OPTIMIZATION OF COLOUR GAMUT IN VARIOUS ELECTRO-PHOTOGRAPHIC PRESSES (DRY TONER) WHILE PRINTING ON DIFFERENT CELLULOSIC SUBSTRATES

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

1. Research Scholar, Department of Printing Technology, GJUS&T, Hisar, Haryana
2. Professor, Department of Printing Technology, GJUS&T, Hisar, Haryana

Abstract

Paper is a thin sheet made up of intermeshed cellulose fibres adhered together with physical H-H bonding. The morphological properties of paper like the shape, size and particle distribution of the coating pigments results into discrete paper finishes and helps in obtaining the desired print quality results. One approach to measure the capability of paper and press is to measure the colour gamut of paper. Objective of this paper is to correlate the substrate surface characteristics of varieties of cellulosic substrates with the colour gamut of various dry toner based digital printing presses and finally suggesting the ways to optimize it. In the present research work, a master test chart was prepared with the help of texts, solids and line images along with 234 number of colour gamut patches. The chart was printed with the help of six prominently used calibrated dry toner based digital printing machines on rough uncoated, finished uncoated, matte coated and gloss coated papers. Fiery Colour Profiler Suite was used as software tool to create the colour measurement patches and producing colour gamut by scanning the patches with the help of i1iO version 2 instrument. The results indicated that surface characteristics of paper are highly responsible for deciding the colour gamut. Further, with the help of discussions, the surface properties of the paper were correlated with the colour gamut of dry toner digital printing presses to optimize it.

Keywords:- Electro-photographic Printing, Dry Toner, Colour Gamut, Uncoated Paper, Gloss Coated Paper, Matte Coated Paper, Surface Properties

Introduction

Digital printing has revolutionized the printing world by making the printing suitable to shorter runs and supporting personalization. Electrophotography is one of the popular dry-toner based digital printing process wherein the latent image is produced on the photoconductive drum and charging is made. Further with the help of dry toner, impression is made onto the substrate [1, 2].

Paper is a thin, flat and complex material produced by the compression of intermeshed cellulose fibers. The enormous varieties of rough uncoated paper stocks pose a challenge when come to meet customer expectations on press. Uncoated papers traditionally have been troublesome on jobs during printing. Paper coating is a finishing process, in which base paper is coated with a thin layer of coating mixture called coating colour to improve its properties. Coating is usually applied to improve paper gloss, brightness, ink receptivity, smoothness and printability [3, 4, 5].

Colour gamut is the range of colours human eyes can see, television monitor can display or any printing process can print on the substrate. The CIE has a defined color gamut as "volume, area, or solid in a colour space, consisting of all those colours that are either: (a) present in a specific scene, artwork, photograph, photomechanical, or other reproduction; (b) capable of being created using a particular output device and/or medium" [6,7]. In the case of a printing process, colour gamut is the capability of a paper to print the maximum range of colours with the combination of ink on a printing press. Colour gamut is majorly decided by the ink coverage or saturation which can exist on the substrate. It has been observed with experiments that printing processes exhibit lower colour gamut compared to the monitor screen. The printing world is moving towards improving the colour gamut and extended gamut has come to exist wherein the additional colours are introduced beyond conventional CMYK by using the extra printing units of a printing process to extend its gamut. Colour gamut is the function of ink coverage/saturation and hence the substrate characteristics play a vital role in deciding the colour gamut. The paper coating helps in improving the ink holdout and coverage on the surface of paper but for the print quality analyst's point of view, there is a strong need to correlate the surface characteristics of papers with the colour gamut [8, 9].

Research Objectives

In the recent few years, printing industry has undergone a tremendous technological adoption program. To take care of a wide range of needs and requirements of the print-end users and penetration of digital media, the traditional printing presses are no longer effective for the short run print volumes and print-on-demand requirements. Electro-photographic printing process is emerging and in the coming time it will certainly occupy a larger portion in the print market. Paper being the prominent raw material in the printing process, has a bigger role to play when it comes to print quality aspects. Objective of this research work is to critically examine the various surface characteristics of different types of papers frequently used in the dry-toner-based electrophotography press and drawing the relationship while taking into care the most important print factor i.e., the colour gamut.

Research Methodology

Selection of Paper and Testing: - From the local market different varieties of papers were explored. The paper best matchable to ISO 12647-2 specifications were taken. The papers of GSM 100 for rough uncoated, finished uncoated, matte coated and gloss coated papers were taken into consideration. The characteristics of papers are shown in table.1 measured in calibrated paper testing laboratory.

Master Test Chart Preparation: - A master test chart was prepared in Corel Draw Graphics Suite 2020 with the help of various elements i.e., line, text, solids, images and 234 colour gamut patches. The colour control having C, M, Y, K solids, 25%-50%-75% tint areas, slur patches and RGB were selected for master test chart with the help of PresSIGN Version 6. The colour gamut patches (total 234) were selected using Fiery Colour Profiler Suite Version 7.2.

Printing Work: - The printing work was carried out on six dry toner based calibrated digital printing machines models; Canon imagePRESS C8000 VP, Konica Minolta AccurioPRESS C3080, Ricoh pro C5100S, Sharp DX 2500, Sindoh D 310 and Xerox colour 570 names given Press I to Press VI respectively in alphabetical order. The prints were taken in standard pressroom conditions. 200 sheets of various papers were printed on each machine and for testing purpose one printed sheet were extracted after the interval of 20 sheets.

Colour Gamut Measurement: - Colour gamut is the maximum range of the colours produced by any printing machines on predefined substrates. The colour gamut was measured with Fiery Colour Profiler Suite 7.2 and i1iO-2 table with the help of i1 basic pro.

Data Collection and Analysis

Table.1. provides various characteristics of different paper stocks taken into consideration, including GSM (grams per square meter), porosity (measured in ml. per minute), roughness (measured in ml. per minute), gloss on the top and bottom surfaces (measured as a percentage of ISO standards), and ash content (measured as a percentage). The different paper stocks compared in the table include Rough Uncoated, Finished Uncoated, Matte Coated, and Gloss Coated. The testing method is also mention in the table given below: -

Table.1. Various characteristics of different paper stocks

	GSM (g/m2), ISO 536:2012	Porosity (ml/min), ISO 5636-5	Roughness (ml/min), ISO 8789-2:2013	Gloss-Top (% ISO), ISO 1060:1	Gloss-Bottom (% ISO), ISO 1060:1	Ash Content (%), Tappi T 211 om-02
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

Rough Uncoated paper has a higher GSM (99.33 g/m2), higher porosity (603.50 ml/min), higher roughness (160.75 ml/min), and lower gloss on both top (34.13% ISO) and bottom (36.13% ISO) surfaces compared to other paper stocks. It also has relatively lower ash content (6.00%). Finished Uncoated paper has a slightly higher GSM (101.65 g/m2) than Rough Uncoated paper, but lower porosity (500.30 ml/min), lower roughness (111.65 ml/min), and lower gloss on the top (29.10% ISO) and bottom (33.23% ISO) surfaces. It has a higher ash content (16.05%) compared to other paper stocks. Matte Coated paper has a similar GSM (101.08 g/m2) to Finished Uncoated paper, but much lower porosity (145.50 ml/min), lower roughness (50.41 ml/min), and slightly higher gloss on the top (35.10% ISO) and bottom (34.80% ISO) surfaces. It has the highest ash content (24.43%) among the paper stocks compared. Gloss Coated paper has a slightly higher GSM (101.73 g/m2) than Matte Coated paper, but much lower porosity (130.92 ml/min), much lower roughness (10.24 ml/min), and much higher gloss on the top (77.98% ISO) and bottom (75.08% ISO) surfaces. It has a high ash content (25.97%) similar to Matte Coated paper.

Overall, the table provides useful information on the characteristics of different paper stocks that can influence the print quality and colour gamut for dry electro-photographic printing process.

Result and Discussion

Comparison of Paper Characteristics: -

A. Porosity: - From the table.1 and fig.1 it is quite evident that when we move towards rough to coated paper stocks the porosity keeps on decreasing. The key reason behind decrease in porosity is the absence of coating pigments on the surface of the coated paper which fills the gaps between intermeshed fibres.

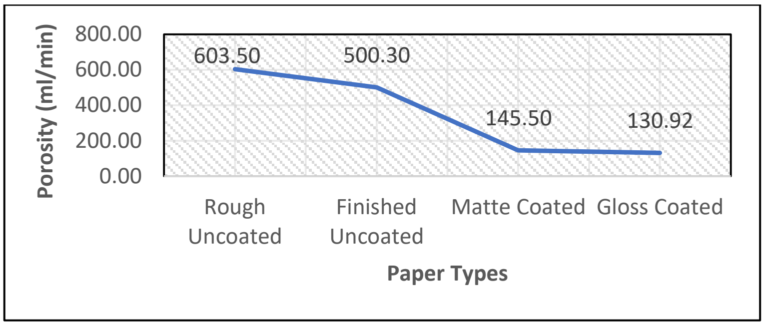

Fig.1. Porosity of different paper types

B. Roughness: - The main function of coating is to fill the inter fibre space. It reduces the roughness of the paper when we move from uncoated to coated paper stocks (Table.1 and Fig.2).

C. Gloss: - Gloss is the measurement of specular reflection from the paper surface. Gloss depends upon micro and macro smoothness of paper. Moving from rough uncoated to gloss coated paper, the gloss in increased from 36% to 75%. The similar trend was found in top and bottom sides both (Table.1 and Fig.3).

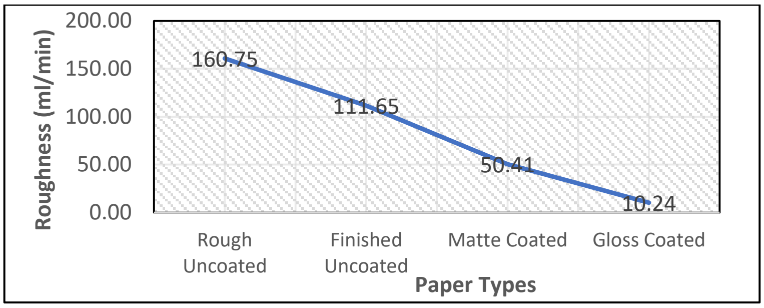

Fig.2. Average Roughness of different paper types

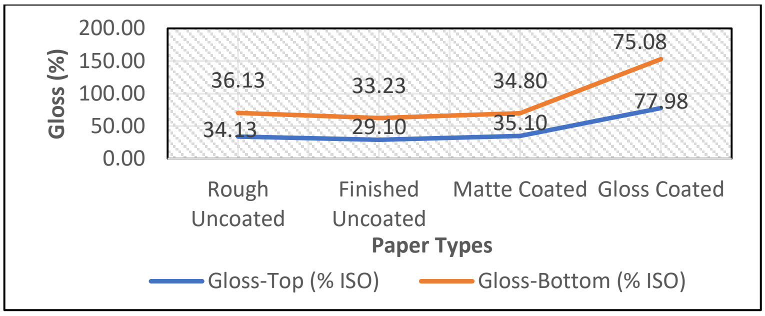

Fig.3. Gloss of different paper types

D. Ash content: - Ash content reveals the inorganic content such as fillers and coating materials used for paper manufacturing. In the rough uncoated stock, ash content is nearly 6%, on the other hand on gloss coated paper ash content is found approx. at 26% (Table.1 and Fig.4).

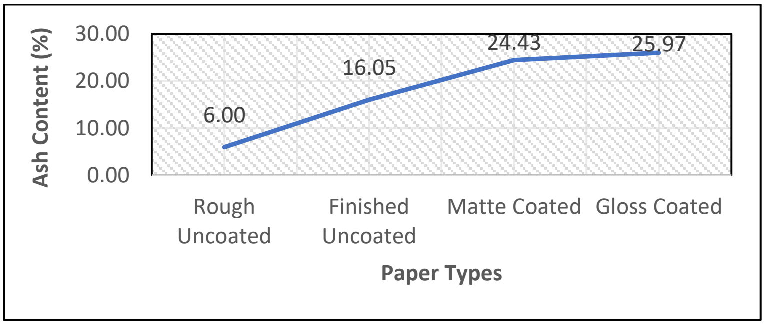

Fig.4. Ash content of different paper types

Impact of Substrate Characteristics on Colour Gamut of Dry Toner based Digital Printing Machines: -

The colour gamut behaviour of all six dry toner based digital printing machines were analysed with the help of CIE lab colour space gamut. It is resulted that the gamut of rough uncoated paper stock (represented with cyan outline) is minimum in most of the regions of CIE lab colour space compared to other paper stocks. The reason behind is the higher roughness and higher porosity (Table.1. and Fig.1, Fig.2.) of the rough uncoated paper causing hills and valleys on its surface. The ink is absorbed inside the paper and ink hold out remains very low on the surface of the paper. Hence, the colour strength remains very low causing loss of colour gamut. Similar pattern is found in the cases of all dry toner-based printing machines (Fig.5.) On the other hand, moving towards higher coated papers, the gloss coated paper results into highest colour gamut. In the case of coated paper, the pours in between the fibres are filled by the coating pigment. The ink is absorbed less causing better ink holdout on the paper surface and hence producing highest colour gamut. Paper manufacturers need to take utmost care to control porosity, roughness and gloss to optimize the colour gamut of dry toner electro-photography.

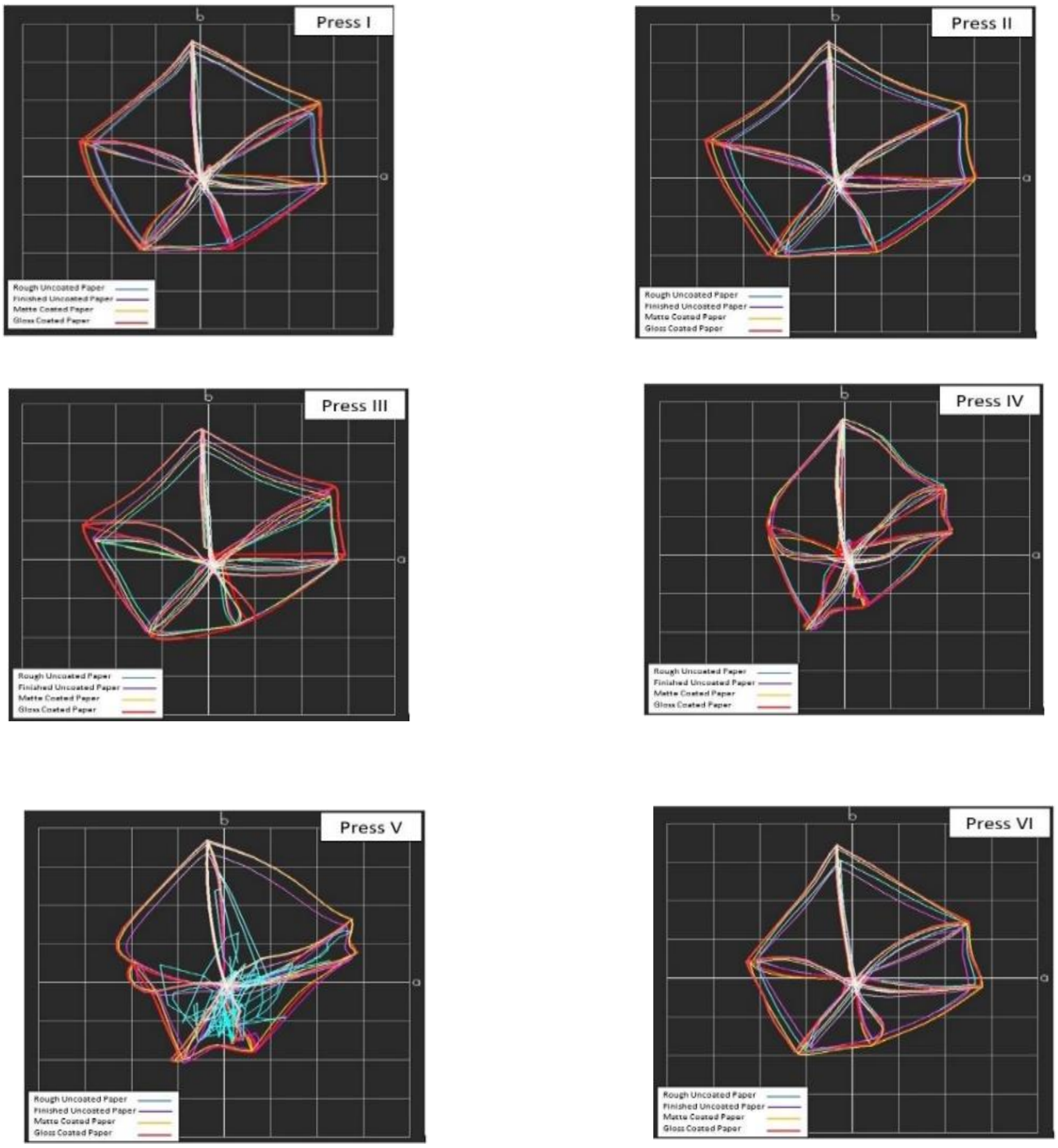

Fig.5. Colour Gamut of different dry toner digital presses on different paper stocks

Conclusion

The surface characteristics and coating pigments of paper are responsible for determining its colour gamut in dry toner based digital printing machines. The gloss coated paper is having maximum surface smoothness and minimum porosity compared to matte coated, rough uncoated and finished uncoated paper stocks. Colour gamut of dry toner based digital printing machines are a function of porosity and smoothness of the paper stocks. In all the six prominent dry toner based digital printing presses, the coated stocks impart higher colour gamut compared to the uncoated paper stocks. The paper with lower porosity results into the higher colour gamut. The paper with higher smoothness results into wider colour gamut. Paper coating fill the space between the fibers resulting into lowering the porosity and improving the smoothness, and hence colour gamut is resulted into maximum in case of coated paper stocks printed with dry toner based digital printing presses.

References

1. Grotans, R. & Fleming, P.D. (2011). The effects of clear toner on the color gamut of a digital press. 385-394.
2. Bailey, M. (2018). Colour management for digital label presses. Global Graphics. https://www.globalgraphics.com
3. Lee, Y., Kim, J. H., & Yun, M. H. (2018). Effects of paper type and toner on the color gamut of dry toner digital printing. Journal of Imaging Science and Technology, 62(2), 20603.
4. Imai, Y., Nagano, M., Naka, Y., & Ohtsuka, Y. (2017). Effect of paper type on the color gamut of electrophotographic prints. Journal of Imaging Science and Technology, 61(4), 40503.
5. Caner, E., Farnood, R., & Yan, N.. Effect of the coating formulation on the gloss properties of coated papers.
6. CIE (International Commission on Illumination). Color gamut.. CIE S17/E:2011 ILV, 17-211
7. Illis, R. (2017). The printer’s guide to expanded gamut [White paper]. Techkon.
8. Hwang, M., & Lin, S. (2022). Perceived Color Gamut in Images: From Boundary to Difference. IEEE Transactions on Visualization and Computer Graphics, 25(3), 1566-1577. doi: 10.1109/TVCG.2018.2874684
9. Werner, S. (2001). Quality limits for the future development of digital printing. In DPP2001: International Conference on Digital Production Printing and Industrial Applications (pp. 370-372).
10. Aliy, G. N., Mikkilineniy, A. K., Chiangz, P.-J., Allebachy, J. P., Chiuz, G. T., & Delpy, E. J. (n.d.). Intrinsic and extrinsic signatures for information hiding and secure printing with electrophotographic devices.
11. Schleusener, M., & Apel, R.. The influence of toner and paper properties on electrophotographic print quality.
12. Oittinen, P., Vikman, K., Sipi, K., & Al-Rubaiey, H. (2001). Research on paper-ink-process interactions in electrophotographic and ink jet printing. International Conference on Digital Production Printing and Industrial Applications, 327-330.
13. Chung, R., & Rees, M. (2007). A survey of digital and offset print quality issues. A Research Monograph of the Printing Industry Centre at RIT Rochester, NY, 1-47.
14. Abouzeid Mohamed, R. S., Dr. (2015). EA toner technology & image quality in electrophotography printing. Research Gate.
15. Weigert, J. (2003). Solutions to reduce the impact of paper properties to print quality and runnability in the NexPress 2100. In IS&Ts International Conference on Digital Production Printing and Industrial Applications (pp. 216-217).
16. Devarajan, K., Jiang, M., Liang, R., & Shen, H. (2016). Color gamut comparison of dry toner and inkjet printing. Journal of Imaging Science and Technology, 60(2), 20401.
17. Kondo, K., Yamada, T., Tsukada, M., Sugimoto, K., & Ikeda, S. (2018). Influence of toner particle size on the color gamut of electro-photographic prints. Journal of Imaging Science and Technology, 62(2), 20604.
18. Schilling, C., Meyer, M., & Schreiber, M. (2019). Comparison of the color gamut of a dry toner printer and a traditional offset printer. Journal of Imaging Science and Technology, 63(1), 10302.