

# COMPARATIVE ANALYSIS OF SOLID INK DENSITY (SID) FOR COATED & UNCOATED PAPER IN SCREEN PRINTING PROCESS USING VARIOUS SCREEN MESH

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**ABSTRACT:** Screen printing continues to be one of the most widely employed printing processes for producing high quality durable images on paper and other irregular substrates owing to its superior ink deposition capability. The increasing demand for standardized colour reproduction and process consistency in commercial printing has highlighted the importance of screen printing. Evaluating print characteristics under controlled production conditions is the most important factor for optimization quality in screen printing. Among the critical parameters in influencing print performance in screen printing are screen materials for screen and mesh resolution, which has direct effect on print quality parameters like TVI, Delta E ( $\Delta E$ ), Solid Ink Density (SID) etc.

Although several studies have examined the individual influence of substrate type or inks, no comprehensive investigation has reported comparative analysis of Solid Ink Density on coated and uncoated papers printed with UV- curable and solvent - based inks using identical screen-printing conditions and on mesh count at 65 & 85 threads per inch.

Print samples were produced under controlled press-room conditions using a flatbed screen-printing machine. Standardized test charts containing solid colour along with 20 other print elements were combined for various observation with different set of materials. Solid Ink Density measurements were performed using a calibrated spectrophotometer in accordance with ISO 5-3 and ISO 13655 standards. Statistical analysis, including mean values, standard deviation and inter-substrate comparisons was conducted to evaluate print consistency.

Findings establish statistically supported framework for evaluating solid ink density in screen printing and demonstrate appropriate selection and combination of substrate and ink system that is essential for achieving optimum colour density, print consistency and process control. The outcomes of this research provide valuable guidance for commercial screen-printing applications and contribute to improved quality assurance and standardization in paper-based printing production.

**Keywords:** Screen Printing, Solid Ink Density (SID), Screen Mesh, Print Quality and Print Optimization.

## 1. Introduction

Screen printing is one of the oldest and most versatile printing processes and continues to play a significant role in industrial, commercial and specialty Printing & Packaging applications. Unlike other conventional printing methods, screen printing transfers ink onto a substrate by forcing it through a stencil mounted on a woven mesh using a squeegee. This process enables the deposition of relatively thick ink films, resulting in excellent colour strength, high opacity and superior durability on a wide variety of substrates, including paper, plastics, textiles, glass, ceramics, metals and electronic components [1][2]. Due to its flexibility and cost-effectiveness, screen printing remains widely used in paper & board Printing, Packaging, Advertising, Graphic arts, Textile printing, Automotive components and printed electronics [3].

The quality of a screen-printed image depends on several parameters, including substrate characteristics, screen mesh count, stencil thickness, squeegee pressure and angle, printing speed, ink rheology, curing conditions and environmental factors [4]. Among these variables, substrate surface properties and ink formulation has a direct influence on ink transfer, colour reproduction and print consistency. Coated papers generally possess a smooth and less absorbent surface, allowing ink to remain near the surface and producing higher colour density and improved image sharpness. Uncoated papers exhibit greater porosity and absorbency, leading to increased ink penetration, lower optical density and potential variations in print quality [5].

Solid ink density (SID) is one of the most important objective parameters used to evaluate print quality and process stability irrespective of printing process. SID represents the optical density of a solid printed area and is closely associated with colour saturation, ink film thickness and ink transfer efficiency [6].



Recent developments in UV-curable and solvent-based ink technologies have further enhanced the capabilities of screen printing [7]. UV-curable inks polymerize rapidly under ultraviolet radiation, offering excellent adhesion, reduced drying time, improved abrasion resistance and lower emissions of volatile organic compounds (VOCs). Solvent-based inks continue to be widely used because of their excellent substrate compatibility, flexibility and outdoor durability [8].

## 2. RESEARCH OBJECTIVES

To compare the Solid Ink Density (SID) of coated and uncoated paper printed by the Screen Printing process by using various screen mesh resolution on coated and uncoated paper.

## 3. Methodology, materials and printing condition

In order to achieve the objective of this empirical study, entire research was critically evaluated and accordingly to achieve the objectives the influence of screen mesh count on the Solid ink density (SID) of coated and uncoated paper in the screen printing process. The research was conducted under controlled conditions to minimize external variations and ensure the reliability and repeatability of the experimental results. The independent variables included substrate type, screen mesh count and ink type, whereas Solid ink density (SID) served as the dependent variable.

**Figure 3.1 FLOW CHART OF STUDY**

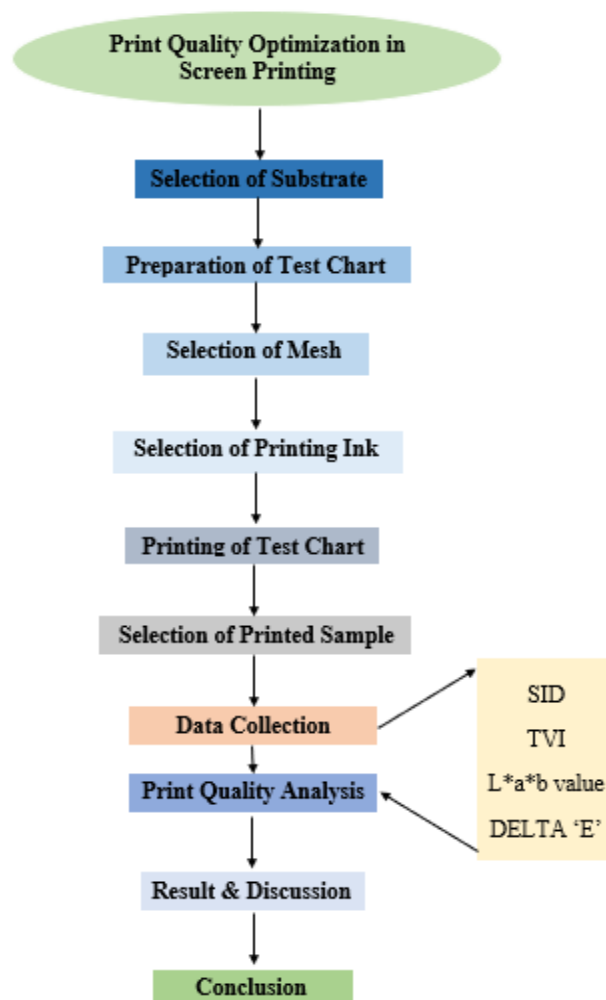


Table 3.1 Description of materials and other factors selected for study

| Sr. No | Technical specification | Selected items             |
|--------|-------------------------|----------------------------|
| 1      | Paper                   | Coated & Uncoated Paper    |
| 2      | Ink                     | UV ink & Solvent based ink |

|    |                                     |                                         |
|----|-------------------------------------|-----------------------------------------|
| 3  | Mesh material                       | Polyester mesh                          |
| 4  | mesh Count                          | 65 & 85 TPI (Threads/inch)              |
| 5  | Squeegee material                   | Polyurethane 85 shore-A                 |
| 6  | Printing Condition                  | ISO-12647-5 (Screen Printing)           |
| 6  | Viewing condition                   | ISO-13655                               |
| 7  | Instrument used for data collection | Spectrophotometer                       |
| 8  | Quality Parameter measured          | SID, TVI, and L*a*b for Delta E         |
| 9  | Measuring condition                 | 2 <sup>0</sup> 15 cm distance, 2000 lux |
| 10 | Filter used in measuring            | M0 and M1                               |

The experimental materials consisted of 110 GSM coated paper and 100 GSM uncoated paper as the printing substrates. Two polyester screen meshes with resolutions of 65 threads per inch (TPI) and 85 threads per inch (TPI) were selected to evaluate the effect of mesh count on ink transfer characteristics. Two commercially available screen-printing inks, namely solvent-based ink and UV-curable ink, were used throughout the study. Printing was carried out using a screen-printing press equipped with a polyurethane squeegee of 75 Shore A hardness. A standardized CMYK test chart containing solid colour patches was prepared in accordance with the recommendations of ISO 12647-5 for process control in screen printing. Solid ink density measurements were performed using an X-Rite eXact Spectrophotometer, and the measurement data were recorded using the associated colour evaluation software.

Prior to printing, separate screens were prepared using 65 TPI and 85 TPI polyester mesh stretched uniformly on identical screen frames. The prepared screens were carefully inspected to ensure proper image reproduction, stencil integrity and uniform coating quality before beginning the printing trials.

Printing was performed by maintaining all production parameters constant throughout the experiment. The same operator conducted all printing trials to eliminate operator-induced variability. Squeegee angle, squeegee pressure, printing speed, snap-off distance and printing direction were maintained consistently for every sample. Each combination of substrate type, screen mesh count and ink type was printed using the standardized CMYK solid test chart

Following the printing process, solvent-based ink prints were allowed to dry naturally under controlled conditions, whereas UV-curable ink prints were immediately cured using a UV curing unit according to the manufacturer's recommended curing parameters. All printed samples were subsequently conditioned for 24 hours at a temperature of  $23 \pm 2^{\circ}\text{C}$  and a relative humidity of  $50 \pm 5\%$  before colour measurements were performed. This conditioning procedure ensured that the printed samples reached equilibrium and eliminated variations caused by environmental factors.

Solid ink density (SID) measurements were carried out using the calibrated x-Rite eXact spectrophotometer. Density values were measured for the Cyan, Magenta, Yellow, and Black (CMYK) solid patches printed on each sample. All measurements were conducted under the standard measurement conditions specified in ISO 13655, while the overall print quality evaluation followed the process control recommendations outlined in ISO 12647-5 for screen printing.

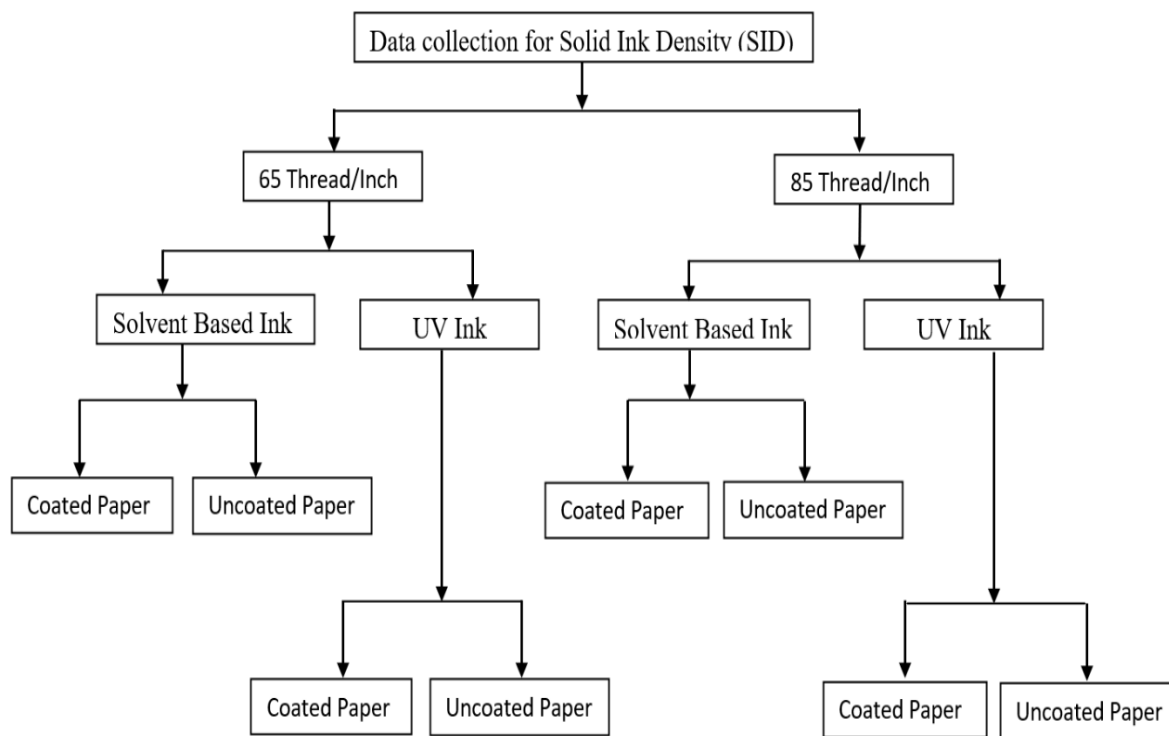
The collected SID data were compiled and organized using Microsoft Excel and subsequently analyzed using appropriate statistical software. Descriptive statistical techniques, including mean and standard deviation, were calculated for each experimental condition. Comparative analyses were performed to evaluate the influence of substrate type, screen mesh count and ink type on solid ink density. The results were presented using tables and graphical representations to facilitate comparison between experimental groups. Statistical significance of the observed differences was determined using Analysis of Variance (ANOVA) at a 95% confidence level ( $p < 0.05$ ).

To ensure the validity and reliability of the experimental findings, all printing conditions were maintained consistently throughout the investigation. The same batch of printing substrates, screen meshes, emulsions, inks and measuring instruments was used for all experiments. The spectrophotometer was calibrated before every measurement session according to the manufacturer's recommendations. Multiple printed samples and repeated measurements were employed to minimize experimental errors and enhance the precision and repeatability of the obtained results mesh count. The overall research procedure consisted of substrate selection, screen preparation, printing under standardized conditions, sample drying and conditioning, Solid Ink Density measurement, statistical analysis of the collected data and interpretation of the results to determine the effect of different screen mesh counts on coated and uncoated paper in the screen printing process.

## 4. Data Collection and analysis

Solid Ink Density (SID) is the optical density measured from a solid printed ink area using a reflection densitometer. It quantifies the amount of ink deposited on the substrate and is a key print quality parameter used to evaluate ink transfer, color intensity and printing consistency in screen printing.

**Figure 4.1: Flow Chart for SID Data Collection**



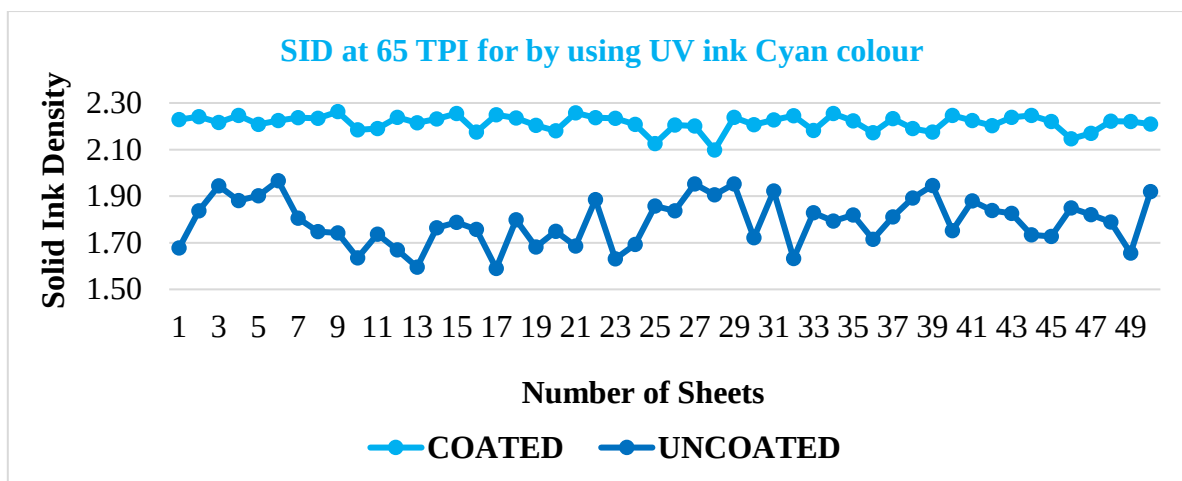
### 4.1.1: SID at 65 TPI by using UV for ink Cyan colour

Measured values for solid ink density (SID) for screen printing at 65 Threads/inch by using UV ink on selected coated and uncoated paper for cyan colour are tabulated in Table 4.1.1 and graphically presented in (Figure 4.1.1)

**Table 4.1.1: SID at 65 TPI by using UV for ink Cyan colour**

| SID        | Coated | Uncoated |
|------------|--------|----------|
| Min. Value | 2.10   | 1.59     |
| Max. Value | 2.26   | 1.97     |
| Average    | 2.21   | 1.79     |
| S.D.       | 0.03   | 0.10     |

The minimum and maximum measured value for SID on coated and uncoated paper were recorded between 2.10 to 1.59, 2.26 to 1.97 respectively. The range of SID for Cyan colour is highest on coated and lowest on uncoated paper. It shows consistent results for cyan colour on coated paper. It shows standard deviation of 0.03, 0.10 on coated and uncoated paper respectively.



**Figure 4.1.1 SID at 65 TPI by using UV ink for Cyan colour**

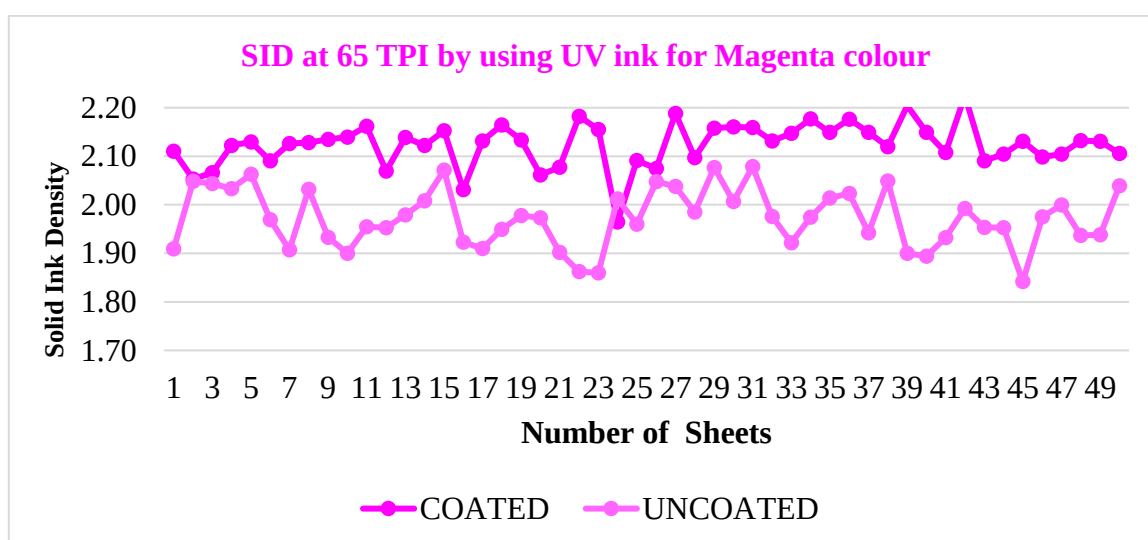
#### 4.1.2: SID at 65 TPI by using UV ink for Magenta colour

The representation of data for solid ink density (SID) for screen printing 65 Threads/inch by using UV ink on coated and uncoated paper magenta colour is tabulated in Table 4.1.2 and graphically presented in (Figure 4.1.2)

**Table 4.1.2: SID at 65 TPI by using UV ink for Magenta colour**

| SID        | Coated | Uncoated |
|------------|--------|----------|
| Min. Value | 2.23   | 2.08     |
| Max. Value | 1.96   | 1.77     |
| Average    | 2.12   | 1.96     |
| S.D.       | 2.12   | 1.97     |

The minimum and maximum measured value for SID on coated and uncoated paper were recorded between 2.23 to 1.96, 2.08 to 1.77 respectively. The range of SID for Cyan colour is highest on coated and lowest on uncoated paper. It shows consistent results for magenta colour on coated paper. It shows standard deviation of 2.12 on coated paper and a standard deviation of 1.97 on uncoated paper.



**Figure 4.1.2: SID at 65 TPI by using UV ink for Magenta colour**

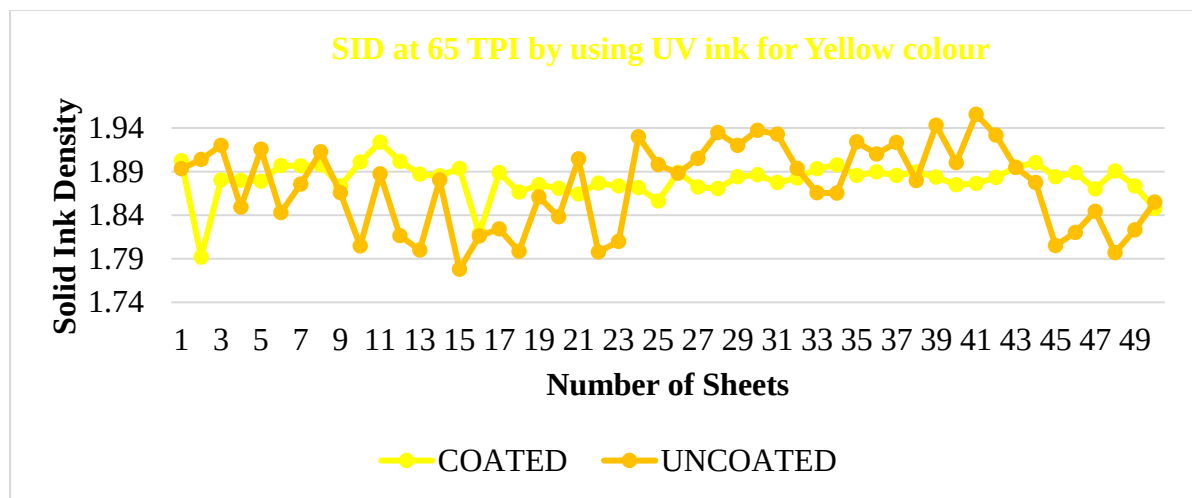
#### 4.1.3: SID at 65 TPI by using UV ink for Yellow colour

The representation of data for solid ink density (SID) for screen printing 65 Threads/inch by using UV ink on coated and uncoated paper yellow colour is tabulated in Table 4.1.3 and graphically presented in (Figure 4.1.3)

**Table 4.1.3: SID at 65 TPI by using UV ink for Yellow colour**

| SID        | Coated | Uncoated |
|------------|--------|----------|
| Min. Value | 1.79   | 1.78     |
| Max. Value | 1.92   | 1.96     |
| Average    | 1.88   | 1.87     |
| S.D.       | 0.02   | 0.05     |

The minimum and maximum measured value for SID on coated and uncoated paper were recorded between 1.79 to 1.92, 1.78 to 1.96 respectively. The range of SID for Yellow colour is highest on coated and lowest on uncoated paper. It shows consistent results for yellow colour on coated paper. It shows standard deviation of 0.02, 0.05 on coated paper and uncoated paper respectively.



**Figure 4.1.3: SID at 65 TPI by using UV ink for Yellow colour**

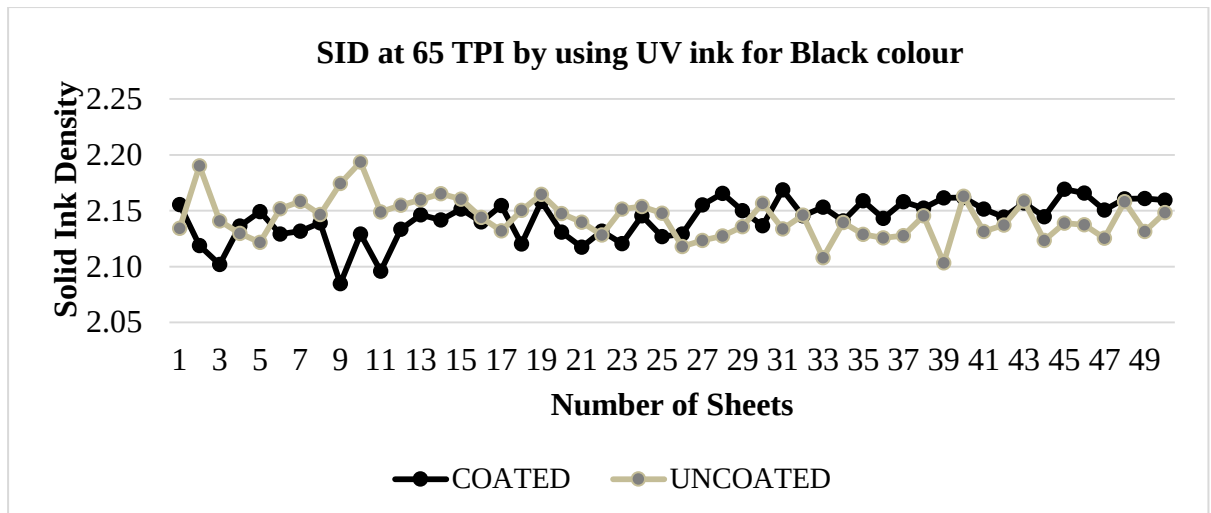
#### 4.1.4: SID at 65 TPI by using UV ink for Black colour

The representation of data for solid ink density (SID) for screen printing 65 Threads/inch by using UV ink on coated and uncoated paper black colour is tabulated in Table 4.1.4 and graphically presented in (Figure 4.1.4)

**Table 4.1.4: SID at 65 TPI by using UV ink for Black colour**

| SID        | Coated | Uncoated |
|------------|--------|----------|
| Min. Value | 2.08   | 2.10     |
| Max. Value | 2.17   | 2.19     |
| Average    | 2.14   | 2.14     |
| S.D.       | 0.02   | 0.02     |

The minimum and maximum measured values for SID on coated and uncoated paper were recorded between 2.08 to 2.17, 2.10 to 2.19 respectively. The range of SID for Black colour is highest on coated and lowest on uncoated paper. It shows consistent results for black colour on coated paper. It shows standard deviation of 0.02 for both coated and uncoated paper respectively.



**Figure 4.1.4: SID at 65 TPI by using UV ink for Black colour**

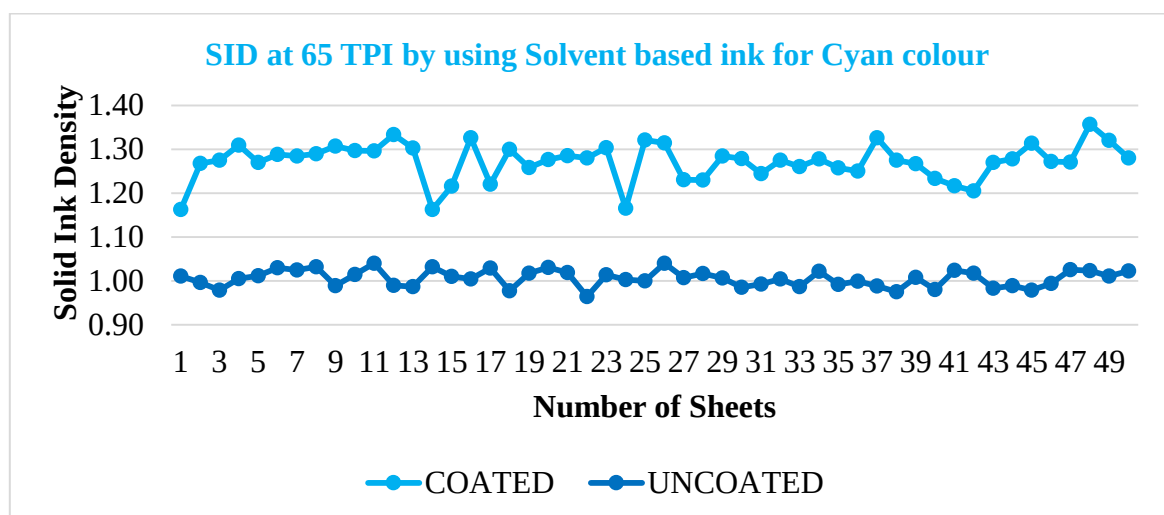
#### 4.1.5: SID at 65 TPI by using Solvent based ink for Cyan colour

Measured values for solid ink density (SID) for screen printing at 65 Threads/inch by using solvent based ink on selected coated paper and uncoated paper for cyan colour are tabulated in Table 4.1.5 and graphically presented in (Figure 4.1.5)

**Table 4.1.5: SID at 65 TPI by using Solvent based ink for Cyan colour**

| SID       | COATED | UNCOATED |
|-----------|--------|----------|
| Min.Value | 1.16   | 0.96     |
| Max.Value | 1.36   | 1.04     |
| Average   | 1.27   | 1.01     |
| S.D.      | 0.04   | 0.02     |

The minimum and maximum measured values for SID on coated and uncoated paper were recorded between 1.16 to 1.36, 0.96 to 1.04 respectively. The range of SID for Cyan colour is highest on coated and lowest on uncoated paper. It shows consistent results for cyan colour on coated paper. It shows standard deviation of 0.04, 0.02 on coated and uncoated paper respectively.



**Figure 4.1.5: SID at 65 TPI by using Solvent based ink for Cyan colour**

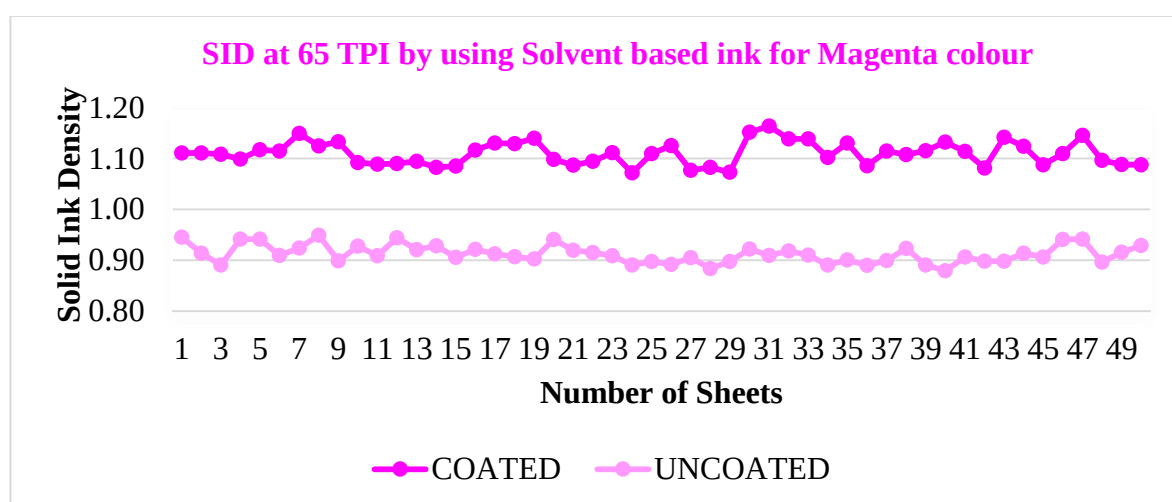
#### 4.1.6: SID at 65 TPI by using Solvent based ink for Magenta colour

The representation of data for solid ink density (SID) for screen printing 65 Threads/inch by using solvent based ink on coated and uncoated paper magenta colour is tabulated in Table 4.1.6 and graphically presented in (Figure 4.1.6)

**Table 4.1.6: SID at 65 TPI by using Solvent based ink for Magenta colour**

| SID        | COATED | UNCOATED |
|------------|--------|----------|
| Min. Value | 1.07   | 0.88     |
| Max. Value | 1.16   | 0.95     |
| Average    | 1.11   | 0.91     |
| S.D.       | 0.02   | 0.02     |

The minimum and maximum measured values for SID on coated and uncoated paper were recorded between 1.16 to 1.36, 0.96 to 1.04 respectively. The range of SID for Magenta colour is highest on coated and lowest on uncoated paper. It shows consistent results for magenta colour on coated paper. It shows standard deviation of 0.02 for both coated and uncoated paper respectively.



**Figure. 4.1.6: SID at 65 TPI by using Solvent based ink for Magenta colour**

#### 4.1.7: SID at 65 TPI by using Solvent based ink for Yellow colour

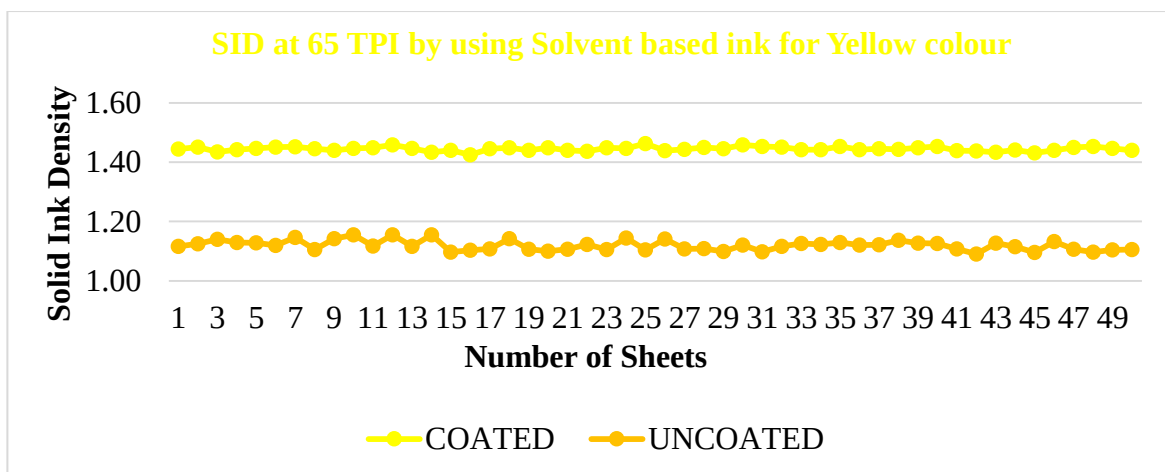
The representation of data for solid ink density (SID) for screen printing 65 Threads/inch by using solvent based ink on coated and uncoated paper yellow colour is tabulated in table 4.1.7 and graphically presented in (Figure 4.1.7)

**Table 4.1.7: SID at 65 TPI by using Solvent based ink for Yellow colour**

| SID        | COATED | UNCOATED |
|------------|--------|----------|
| Min. Value | 1.43   | 1.09     |
| Max. Value | 1.46   | 1.16     |
| Average    | 1.45   | 1.12     |
| SD         | 0.01   | 0.02     |

The minimum and maximum measured values for SID on coated and uncoated paper were recorded between 1.43 to 1.46, 1.09 to 1.16 respectively. The range of SID for Yellow colour is highest on coated and lowest on uncoated paper. It shows consistent results for yellow colour on coated paper. It shows standard deviation of 0.01, 0.02 on coated and uncoated paper respectively.





**Figure. 4.1.7: SID at 65 TPI by using Solvent based ink for Yellow colour**

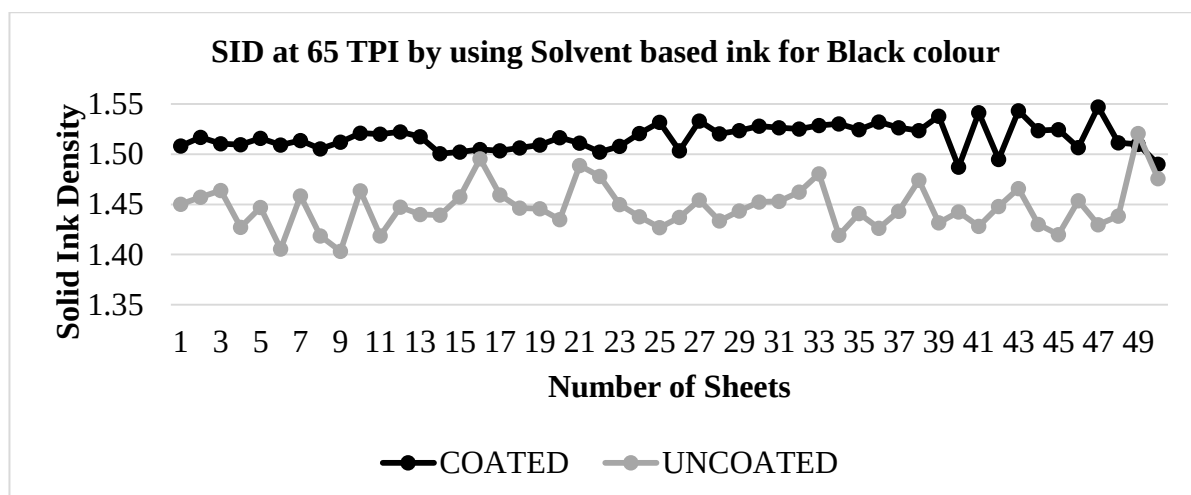
#### 4.1.8: SID at 65 TPI by using Solvent based ink for Black colour

The representation of data for solid ink density (SID) for screen printing 65 Threads/inch by using Solvent based ink on coated and uncoated paper black colour is tabulated in Table 4.1.8 and graphically presented in (Figure 4.1.8)

**Table 4.1.8: SID at 65 TPI by using Solvent based ink for Black colour**

| SID        | COATED | UNCOATED |
|------------|--------|----------|
| Min. Value | 1.28   | 1.40     |
| Max. Value | 1.28   | 1.52     |
| Average    | 1.28   | 1.45     |
| S.D.       | 1.28   | 0.02     |

The minimum and maximum measured values for SID on coated and uncoated paper were recorded between 1.28 to 1.28, 1.40 to 1.52 respectively. The range of SID for Black colour is highest on coated and lowest on uncoated paper. It shows consistent results for black colour on coated paper. It shows standard deviation of 1.28, 0.02 on coated and uncoated paper respectively.



**Figure. 4.1.8: SID at 65 TPI by using Solvent based ink for Black colour**

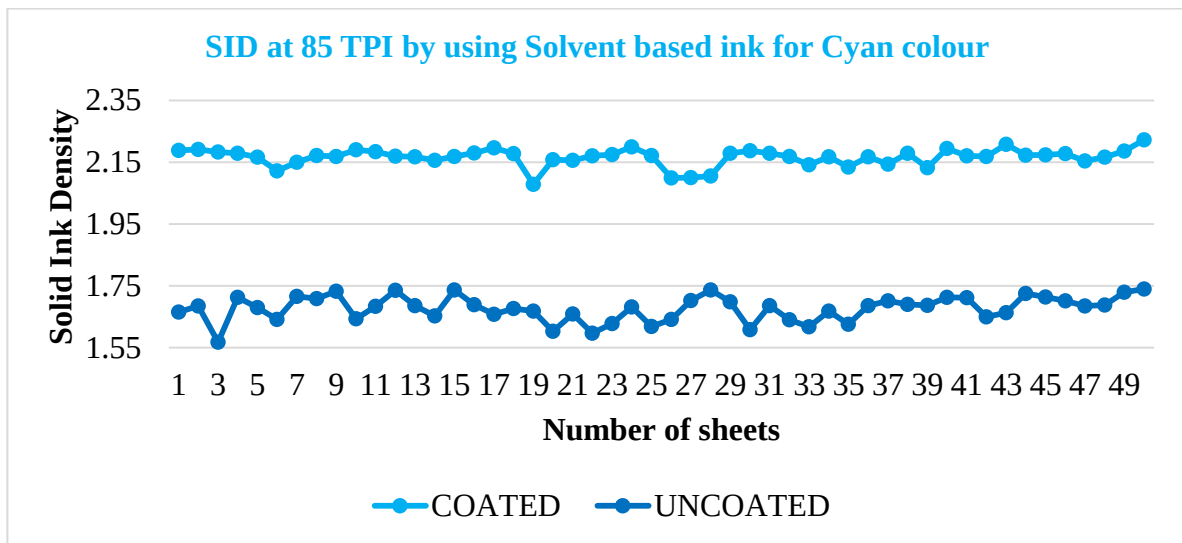
#### 4.1.9: SID at 85 TPI by using Solvent based ink for Cyan colour

Measured values for solid ink density (SID) for screen printing at 85 Threads/inch by using UV ink on selected coated and uncoated paper for cyan colour are tabulated in table 5.1.9 and graphically presented in (Figure 5.1.9)

**Table 4.1.9: SID at 85 TPI by using Solvent based ink for Cyan colour**

| SID        | COATED | UNCOATED |
|------------|--------|----------|
| Min. Value | 2.08   | 1.57     |
| Max. Value | 2.22   | 1.74     |
| Average    | 2.17   | 1.68     |
| S.D.       | 0.03   | 0.04     |

The minimum and maximum measured values for SID on coated and uncoated paper were recorded between 2.08 to 2.22, 1.57 to 1.74 respectively. The range of SID for Cyan colour is highest on coated and lowest on uncoated paper. It shows consistent results for cyan colour on coated paper. It shows standard deviation of 0.03, 0.04 on coated and uncoated paper respectively.



**Figure 4.1.9: SID at 85 TPI by using Solvent based ink for Cyan colour**

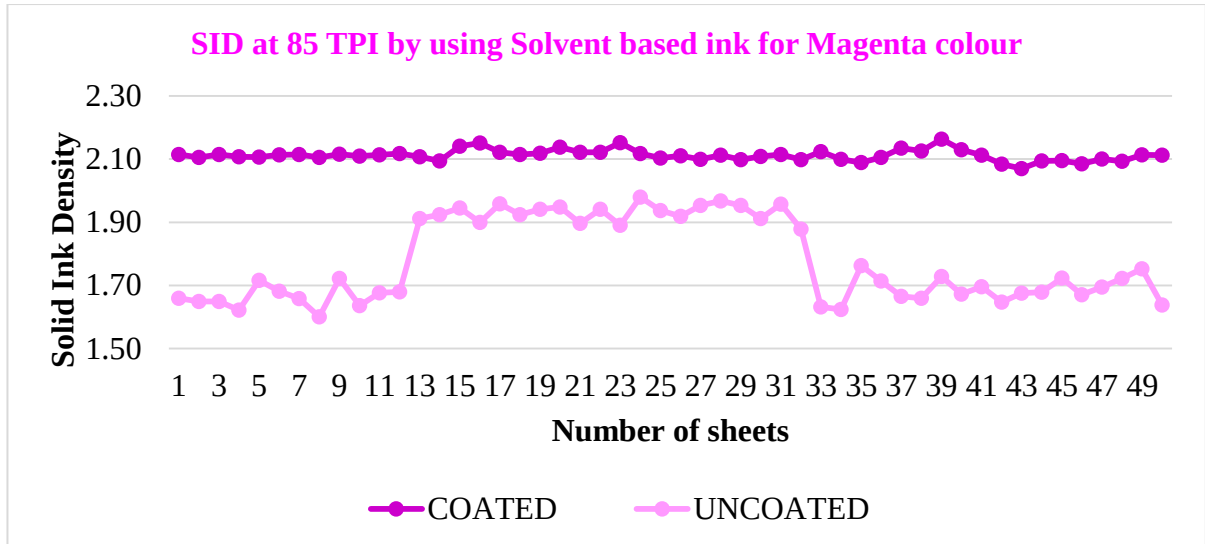
#### 4.1.10: SID at 85 TPI by using Solvent based ink for Magenta colour

Measured values for solid ink density (SID) for screen printing at 85 Threads/inch by using UV ink on selected coated and uncoated paper for magenta colour are tabulated in Table 4.1.10 and graphically presented in (Figure 4.1.10)

**Table 4.1.10: SID at 85 TPI by using Solvent based ink for Magenta colour**

| SID        | COATED | UNCOATED |
|------------|--------|----------|
| Min. Value | 2.07   | 1.60     |
| Max. Value | 2.16   | 1.98     |
| Average    | 2.11   | 1.78     |
| S.D.       | 0.02   | 0.13     |

The minimum and maximum measured values for SID on coated and uncoated paper were recorded between 2.07 to 2.16, 1.60 to 1.98 respectively. The range of SID for Cyan colour is highest on coated and lowest on uncoated paper. It shows consistent results for cyan colour on coated paper. It shows standard deviation of 0.02, 0.13 on coated and uncoated paper respectively.



. Figure 4.1.10: SID at 85 TPI by using Solvent based ink for Magenta colour

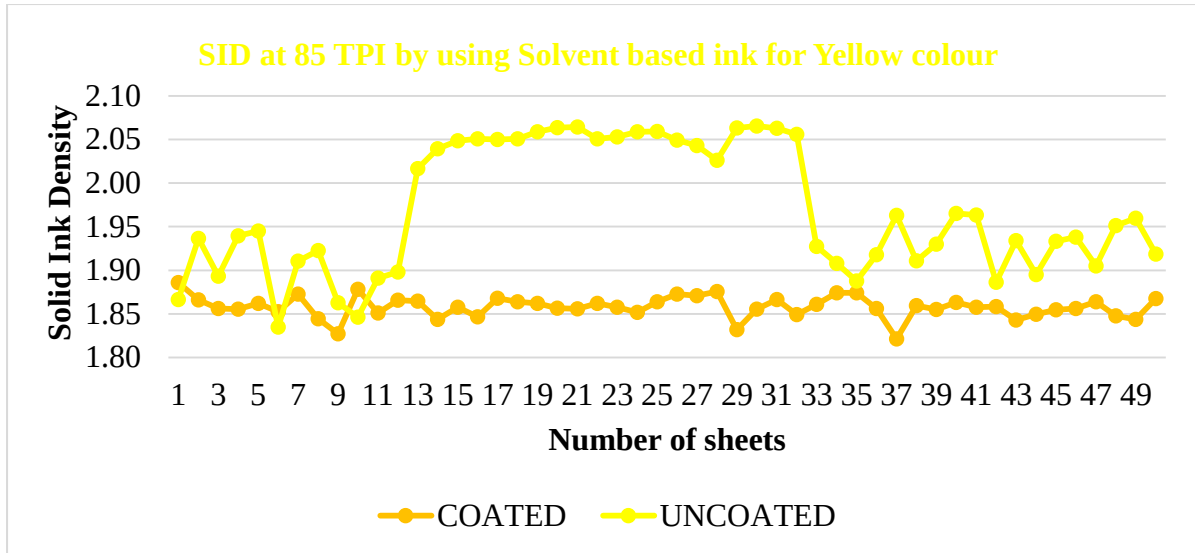
#### 4.1.11: SID at 85 TPI by using Solvent based ink for Yellow colour

Measured values for Solid ink density (SID) for screen printing at 85 Threads/inch by using UV ink on selected coated and uncoated paper for yellow colour are tabulated in Table 4.1.11 and graphically presented in (Figure 4.1.11)

**Table 4.1.11: SID at 85 TPI by using Solvent based ink for Yellow colour**

| SID        | COATED | UNCOATED |
|------------|--------|----------|
| Min. Value | 1.82   | 1.83     |
| Max. Value | 1.89   | 2.07     |
| Average    | 1.86   | 1.97     |
| S.D.       | 0.01   | 0.07     |

The minimum and maximum measured values for SID on coated and uncoated paper were recorded between 1.82 to 1.89, 1.83 to 2.07 respectively. The range of SID for Yellow colour is highest on coated and lowest on uncoated paper. It shows consistent results for yellow colour on coated paper. It shows standard deviation of 0.01, 0.07 on coated and uncoated paper respectively.



**Figure 4.1.11: SID at 85 TPI by using Solvent based ink for Yellow colour**

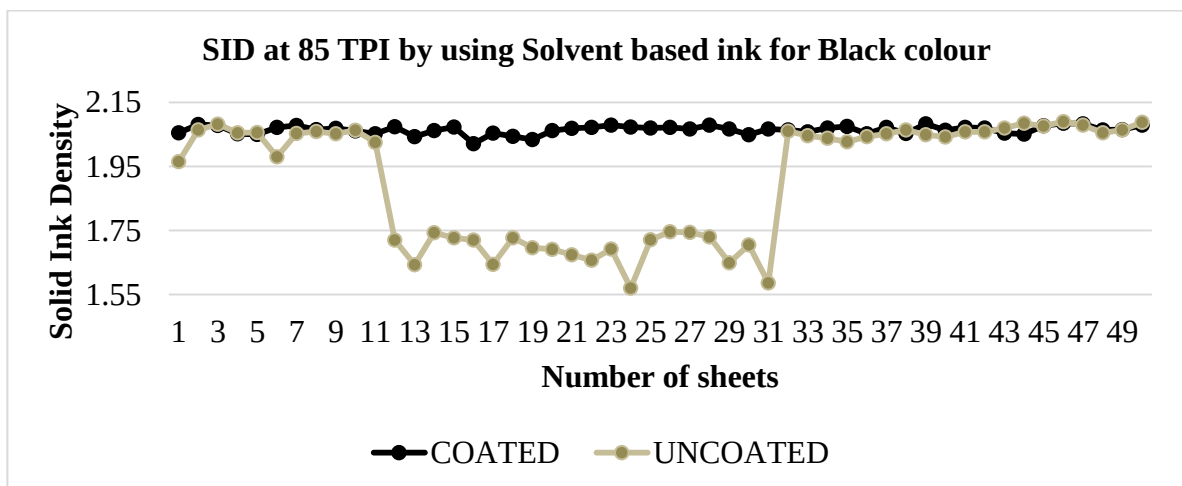
#### 4.1.12: SID at 85 TPI by using Solvent based ink for Black colour

Measured values for Solid Ink Density (SID) for screen printing at 85 Threads/inch by using UV ink on selected coated and uncoated paper for black colour are tabulated in Table 5.1.12 and graphically presented in (Figure 5.1.12)

**Table 4.1.12: SID at 85 TPI by using Solvent based ink for Black colour**

| SID        | COATED | UNCOATED |
|------------|--------|----------|
| Min. Value | 2.02   | 1.57     |
| Max. Value | 2.08   | 2.09     |
| Average    | 2.06   | 1.91     |
| S.D.       | 0.01   | 0.18     |

The minimum and maximum measured values for SID on coated and uncoated paper were recorded between 2.02 to 2.08, 1.57 to 2.09 respectively. The range of SID for Black colour is highest on coated and lowest on uncoated paper. It shows consistent results for black colour on coated paper. It shows standard deviation of 0.01, 0.18 on coated and uncoated paper respectively.



**Figure 4.1.12: SID at 85 TPI by using Solvent based ink for Black colour**

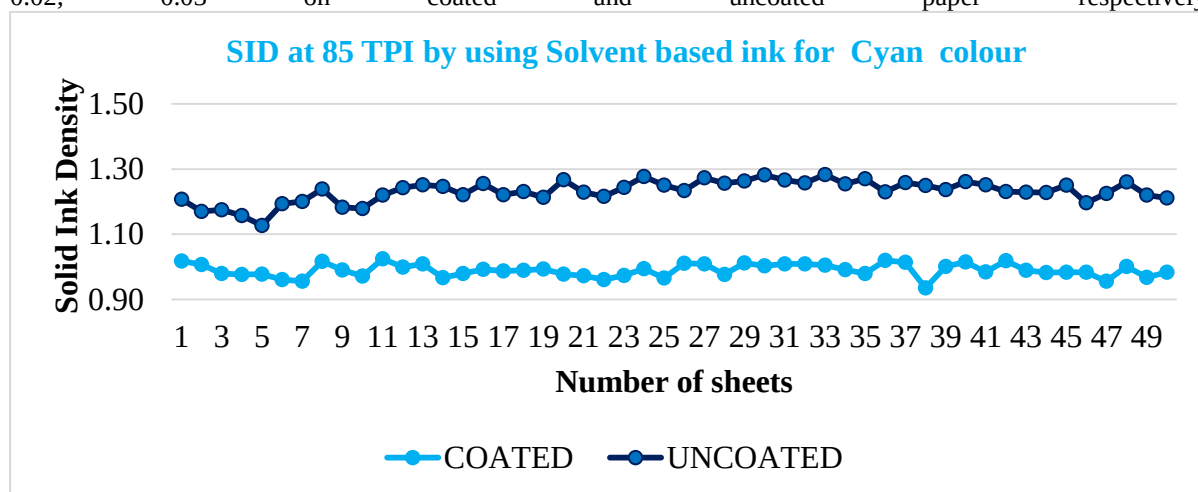
#### 4.1.13: SID at 85 TPI by using Solvent based ink for Cyan colour

Measured values for Solid ink density (SID) for screen printing at 85 Threads/inch by using Solvent based ink on selected coated and uncoated paper for Cyan colour are tabulated in Table 4.1.13 and graphically presented in (Figure 4.1.13)

**Table 4.1.13: SID at 85 TPI by using Solvent based ink for Cyan colour**

| SID        | COATED | UNCOATED |
|------------|--------|----------|
| Min. Value | 0.94   | 1.13     |
| Max. Value | 1.03   | 1.28     |
| Average    | 0.99   | 1.23     |
| S.D.       | 0.02   | 0.03     |

The minimum and maximum measured values for SID on coated and uncoated paper were recorded between 0.94 to 1.03, 1.13 to 1.28 respectively. The range of SID for Cyan colour is highest on coated and lowest on uncoated paper. It shows consistent results for cyan colour on coated paper. It shows standard deviation of 0.02, 0.03 on coated and uncoated paper respectively.



**Figure 4.1.13: SID at 85 TPI by using Solvent based ink for Cyan colour**

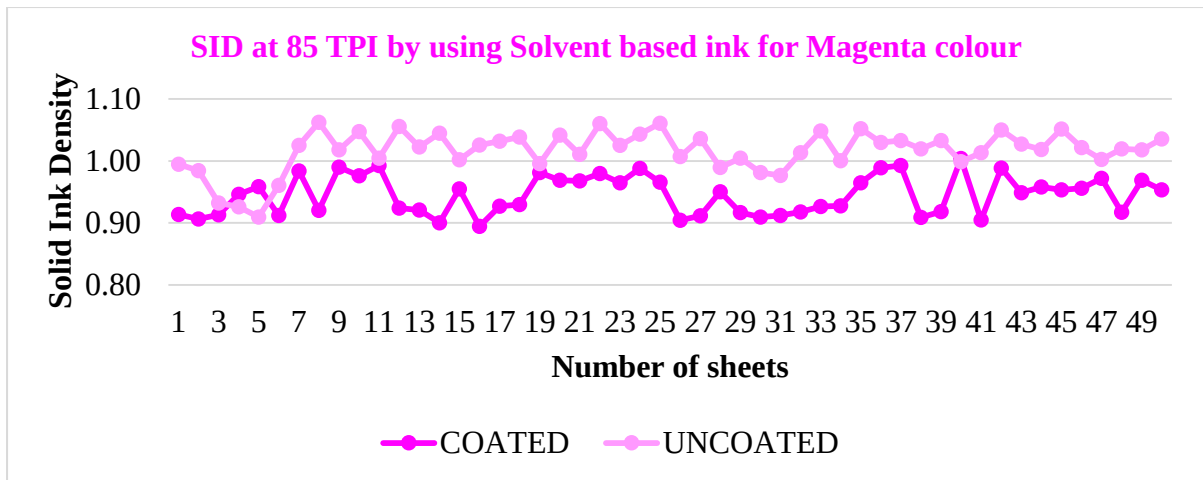
#### 4.1.14: SID at 85 TPI by using Solvent based ink for Magenta colour

Measured values for Solid ink density (SID) for screen printing at 85 Threads/inch by using Solvent based ink on selected coated and uncoated paper for magenta colour are tabulated in Table 4.1.14 graphically presented in (Figure 4.1.14)

**Table 4.1.14: SID at 85 TPI by using Solvent based ink for Magenta colour**

| SID        | COATED | UNCOATED |
|------------|--------|----------|
| Min. Value | 0.89   | 0.91     |
| Max. Value | 1.00   | 1.06     |
| Average    | 0.94   | 1.02     |
| S.D.       | 0.03   | 0.03     |

The minimum and maximum measured values for SID on coated and uncoated paper were recorded between 0.89 to 1.00, 0.91 to 1.06 respectively. The range of SID for Magenta colour is highest on coated and lowest on uncoated paper. It shows consistent results for magenta colour on coated paper. It shows standard deviation of 0.03 for both coated and uncoated paper respectively.



**Figure 4.1.14: SID at 85 TPI by using Solvent based ink for Magenta colour**

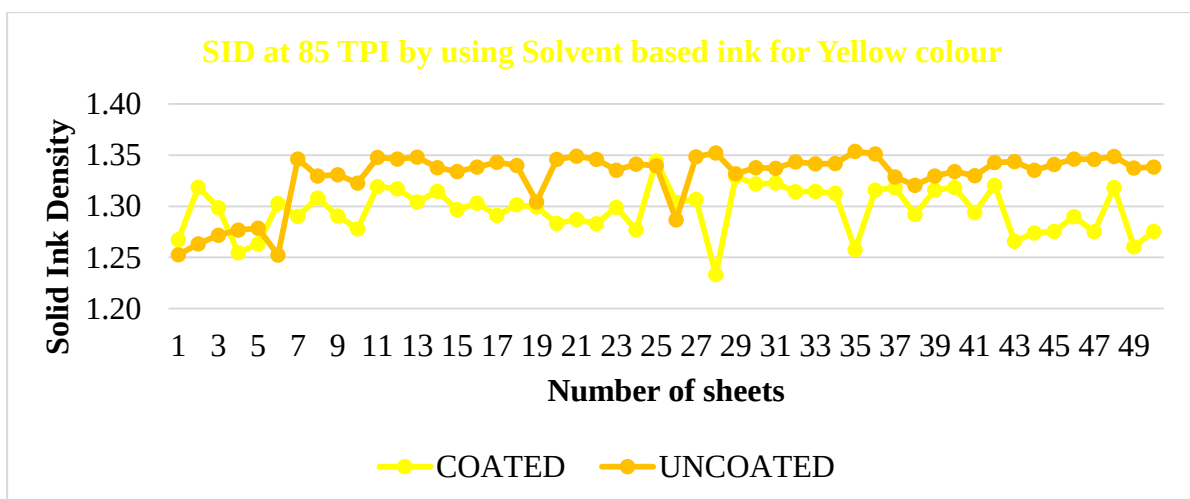
#### 4.1.15: SID at 85 TPI by using Solvent based ink for Yellow colour

Measured values for Solid ink density (SID) for screen printing at 85 Threads/inch by using solvent based ink on selected coated and uncoated paper for yellow colour are tabulated in Table 4.1.15 and graphically presented in (Figure 4.1.15)

**Table 4.1.15: SID at 85 TPI by using Solvent based ink for Yellow colour**

| SID        | COATED | UNCOATED |
|------------|--------|----------|
| Min. Value | 1.23   | 1.25     |
| Max. Value | 1.34   | 1.35     |
| Average    | 1.30   | 1.33     |
| S.D.       | 0.02   | 0.03     |

The minimum and maximum measured values for SID on coated and uncoated paper were recorded between 1.23 to 1.34, 1.25 to 1.35 to 1.35 respectively. The range of SID for Yellow colour is highest on coated and lowest on uncoated paper. It shows consistent results for yellow colour on coated paper. It shows standard deviation of 0.02, 0.03 on coated and uncoated paper respectively.



**Figure 4.1.15: SID at 85 TPI by using Solvent based ink for Yellow colour**

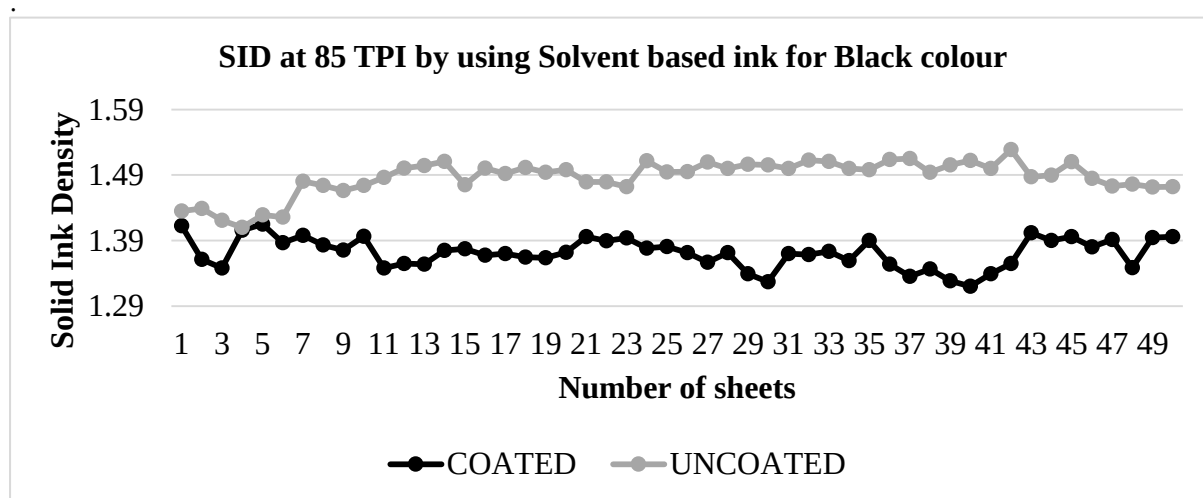
#### 4.1.16: SID at 85 TPI by using Solvent based ink for Black colour

Measured values for Solid ink density (SID) for screen printing at 85 Threads/inch by using solvent based ink on selected coated and uncoated paper for black colour are tabulated in Table 4.1.16 and graphically presented in (Figure 4.1.16)

**Table 4.1.16: SID at 85 TPI by using Solvent based ink for Black colour**

| SID        | COATED | UNCOATED |
|------------|--------|----------|
| Min. Value | 1.32   | 1.41     |
| Max. Value | 1.41   | 1.53     |
| Average    | 1.37   | 1.49     |
| S.D.       | 0.02   | 0.03     |

The minimum and maximum measured values for SID on coated and uncoated paper were recorded between 1.32 to 1.41, 1.41 to 1.53 respectively. The range of SID for Black colour is highest on coated and lowest on uncoated paper. It shows consistent results for black colour on coated paper. It shows standard deviation of 0.02, 0.03 on coated and uncoated paper respectively.



**Figure 4.1.16: SID at 85 TPI by using Solvent based ink for Black colour**

## 5 Results and Discussion

The results obtained after analyzing the data collected while carrying the research work entitled results and discussion in context to research objectives are explained here using the bar chart which is based on the average occurred in respect to technical parameter solid ink density.

### 5.1: SOLID INK DENSITY (SID)

#### 5.1.1: SID at 65 TPI by using UV ink for process colour on coated paper

The results of solid ink density for process colour (Cyan, Magenta, Yellow and Black) colour on coated paper in screen printing (at 65 TPI) by UV Ink is presented in Table 5.1.1

**Table 5.1.1: SID at 65 TPI by using UV ink for process colour on coated paper**

| SID        | Cyan | Magenta | Yellow | Black |
|------------|------|---------|--------|-------|
| Max. Value | 2.26 | 2.23    | 1.92   | 2.17  |
| Min. Value | 2.10 | 1.96    | 1.79   | 2.08  |
| Average    | 2.21 | 2.12    | 1.88   | 2.14  |
| S.D.       | 0.03 | 0.05    | 0.02   | 0.02  |

The results indicate that Cyan colour exhibited the highest value of SID which was 2.21 and Yellow colour exhibited lowest value 1.88 on coated paper in screen printing (at 65 TPI) by UV Ink.

The maximum values for SID were recorded 2.26 for Cyan, 2.23 for Magenta, 1.92 for Yellow and 2.17 for Black, while the minimum values were 2.10, 1.96, 1.79 and 2.08, respectively.

#### 5.1.2: SID at 65 TPI by using UV ink for process colour on uncoated paper

The results of solid ink density for process colour (Cyan, Magenta, Yellow and Black) colour on uncoated paper using screen printing (at 65 TPI) by UV Ink is presented in Table.5.1.2

**Table 5.1.2: SID at 65 TPI by using UV ink for process colour on uncoated paper**

| SID        | Cyan | Magenta | Yellow | Black |
|------------|------|---------|--------|-------|
| Max. Value | 1.97 | 2.08    | 1.96   | 2.19  |
| Min. Value | 1.59 | 1.77    | 1.75   | 2.10  |
| Average    | 1.79 | 1.97    | 1.87   | 2.14  |
| S.D.       | 0.10 | 0.07    | 0.06   | 0.02  |

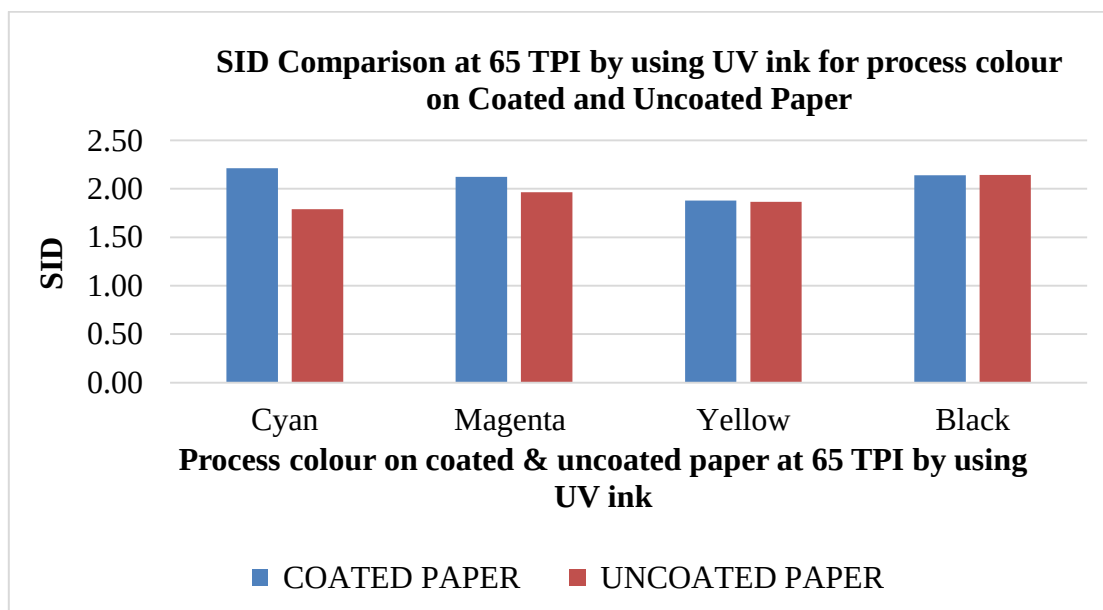
The results indicate that Cyan colour exhibited the highest value of SID which was 2.14 and Yellow colour exhibited lowest value 1.79 on coated paper in screen printing (at 65 TPI) by UV Ink.

The maximum values for SID were recorded 1.97 for Cyan, 2.08 for Magenta, 1.96 for Yellow and 2.19 for Black, while the minimum values were 1.59, 1.77, 1.75 and 2.10, respectively.

#### 5.1.3: Solid ink density Comparison

**Table 5.1.3: SID Comparison at 65 TPI by using UV ink for process colour on Coated and Uncoated Paper**

| Averages | Cyan | Magenta | Yellow | Black |
|----------|------|---------|--------|-------|
| Coated   | 2.21 | 2.12    | 1.88   | 2.14  |
| Uncoated | 1.79 | 1.97    | 1.87   | 2.14  |



**Figure 5.1: SID Comparison at 65 TPI by using UV ink for process colour on Coated and Uncoated Paper**



Solid ink density (SID) values of coated and uncoated paper printed by Screen printing process showed slight but noticeable variations across all CMYK colour. The average SID values obtained from selected printed sheets indicate the coated paper achieved higher density values compared to uncoated Paper. The coated paper obtained average SID values of 2.21 for Cyan, 2.12 for Magenta, 1.88 for Yellow and 2.14 for Black, the uncoated paper obtained 1.79 for Cyan, 1.97 for Magenta, 1.87 for Yellow and 2.14 for Black. Among all process colors Cyan showed the highest SID values on both substrates, it means they indicate stronger density and better visual strength in solid areas while yellow obtained the lowest SID values which indicates its lighter nature and lower perceived density. These differences may occur because coated paper has a smoother surface, which helps with better transfer of UV ink and improves color density during the screen printing process.

#### 5.1.4: SID at 65 TPI by using solvent based ink for process colour on coated paper

The results of solid ink density for process colour (Cyan, Magenta, Yellow and Black) colour on coated paper in screen printing (at 65 TPI) by using solvent based ink is presented in Table.5.1.4

**Table 5.1.4: SID at 65 TPI by using solvent based ink for process colour on coated paper**

| SID        | Cyan | Magenta | Yellow | Black |
|------------|------|---------|--------|-------|
| Max. Value | 1.03 | 1.07    | 1.43   | 1.28  |
| Min. Value | 1.63 | 1.16    | 1.46   | 1.55  |
| Average    | 1.27 | 1.11    | 1.45   | 1.51  |
| S.D.       | 0.10 | 0.02    | 0.01   | 0.04  |

The results indicate that Black colour exhibited the highest value of SID which was 1.51 and Magenta colour exhibited lowest value 1.11 on coated paper in screen printing (at 65 TPI) by Solvent based ink.

The maximum values for SID were recorded 1.03 for Cyan, 1.07 for Magenta, 1.43 for Yellow and 1.28 for Black, while the minimum values were 1.63, 1.16, 1.46 and 1.55, respectively.

#### 5.1.5: SID at 65 TPI by using solvent based ink for process colour on uncoated paper

The results of solid ink density for process colour (Cyan, Magenta, Yellow and Black) colour on uncoated paper in screen printing (at 65 TPI) by Solvent based ink is presented in Table.5.1.5

**Table 5.1.5: SID at 65 TPI by using solvent based ink for process colour on uncoated paper**

| SID        | Cyan | Magenta | Yellow | Black |
|------------|------|---------|--------|-------|
| Max. Value | 0.96 | 0.88    | 1.09   | 1.29  |
| Min. Value | 1.04 | 0.95    | 1.16   | 1.52  |
| Average    | 1.01 | 0.91    | 1.12   | 1.44  |
| S.D.       | 0.02 | 0.02    | 0.02   | 0.03  |

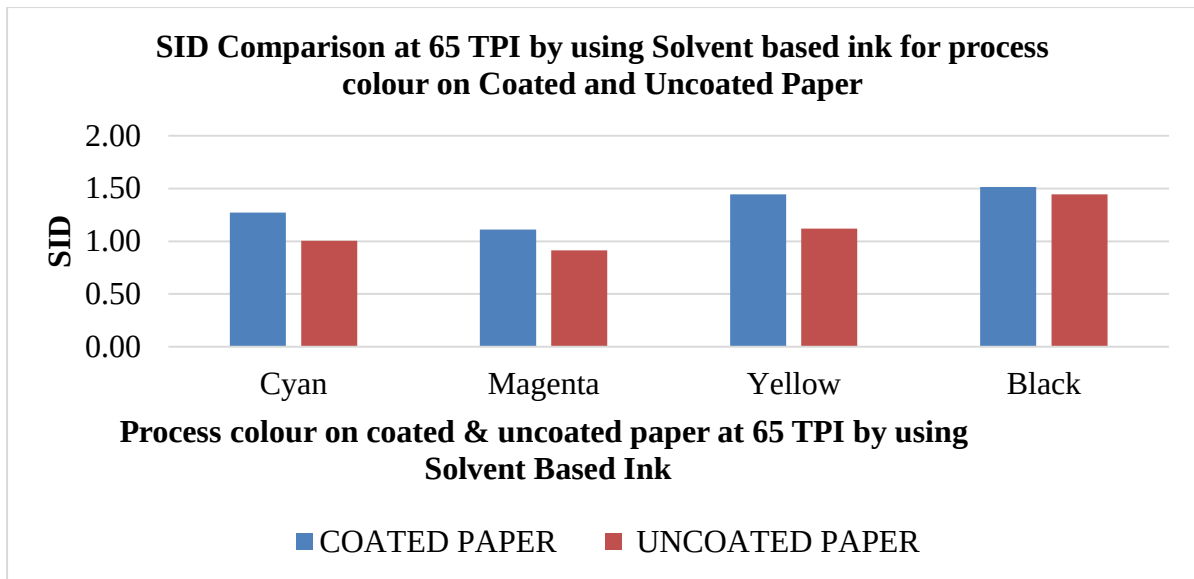
The results indicate that Black colour exhibited the highest value of SID which was 1.44 and Magenta colour exhibited lowest value 0.95 on uncoated paper in screen printing (at 65 TPI) by Solvent based ink

The maximum SID values recorded were 0.96 for Cyan, 0.88 for Magenta, 1.09 for Yellow and 1.29 for Black, while the minimum values were 1.04, 0.95, 1.16 and 1.52, respectively.

#### 5.1.6: SID Comparison at 65 TPI by using Solvent based ink for process colour on Coated and Uncoated Paper

**Table 5.1.6: SID Comparison at 65 TPI by using Solvent based ink for process colour on Coated and Uncoated Paper**

| Average  | Cyan | Magenta | Yellow | Black |
|----------|------|---------|--------|-------|
| Coated   | 1.27 | 1.11    | 1.45   | 1.51  |
| Uncoated | 1.01 | 0.91    | 1.12   | 1.44  |



**Figure 5.2: SID Comparison at 65 TPI by using Solvent based ink for process colour on Coated and Uncoated Paper**

Solid ink density (SID) values of coated and uncoated paper printed using the Screen Printing process showed slight but noticeable variations across all CMYK colors. The average SID values obtained from selected printed sheets indicate the coated paper achieved higher density values compared to uncoated paper. The coated paper obtained average SID values of 1.27 for Cyan, 1.11 for Magenta, 1.45 for Yellow and 1.51 for Black, the uncoated paper obtained 1.01 for Cyan, 0.91 for Magenta, 1.12 for Yellow and 1.44 for Black. Among all process colour Cyan showed the highest SID values on both substrates it means they indicate stronger density and better visual strength in solid areas while Magenta obtained the lowest SID values which indicates its lighter nature and lower perceived density. These differences may occur because coated paper has a smoother surface, which helps with better transfer of solvent based ink and improves color density during the screen printing process.

#### 5.1.7: SID at 85 TPI by using UV ink for process colour on coated paper

The results of Solid Ink Density for process colour (Cyan, Magenta, Yellow and Black) colour on coated paper in screen printing (at 85 TPI) by UV ink is presented in Table 5.1.7

**Table 5.1.7: SID at 85 TPI by using UV ink for process colour on coated paper**

| SID        | Cyan | Magenta | Yellow | Black |
|------------|------|---------|--------|-------|
| Max. Value | 2.22 | 2.16    | 1.89   | 2.08  |
| Min. Value | 2.08 | 2.07    | 1.82   | 2.02  |
| Average    | 2.17 | 2.11    | 1.86   | 2.06  |
| S.D.       | 0.03 | 0.02    | 0.01   | 0.01  |

The results indicate that Cyan colour exhibited the highest value of SID which was 2.17 and Yellow colour exhibited lowest value 1.86 on coated paper in screen printing (at 85 TPI) by UV ink.

The maximum values for SID recorded were 2.22 for Cyan, 2.16 for Magenta, 1.89 for Yellow and 2.08 for Black, while the minimum values were 2.08, 2.07, 1.82 and 2.02 respectively.

#### 5.1.8: SID at 85 TPI by using UV ink for process colour on uncoated paper

The results of solid ink density for process colour (Cyan, Magenta, Yellow and Black) colour on uncoated paper in screen printing (at 85 TPI) by UV ink is presented in Table 5.1.8

**Table.5.1.8: SID at 85 TPI by using UV ink for process colour on uncoated paper**

| SID        | Cyan | Magenta | Yellow | Black |
|------------|------|---------|--------|-------|
| Max. Value | 1.74 | 1.98    | 2.07   | 2.09  |
| Min. Value | 1.57 | 1.54    | 1.83   | 1.57  |

|                |      |      |      |      |
|----------------|------|------|------|------|
| <b>Average</b> | 1.68 | 1.77 | 1.97 | 1.90 |
| <b>S.D.</b>    | 0.04 | 0.13 | 0.07 | 0.18 |

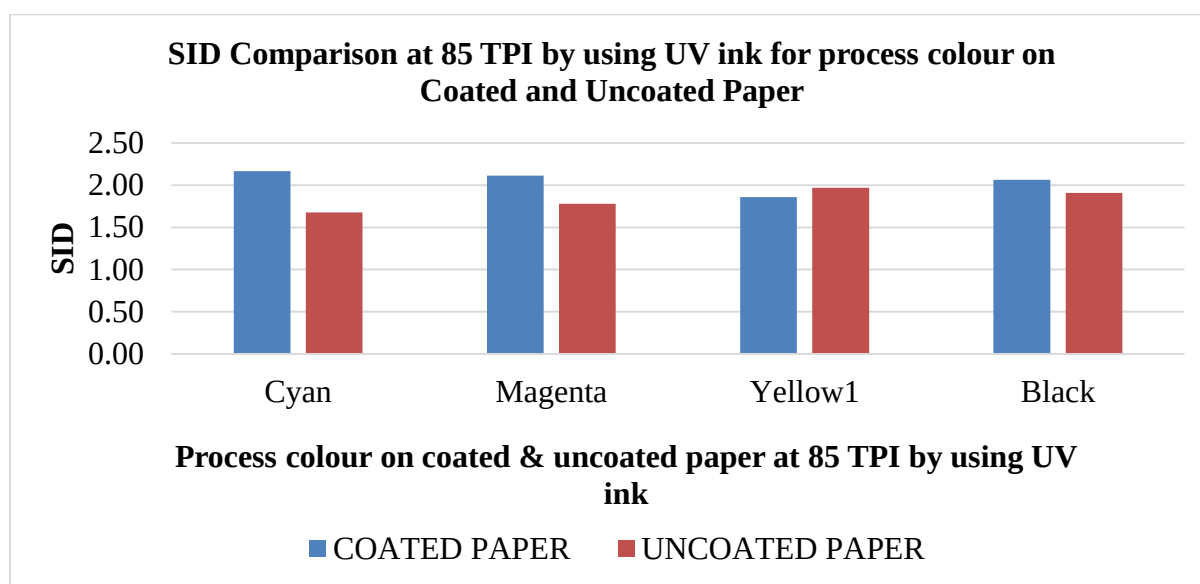
The results indicate that Yellow colour exhibited the highest value of SID which was 1.97 and Cyan colour exhibited lowest value 1.68 on coated paper media using screen printing (at 85 TPI) by UV ink.

The maximum values for SID were recorded 1.74 for Cyan, 1.98 for Magenta, 2.07 for Yellow and 2.09 for Black, while the minimum values were 1.57, 1.54, 1.83 and 1.57 respectively.

#### 5.1.9: SID Comparison at 85 TPI by using UV ink for process colour on Coated and Uncoated Paper

**Table.5.1.9: SID Comparison at 85 TPI by using UV ink for process colour on Coated and Uncoated Paper**

|                 |             |                |               |              |
|-----------------|-------------|----------------|---------------|--------------|
| <b>Average</b>  | <b>Cyan</b> | <b>Magenta</b> | <b>Yellow</b> | <b>Black</b> |
| <b>Coated</b>   | 2.17        | 2.11           | 1.86          | 2.06         |
| <b>Uncoated</b> | 1.68        | 1.78           | 1.97          | 1.91         |



**Figure 5.3: SID Comparison at 85 TPI by using UV ink for process colour on Coated and Uncoated Paper**

Solid ink density (SID) values of coated and uncoated paper printed using the screen printing process showed slight but noticeable variations across all CMYK colors. The average SID values obtained from selected printed sheets indicate the coated Paper achieved higher density values compared uncoated paper. The coated paper obtained average SID values of 2.17 for Cyan, 2.11 for Magenta, 1.86 for Yellow and 1.51 for Black, the uncoated paper obtained 1.01 for Cyan, 0.91 for Magenta, 1.12 for Yellow and 1.44 for Black. Among all process colors Cyan showed the highest SID values on both substrates it means they indicate stronger density and better visual strength in solid areas while Magenta obtained the lowest SID values which indicates its lighter nature and lower perceived density. These differences may occur because coated paper has a smoother surface, which helps with better transfer of UV ink and improves color density during the screen printing process.

#### 5.1.10: SID at 85 TPI by using solvent based ink for process colour on coated paper

The results of solid ink density of (Cyan, Magenta, Yellow and Black) colour on coated paper in screen printing (at 85 TPI) by solvent based ink is presented in Table 6.1.10

**Table.5.1.10: SID at 85 TPI by using solvent based ink for process colour on coated paper**

|                   |             |                |               |              |
|-------------------|-------------|----------------|---------------|--------------|
| <b>SID</b>        | <b>Cyan</b> | <b>Magenta</b> | <b>Yellow</b> | <b>Black</b> |
| <b>Max. Value</b> | 1.03        | 1.00           | 1.34          | 1.41         |
| <b>Min. Value</b> | 0.94        | 0.89           | 1.23          | 0.93         |

|                |      |      |      |      |
|----------------|------|------|------|------|
| <b>Average</b> | 0.99 | 0.94 | 1.30 | 1.36 |
| <b>S.D.</b>    | 0.02 | 0.03 | 0.02 | 0.07 |

The results indicate that Black colour exhibited the highest value of SID which was 1.41 and Magenta colour exhibited lowest value 1.00 on coated paper in screen printing (at 85 TPI) by Solvent Based Ink.

The maximum values for SID were recorded 1.03 for Cyan, 1.00 for Magenta, 1.34 for Yellow and 1.41 for Black, while the minimum values were 0.94, 0.89, 1.23 and 0.93 respectively.

#### 5.1.11: SID at 85 TPI by using solvent based ink for process colour on uncoated paper

The results of solid ink density of Cyan, Magenta, Yellow and Black colour on uncoated paper in screen printing (at 85 TPI) by solvent based ink is presented in Table 5.1.11.

**Table.5.1.11: SID at 85 TPI by using solvent based ink for process colour on uncoated paper**

| <b>SID</b>        | <b>Cyan</b> | <b>Magenta</b> | <b>Yellow</b> | <b>Black</b> |
|-------------------|-------------|----------------|---------------|--------------|
| <b>Max. Value</b> | 1.28        | 1.24           | 1.35          | 1.53         |
| <b>Min. Value</b> | 1.13        | 0.91           | 1.25          | 1.41         |
| <b>Average</b>    | 1.23        | 1.02           | 1.33          | 1.49         |
| <b>S.D.</b>       | 1.23        | 1.02           | 1.33          | 1.49         |

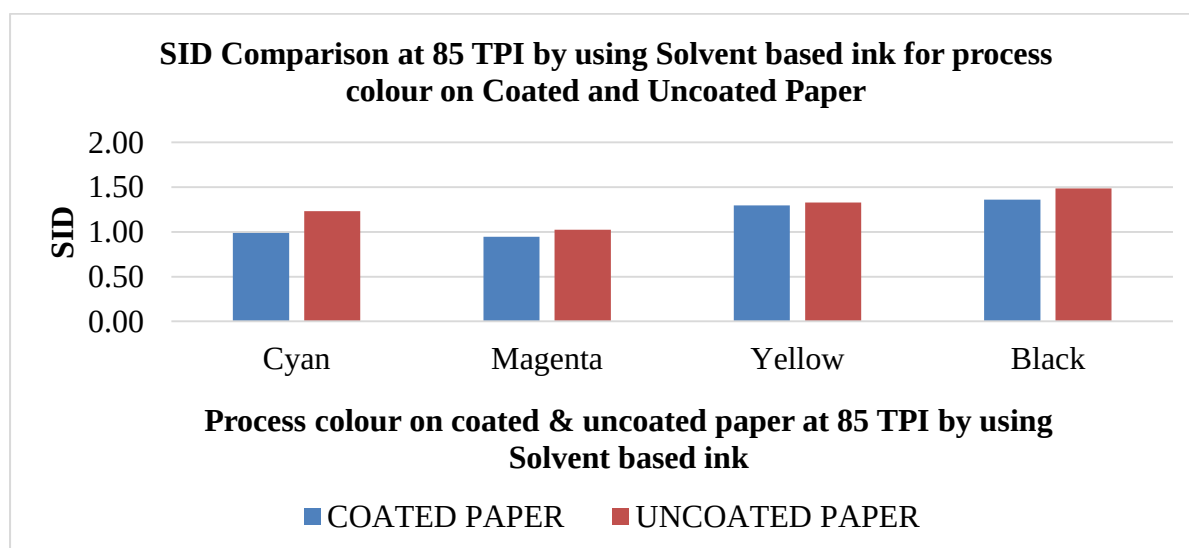
The results indicate that Black colour exhibited the highest value of SID which was 1.53 and Magenta colour exhibited lowest value 1.24 on coated paper in screen printing (at 85 TPI) by solvent based ink.

The maximum values for SID were recorded 1.28 for Cyan, 1.24 for Magenta, 1.35 for Yellow and 1.53 for Black, while the minimum values were 1.13, 0.91, 1.25 and 1.41 respectively.

#### 5.1.12: SID Comparison at 85 TPI by using Solvent based ink for process colour on Coated and Uncoated Paper

**Table 5.1.12: SID Comparison at 85 TPI by using Solvent based ink for process colour on Coated and Uncoated Paper**

| <b>SID</b> | <b>Cyan</b> | <b>Magenta</b> | <b>Yellow</b> | <b>Black</b> |
|------------|-------------|----------------|---------------|--------------|
| Coated     | 0.99        | 0.94           | 1.30          | 1.36         |
| Uncoated   | 1.23        | 1.02           | 1.33          | 1.49         |



**Figure 5.4: SID Comparison at 85 TPI by using Solvent based ink for process colour on Coated and Uncoated Paper**

Solid ink density (SID) values of coated and uncoated paper printed using the screen printing process showed slight but noticeable variations across all CMYK colors. The average SID values obtained from selected printed sheets indicate the coated Paper achieved higher density values compared uncoated paper. The coated paper obtained average SID values of 0.99 for Cyan, 0.94 for Magenta, 1.30 for Yellow and 1.36 for Black, the uncoated paper obtained 1.23 for Cyan, 1.02 for Magenta, 1.33 for Yellow and 1.49 for Black. Among all process colors Black showed the highest SID values on both substrates it means they indicate stronger density and better visual strength in solid areas while Magenta obtained the lowest SID values which indicates its lighter nature and lower perceived density. These differences may occur because coated paper has a smoother surface, which helps with better transfer of UV Ink and improves color density during the screen printing process.

## 6. Conclusion

### 6.1 Solid ink density (SID)

The experimental results show that Solid ink density was significantly influenced by the screen mesh count, ink type and substrate characteristics. 65 TPI screen mesh have large mesh openings, higher ink film thickness on to the substrate, resulting in comparatively higher SID values than the 85 TPI mesh because 85, TPI have less mesh opening in compared to 65 TPI resulting lower ink film thickness on the printed substrate.

UV based ink generally produced higher and more stable solid ink density due to its high pigment concentration, rapid curing and reduced ink penetration into the substrate. The Solvent based ink exhibited relatively lower density because of solvent evaporation and greater penetration into the surface of paper.

The substrate also had a considerable influence on SID. The 110 GSM coated paper shows higher solid ink density than the 100 GSM uncoated paper because its surface is smooth and less porous surface retained more ink on surface that enhances colour strength and optical density, while uncoated the porous nature of the uncoated paper allowed greater ink absorption, reducing the effective ink film thickness

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### References

1. J. I. Biegeleisen, *Screen Printing: A Contemporary Approach*. Albany, NY, USA: Delmar Publishers, 1998.
2. R. Leach and R. J. Pierce, *The Printing Ink Manual*, 6th ed. Dordrecht, Netherlands: Springer, 2012.
3. H. Kipphan, *Handbook of Print Media: Technologies and Production Methods*. Berlin, Germany: Springer, 2001.
4. P. M. Dennis and T. J. Claypole, "Process variables affecting screen printing quality: A review," *Journal of Imaging Science and Technology*, vol. 52, no. 4, pp. 040201–040210, 2008.
5. H. Kipphan, *Handbook of Print Media: Technologies and Production Methods*. Berlin, Germany: Springer, 2001.
6. ISO 5-3:2009, *Photography—Density Measurements—Part 3: Spectral Conditions*. Geneva, Switzerland: International Organization for Standardization, 2009.
7. ISO 13655:2017, *Graphic Technology—Spectral Measurement and Colorimetric Computation for Graphic Arts Images*. Geneva, Switzerland: International Organization for Standardization, 2017.
8. F. Romano, *Screen Printing Technology Handbook*. Pittsburgh, PA, USA: GATF Press, 2004.
9. Kumar, P., Pandey, A., & Anayath, R. (2024). Study of print suitability of environment-friendly plastics using flexography printing. *The Scientific Temper*, 15(01), 1678-1684.
10. Jangra, V., Pandey, A., & Anayath, R. K. (2023). Print consistency evaluation on uncoated paper using various digital print engines. *The Scientific Temper*, 14(03), 735-740.
11. Kumar, P., Pandey, A., & Anayath, R. (2024). Comparative study of print quality attributes on bio-based biodegradable plastic using flexography and gravure printing process. *The Scientific Temper*, 15(01), 1689-1696.
12. Kumar, P., Pandey, A., & Anayath, R. (2023). Comparative analysis of Solid Ink Density on Conventional and Bio-based plastics using Gravure Process. *European Chemical Bulletin*, 12(Special Issue 4), 13399–13405
13. Kumar, P., Pandey, P. A., & Anayath, P. R. (2023b). Study of Printability of Bio - based Plastic in Gravure Process. *European Chemical Bulletin*, 12(4), 13399–13405.

14. Kumar, P., Pandey, A., & Anayath, R. (2024). Study of print suitability of environment-friendly plastics using flexography printing. *The Scientific Temper*, 15(01), 1678-1684.
15. Kumar, P., Pandey, A., & Anayath, R. (2024). Comparative study of print quality attributes on bio-based biodegradable plastic using flexography and gravure printing process. *The Scientific Temper*, 15(01), 1689-1696. Doi: 10.58414/SCIENTIFICTEMPER.2024.15.1.17
16. Jangra, V., & Kumar, P. (2024). Comparative study of color difference on coated and uncoated paper in digital printing. *The Scientific Temper*, 15(01), 1755-1758.