Section A-Research paper
ISSN 2063-5346

FACTORS CONTRIBUTING FOR OPTIMIZING SOLID INK DENSITY (SID) IN IJKJET PRESSES WITH RELATION TO STRENGTH & SURFACE PROPERTIES OF PRITNING PAPER SUBSTRATES

Ankit Boora[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

Published: 24-July-2023 Accepted: 02-June-2023
DOI: 10.48047/ecb/2023.12.si4.1723

ABSTRACT

In Inkjet printing technology, the tiny droplets of ink are directed onto a substrate to create the print output. Inkjet printing technique comes in two main forms; Continuous Inkjet (CIJ) and Drop-on-Demand (DOD). In Continuous Inkjet, ink is continuously expelled as dots, guided by a deflection system, to bombard the substrate on the required image areas. On the other hand, in the case of Drop-on-Demand (Piezoelectric) abbreviated as DoD-PIJ, ink is expelled from the ink reservoir on the required print areas as per droplet requirements, using a piezoelectric crystal. The main objective of this paper is to explore various factors contributing to optimum Solid Ink Density in CIJ and DoD-PIJ presses in relation to strength and surface properties of paper substrates.

For conducting the research, a master test chart was prepared, including presSIGN colour control bar solid patches for cyan, magenta, yellow and black solids and tint areas. This chart was then printed using both CIJ and DOD-PIJ presses under standard pressroom conditions. Subsequently, the printed sheets were analyzed, focusing on solid ink density of four primaries on cyan, magenta, yellow and black patches, using the X-rite e-Exact spectro-densitometer. The resulting solid ink density data was compared on the various factors contributing to the optimization of SID.

KEYWORDS: - Continuous Inkjet, Drop-on-Demand (Piezoelectric), Inkjet Print Engines, Ink Density, Tint Patches, Surface Characteristics, Strength Characteristics.

INTRODUCTION

In recent times, digital printing has gained widespread popularity due to its advantages in handling short print runs and enabling personalized printing. One of the prominent forms of digital printing is inkjet printing, which utilizes ink droplets and appropriate programming to produce prints. Inkjet is a relatively new printing technology that is rapidly gaining traction in

the print market, offering impressive print quality and speed (Adams, 2022). Inkjet printing has experienced a surge in demand for various applications, such as personalized Medical Unique Device Identification (UIDs), compliance with pharmaceutical regulations, e-commerce product packaging, private labeling, and the need for fast-drying prints. These requirements have compelled inkjet printing systems to prioritize speed and accuracy. Modern inkjet technologies are designed with a focus on high-speed printing, and there is a significant emphasis on rapid curing to support efficient production (Uddin et al, 2022).

Many experts believe that inkjet represents the future of digital printing and could potentially replace web offset printing in packaging and publication segments in the near future. As inkjet technology continues to advance and meet the demands accuracy, and quick curing, it is likely to become a dominant printing process in the printing industry (Collins, 2022 & Wickstrom, 2017). Continuous Inkjet (CIJ) printing operates by continuously expelling ink from the ink reservoir. A deflection system is used to direct the ink to specific image areas, while any surplus ink is returned back to the reservoir for reuse. On the other hand, Drop-on-Demand (Piezoelectric-PIJ) inkjet printing functions differently. It selectively places ink droplets only in the areas where printing is necessary. This precise ink droplet ejection is achieved using a piezoelectric crystal that expands and contracts in response to an electric charge. This controlled expansion and contraction enable the formation of ink droplets at the exact locations required for the printing process (Gudapati et al, 2016).

Continuous Inkjet (CIJ) technology finds applications in printing batch numbers, prices, and other details on package prints. It is also widely used for commercial purposes and speedy production. However, when it comes to colored jobs, the commercialization of CIJ technology may take some time to fully mature. On the other hand, Drop-on-Demand (DOD-PIJ) technology is well-suited for applications where speed is not the primary concern. DOD inkjet printers are extensively used in various industrial settings, including printing on materials like cardboard, plastics, timber and hardware, metals, packaging, and concrete products (Oittinen, 2001).

DOD printing offers several advantages, including flexibility, reduced downtime, the ability for mass personalization, and enhanced functionality. These benefits are key drivers propelling the market growth of DOD-PIJ technology in the forthcoming years. As industries seek more versatile and efficient printing solutions, DOD inkjet technology is expected to see increased adoption in diverse industrial applications (Mei et al, 2004).

REVIEW OF LITERATURE

Paper is basically available in uncoated and coated substrate and the particular selection of paper is dependent upon the end-use requirement. Coated paper comes with a coating layer on the surface of the base paper, which is basically a fine and thin layer of mineral pigment and polymeric binder to improve its optical properties and printability related properties (Preston, 2009).

Although inkjet printing can be used for printing on a wide range of printing substrates, for the applications in graphic arts industry, paper is considered as the most preferred printing substrate. Accordingly, most of the inkjet printing inks are highly surface active and penetrative. The resulting inkjet printer output is highly controlled by the viscosity and surface tension of the inkjet inks and to a large extent the porosity, roughness, and surface tension of the printing substrate (Svanholm, 2007).

Density of the printed ink is considered as one of the most important print qualities. Density of the printed ink of the printed substrates is generally measured by reflective density, and is calculated from the amount of light that is reflected from the substrate (paper, film, etc.) and the ink. As a general rule, the increase in ink thickness or the concentration of the printed ink, more incident light is absorbed, and less is reflected back, the higher the density value and vice-versa (Gundlach, 2020).

As a basic rule, increase in solid ink density, contrast of the final printed output can also be increased to a certain point, and then the contrast is decreased as the reproduction gets darker (Adamcewicz, 1994). There is no direct method to measure the ink densities of the printed colours on a press printed sheets, however, in an indirect war, the solid ink density (SID) of the printed ink layers can be effectively measured with the help of a measuring instrument known as densitometer (Pritchard, 2010).

The ink in use, the surface & strength characteristics of the paper to be printed and the press in use for printing can influence certainly the choice of target solid ink densities. Too high printing ink density leads to, clogging the shadows, warm the magentas and yellows, dirty the appearance of the final printed sheets, whereas the low targeted values lead to give a washed-out look to the printed sheets. The colour densities of the printed output should be set and balanced to give neutral greys over the entire range of gray values. Care should be given to monitor on a continuous basis for any possible variation in ink densities from the target, or reference values, for maintaining consistency in colour reproduction throughout the whole printing run. It is always advised to the ink densities are to be balanced for minimizing the possible colour shift (Tobais, 2019).

RESEARCH OBJECTIVES

With the passage of time with the increased quality consciousness among the customers and printers, digital printers are now required to be working on the print quality. Achieving high-quality prints involves not only the characteristics of the paper but also the dynamic interactions between the paper and ink during the printing process. To enhance printability and performance, there is an increased demand for papers with the ability to rapidly absorb oils/solvents and retain colorants on the surface, particularly to meet Solid Ink Density (SID) targets effectively. This need for optimization of solid ink density on the prints is the need of the hour and printers are required to work on it.

Solid Ink Density is a critical print quality parameter that indicates the color intensity on the 100% areas of cyan, magenta, yellow and black in the prints. Other quality parameters, such

as dot gain, print contrast, hue-error, and trapping, depend on SID, making ink density control essential for quality-conscious printers. This paper aims to explore various factors contributing to optimum Solid Ink Density in CIJ and DoD-PIJ presses in relation to strength and surface properties of paper substrates.

RESEARCH METHODOLOGY

In the local market, various types of papers were examined, and those that closely matched ISO specifications were considered. Ultimately, GSM 130 paper was chosen for further evaluation. Three paper varieties were selected for the study: uncoated, matte coated, and gloss coated. These are the main categories of paper substrates commonly find their applications in printing industry for taking care of wide range of printing jobs with different quality level and end uses.

The objective was to assess their Solid Ink Density (SID) behavior in both Continuous Inkjet (CIJ) and Drop-on-Demand (PIJ) forms of Inkjet printing. To conduct the experiment, a master test chart was designed using Corel Draw Graphics Suite 2020, incorporating different tint patches. The SID patches were created using a color control strip provided by presSIGN. Printing was carried out using three different presses: Canon VarioPrint i-series for CIJ, and Kodak Prosper 6000 for DOD-PIJ.

The printing work was conducted under standard pressroom conditions. A total of 500 sheets of various papers were printed, and for testing purposes, a sheet was extracted after every 20 printed sheets for each paper type. Objective measurements of SID were obtained using X-Rite (Exact) Spectro-densitometer available in the Quality Control Laboratory of the Department of Printing Technology, GJUS&T, Hisar. To measure ink density, Cofomegra standard solid ink density values were used as a reference for the measurements, as shown in the table below. This comparison allowed for a thorough evaluation of the ink density and SID performance for each paper type and inkjet technology. Table 1, indicate the standard reference values solid ink densities of the four primary colours.

Table.1. Cofomegra standard SID reference values

	Cyan	**Magenta**	**Yellow**	**Black**
Uncoated Paper	1.20+/-0.05	1.15+/-0.05	1.10+/-0.05	1.60+/-0.10
Matte Coated Paper	1.35+/-0.05	1.30+/-0.05	1.25+/-0.05	1.75+/-0.10
Gloss Coated Paper	1.45+/-0.05	1.40+/-0.05	1.35+/-0.05	1.80+/-0.10

DATA COLLECTION & ANALYSIS

The solid ink density was measured on 20 printed seats extracted after specific interval and further average was taken. Cofomegra SID values shown in the table.1 were taken as reference. The average density measured values on uncoated paper, matte coated paper and gloss coated paper are shown in table 2 to table 4 respectively given below: -

Table.2. Average SID values on Uncoated Paper Stock on CIJ and DoD (PIJ) Presses

Solid Ink Density	Cyan	Magenta	Yellow	Black
CIJ	1.01	0.97	0.92	1.32
DoD (PIJ)	1.06	1.01	0.97	1.38

From Table.2. and Chart.1. it is quite evident that Solid Ink Density of Piezoelectric was found more compared to the DOD-PIJ on uncoated paper stocks. The possible reason is the controlled uniform supply of inks in PIJ presses which penetrate more into the uncoated paper stocks with high resolution resulting into high ink hold out and hence more solid ink density is found in case of DOD-PIJ presses.

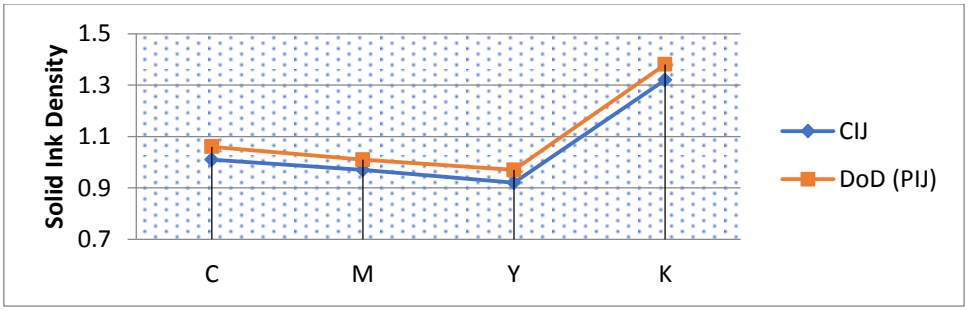

Chart.1. Average SID values on uncoated paper stocks

From the Table.3., Chart.2. it is found that Solid Ink Density of Continuous Inkjet was found less compared to the DOD-PIJ form of the Inkjet on mate coated paper stocks. The reason is the technology and inks of the PIJ presses which could not penetrates more into the matte coated paper stocks resulting into more ink hold out and hence more density is found in case of DOD.

Table.3. Average SID values on Matte Coated Paper Stock on CIJ and DoD (PIJ) Presses

Solid Ink Density	Cyan	Magenta	Yellow	Black
CIJ	1.14	1.1	1.05	1.5
DoD (PIJ)	1.2	1.15	1.1	1.57

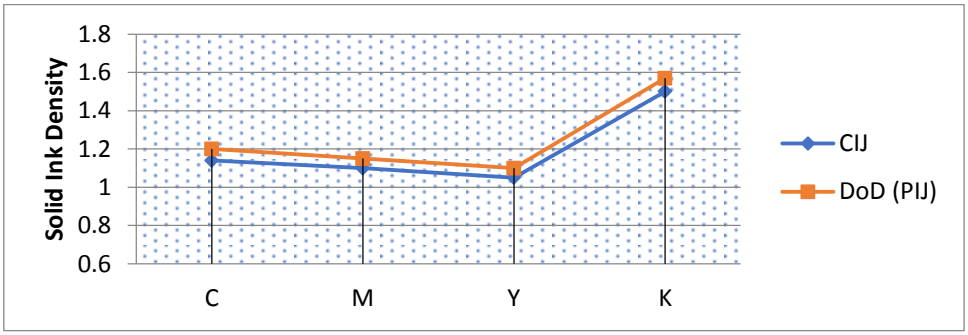

Chart.2. Average SID values on matte coated paper stocks

Table.4. Average SID values on Gloss Coated Paper Stocks on CIJ and DoD (PIJ) Presses

Solid Ink Density	Cyan	Magenta	Yellow	Black
CIJ	1.23	1.19	1.14	1.5
DoD (PIJ)	1.29	1.24	1.2	1.56

From the Table.4., Chart.3. it is evitable that Solid Ink Density of PIJ inkjet was found more compared to the CIJ form of the Inkjet on gloss coated paper stocks. The reason might be the inks of the PIJ presses which could not penetrates more into the gloss coated paper stocks resulting into more ink hold out and hence more density is found in case of DOD-PIJ.

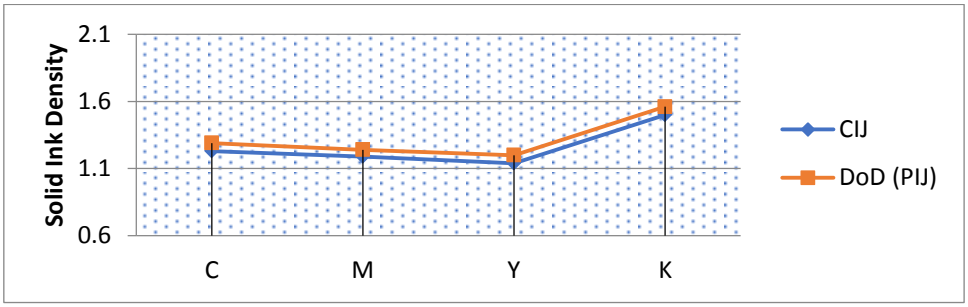

Chart.3. Average SID values on gloss coated paper stocks

RESULTS AND DISCUSSION

Solid ink density values in Continuous Inkjet Presses were found 12-15% lower than the standard Cofomegra reference values. The possible reason for the lower values is the bombarding of low viscosity inks on the paper substrate which penetrates the surface structure of the paper. The compatibility between the printing ink and the paper substrate to be printed is highly crucial for achieving optimum values of solid ink density in CIJ and PIJ presses. There are inks which are specially designed for the uncoated papers and for the coated papers.

Even there are inks which are formulated for the matte paper and gloss coated papers separately, and inks which are very much compatible to both the matte and gloss coated papers. It is highly essential, to select a desired ink which suits to the particular paper for better solid ink densities. Result shows in the coated paper category, due to higher coating thicknesses on gloss coated papers than the matte coated papers, produces a higher smoother surface, and hence a better ink density values achieved on gloss coated papers.

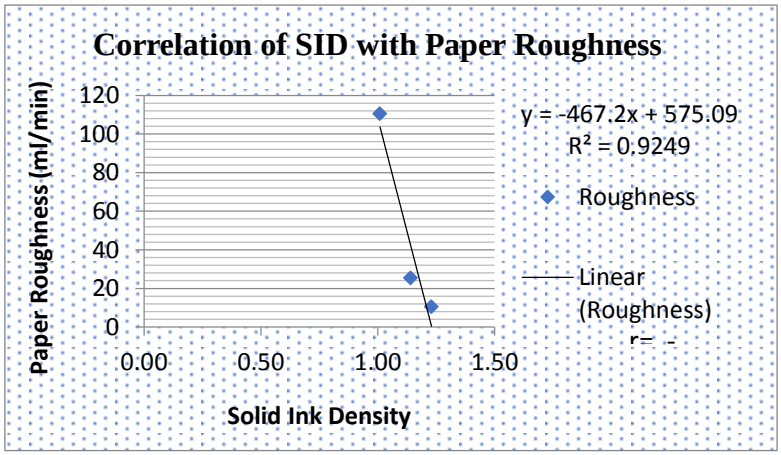

Fig. 4 Correlation of SID with Paper Roughness

Figure.4 indicates that, the value of coefficient of correlation "r" was found -0.961 which shows that the value of SID decrease with the increase in paper roughness. While discussing the CIJ and PIJ presses, with respect to solid ink densities of the four primary colours on the uncoated, matte coated and gloss coated papers, it is very much visible that, PIJ presses are designed to have better ink densities than the CIJ presses. This is due to the fact that, better control of ink is in PIJ presses and the same is true on all the three types papers taken into research work. This indicates, continuous inkjet presses are designed and manufactured for high-speed operation and piezoelectric inkjet presses are for high quality applications, irrespective of the paper substrate types; uncoated, matte coated, and gloss coated papers.

CONCLUSION

Solid ink density of the four primary colours essentially controls the printed colour consistency, sharpness, and dot reproducibility of the printed products. Configuration of the inkjet press along with the surface properties of the printing substrates and the working properties of the inkjet inks are the possible factors which essentially control the optimum range of solid ink density of the printing colours. This research work reveals that, uncoated papers with high surface roughness and porosity properties are not able to produce solid ink density values near to the standard reference values. The ink effectively absorbed into the paper surface, reducing the solid ink density values on uncoated papers. If the normal ink can be replaced with high density pigments, then the inkjet heads may face clogging of the nozzles, creating other operational problems.

The uncoated paper has resulted into lowest solid ink density. In case of coated papers, both matte coated and gloss coated papers, the value of the resulted solid ink density is certainly better than the uncoated paper results. As a suitable coating layer is given on the paper surface, better holding of the ink on the paper surface causes better solid ink densities. Gloss coated papers with higher thickness of the coating layer than the matte coated papers, produces excellent result than the matte coated and uncoated papers, hence is recommended for high quality printing applications. While comparing the Continuous inkjet and piezoelectric DoD inkjet presses, PIJ produces better solid ink density on all the three types

of papers (uncoated, matte coated, and gloss coated), as because of better control of ink droplets onto the paper surface and the characteristics of the printing ink used in these presses.

REFERENCES

- Adamcewicz, J. E. (1994). A study on the effects of dot gain, print contrast and tone reproduction as it relates to increased solid ink density on stochastically screened images versus conventionally screened images. Rochester Institute of Technology, RIT Scholar Works.
- Adams, K. (2022). Five Trends for Industrial Inkjet Printing in 2022. Packaging Technology Today, https://www.packagingtechtoday.com/featureds/five-trends-for-industrial-inkjet-printing-in-2022/.
- Collins, K. (2021). Six Trends in Industrial Inkjet Printing in 2021. Ink World Magazine, https://www.inkworldmagazine.com.
- Gans, B., Paul, C., & Ulrich S. S. (2004). Inkjet Printing of Polymers: State of the Art and Future Developments. Weinheim, pp. 203-213.
- Gigac, J., Stankovska, M., Opálená, E., & Letko, M. (2014). The effect of base papers properties on inkjet print quality. Wood Research, 59(5): 717-730.
- Gudapati, H.; Dey, M.; Ozbolat, I. (2016). A Comprehensive Review on Droplet-Based Bioprinting: Past, Present and Future. Biomaterials, 102, 20–42.
- Gundlach, M. (2020). Measuring density with a densitometer. X-rite.
- Mei, J., Lovell, M., Mickle, M., & Heston, S. (2004). Continuous ink-jet printing electronic components using novel conductive inks, University of Pittsburgh, pp. 334-345.
- Oittinen, P., AL-Rubaiey, H., Sipi, K. and Vikman, K. (2001). Research on Paper-Ink-Process Interactions in Electro-photographic and Ink Jet Printing. Graphic Arts in Finland, 30 (2), pp. 5-10.
- Preston, J. (2009). The surface analysis of paper. Advances in Pulp and Paper
- Pritchard, G. (2010). Tolerancing color in presswork using solid ink density. The Print Guide.
- Svanholm, E. (2007). Printability and Ink-Coating Interactions in Inkjet Printing. Dissertation, Karlstad University Studies, pp. 1-81.
- Tobais. (2019). Basics of densitometry.
- Uddin, M.J., Hassan, J., Douroumis, D. (2022). Thermal Inkjet Printing: Prospects and Applications in the Development of Medicine. Technologies, 10, 108. https://doi.org/10.3390/technologies10050108.
- Wickström, H.; Nyman, J.O.; Indola, M.; Sundelin, H.; Kronberg, L.; Preis, M.; Rantanen, J.; Sandler, N. (2017). Colorimetry as Quality Control Tool for Individual Inkjet-Printed Pediatric Formulations. AAPS PharmSciTech, 18, 293–302.
- Wijshoff, H. (2010). The Dynamics of the Piezo Inkjet Printhead Operation. Phys. Rep., 491, 77–177.