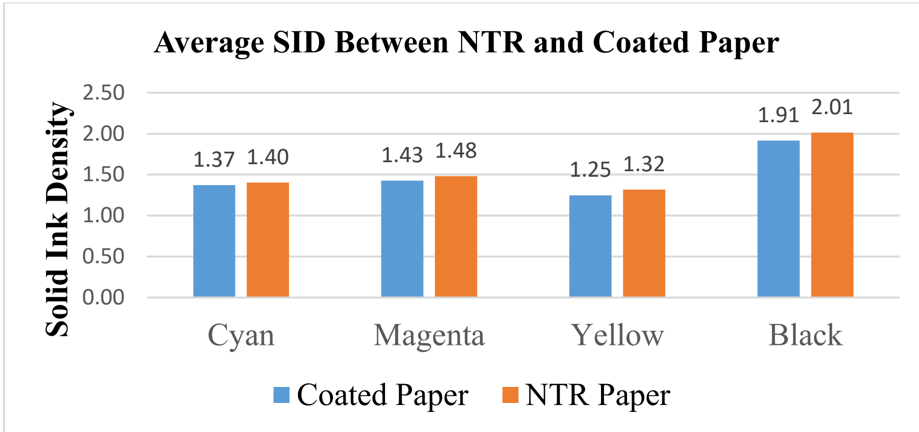

Figure.1. SID results of Coated and NTR Paper (Average 50 sheets)

Solid ink Density (SID) values of coated paper and non-tearable (NTR) paper printed using the LEP process showed slight but noticeable variations across all CMYK colors. The average SID values obtained from fifty printed sheets indicate the NTR Paper achieved higher density values compared Coated Paper. The NTR paper obtained average SID values of 1.40 cyan, 1.48 magenta, 1.32 yellow and 2.01 black. The coated paper obtained 1.37 cyan, 1.43 magenta, 1.25 yellow and 1.91 black. Among all process colors black showed the highest SID values on both substrates its means they indicating stronger density and better visual strength in solid black areas, while yellow obtained the lowest SID values, which indicates its lighter nature and lower perceived density. So that the average SID of ntr paper were found to be slightly higher than coated paper for all CMYK colors. These differences may occur because coated paper has a smoother surface, which helps better toner transfer and improves color density during the LEP printing process.

TVI (%) Average Comparison at 25%, 50% and 75%

The Average of Dot gain / TVI results of coated paper and NTR Paper were analysed at 25%, 50% and 75% tonal Values to evaluate tonal reproduction performance in the LEP printing process. The measurements were obtained from the average of 50 printed sheets using a densitometer through the Master test chart. The testing conditions were maintained constant to ensure consistency and reliability of results.

Table.2. Average comparison of Dot Gain (TVI %) of Coated Paper and NTR Paper at 25% Area

Averages	Cyan	Magenta	Yellow	Black
NTR Paper	2.12	3.78	8.15	5.26
Coated Paper	6.59	8.21	10.56	11.04

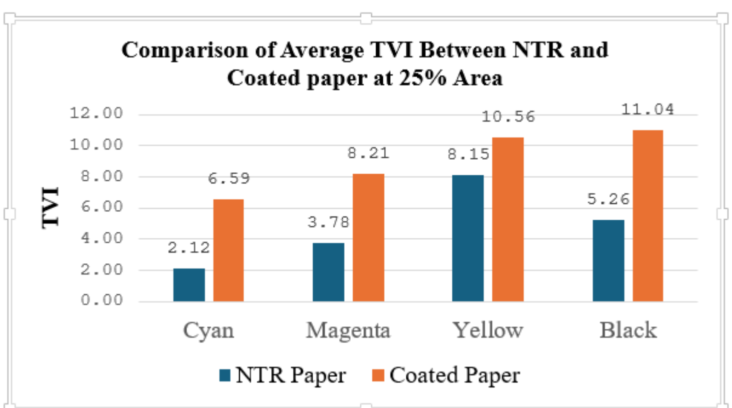

Figure.2. Dot Gain (TVI %) results of Coated and NTR Paper (Average 50 Sheets)

The average comparison of Tonal Value Increase (TVI) in the LEP Process between Coated and NTR Paper is presented in Figure 2 To ensure reliable and consistent results, the testing conditions were kept constant while evaluating the TVI values using a Master test chart and densitometer. The average value was obtained from 50 printed sheets under controlled printed conditions. The results indicate that coated paper exhibited higher TVI values compared to NTR paper across all CMYK colors at 25% tone value. The average TVI values for NTR paper were 2.12 Cyan, 3.78 Magenta, 8.15 Yellow and 5.26 Black, whereas Coated paper obtained 6.59 Cyan, 8.21 magenta, 10.56 Yellow and 11.04 Black.

Among the all-process colors, Black showed the highest TVI value on coated Paper (11.04) while Cyan showed the lowest TVI value on NTR paper (2.12). the result suggest that coated paper produced greater tonal increase at 25% tone value indicating stronger toner build-up and tonal reproduction during the LEP printing process. In comparison NTR paper showed lower TVI values which indicate comparatively lower tonal increase.

Table.3. Average comparison of Dot Gain (TVI %) of Coated Paper and NTR Paper at 50% Area

Averages	Cyan	Magenta	Yellow	Black
NTR Paper	6.40	7.80	10.98	9.40
Coated Paper	11.22	12.84	14.64	14.89

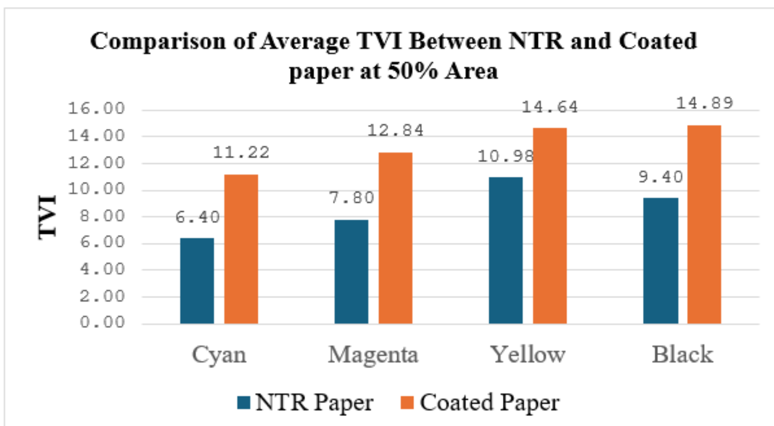

Figure.3. Dot Gain (TVI %) results of Coated and NTR Paper (Average 50 Sheets)

The average comparison of Tonal Value Increase (TVI) in the LEP Process between Coated and NTR Paper is presented in Figure 2 To ensure reliable and consistent results, the testing conditions were kept constant while evaluating the TVI values using a Master test chart and densitometer. The average value was obtained from 50 printed sheets under controlled printed conditions. The results indicate that coated paper exhibited higher TVI values compared to NTR paper across all CMYK colors at 50% tone value. The average TVI values for NTR paper were 6.40 Cyan, 7.80 Magenta, 10.98 Yellow and 9.40 Black, whereas Coated paper Showed 11.22 Cyan, 12.84 Magenta, 14.64 Yellow and 14.89 Black.

Among the all-process colors, Black showed the highest TVI value on coated Paper (14.89) while Cyan showed the lowest TVI value on NTR paper (6.40). the result suggest that coated paper produced greater tonal increase at 50% tone value indicating stronger toner build-up and tonal reproduction during the LEP printing process. In comparison NTR paper showed lower TVI values which indicate comparatively lower tonal increase.

Table.4. Average comparison of Dot Gain (TVI %) of Coated Paper and NTR Paper at 75% Area

Averages	Cyan	Magenta	Yellow	Black
NTR Paper	6.78	8.09	9.23	8.90
Coated Paper	9.09	11.14	11.61	11.82

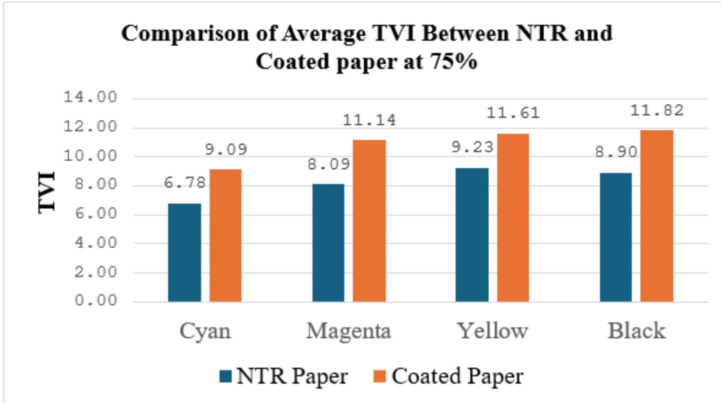

Figure.4. Dot Gain (TVI %) results of Coated and NTR Paper (Average 50 Sheets)

The average comparison of Tonal Value Increase (TVI) in the LEP Process between Coated and NTR Paper is presented in Figure 2 To ensure reliable and consistent results, the testing conditions were kept constant while evaluating the TVI values using a Master test chart and densitometer. The average value was obtained from 50 printed sheets under controlled printed conditions. The results indicate that coated paper exhibited higher TVI values compared to NTR paper across all CMYK colors at 75% tone value. The average TVI values for NTR paper were 6.78 Cyan, 8.09 Magenta, 9.23 Yellow and 8.90 Black, whereas Coated paper Showed 9.09 Cyan, 11.14 Magenta, 11.61 Yellow and 11.82 Black.

Among the all-process colors, Black showed the highest TVI value on coated Paper (11.82) while Cyan showed the lowest TVI value on NTR paper (6.78). the result suggest that coated paper produced greater tonal increase at 75% tone value indicating stronger toner build-up and tonal reproduction during the LEP printing process. In comparison NTR paper showed lower TVI values which indicate comparatively lower tonal increase.

3. Results and Discussion

3.1 Solid Ink Density (SID)

The analysis revealed that average SID of NTR paper were found to be slightly higher than coated paper for all CMYK colors. Higher SID values indicate improved toner transfer and better ink coverage on the substrate surface. These differences may occur because ntr paper has a smoother surface, which helps better toner acceptance and enhance color density during the LEP printing process. Coated paper showed slightly lower SID values as compared to NTR paper. Which may be due to differences in surface properties and toner acceptance. Lower SID values indicate relatively lower toner deposition, which can slightly affect color density and the visual quality of printed output.

3.2 Dot Gain (TVI)

The TVI analysis revealed that coated paper showed higher dot gain at 25%, 50% and 75% area as compared to NTR paper for CMYK colors. Higher TVI values indicate greater dot expansion during the printing process, which may affect tonal accuracy and image sharpness. NTR paper showed comparatively lower values suggesting better control over dot spreading and improved reproduction of halftone dots. Lower dot gain generally results in sharper dot formation, improved tonal reproduction and print consistency. Due to reduced dot expansion NTR paper maintained more accurate tonal values and enhanced image clarity.

4. CONCLUSION

The comparative analysis of SID and TVI showed that both coated and ntr papers exhibited different print characteristics in the LEP printing process. NTR paper achieved slightly higher SID values indicating better toner transfer and improved color density. On the other hand coated paper showed higher dot gain (TVI) at different tonal areas which indicates greater dot expansion during printing the lower TVI values of NTR paper suggest dot control and sharper print reproduction. Overall, NTR paper provided more consistent and stable print quality than coated paper. It gives better print quality performance in LEP printing process.

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