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Comparative Analysis of Print Quality on PP-White and PP-Clear Substrates Using the Flexographic Printing Process with UV-Based Inks

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This study focuses on the comparative analysis of polypropylene (PP) substrates i.e., PP-White and PP-Clear in flexographic printing, specifically evaluating Tone Value Increase (TVI), Solid Ink Density (SID), and Print Contrast (PC). Flexography, known for its adaptability in printing on diverse substrates, is widely used in packaging and labelling industries. The substrate plays a pivotal role in achieving optimal print quality, influencing how inks adhere and interact with the surface. Using a UV Graphics flexography printing press with UV-based inks, test prints were produced under controlled conditions. Measurements were conducted using a spectrophotometer to examine TVI, SID, and PC for each substrate. PP-White substrate demonstrated superior performance, providing consistent tonal reproduction, higher solid ink density, and improved print contrast compared to PP-Clear. These findings emphasize the importance of substrate selection in achieving high-quality output in flexographic printing.

1. Introduction

Flexography is a versatile printing process that uses flexible relief plates and is known for its ability to print on a wide range of substrates, including films, foils, paper, and plastics. It is particularly popular in the packaging industry due to its efficiency and adaptability. The quality of a flexographic print is highly influenced by the substrate used, making substrate selection a critical factor in achieving optimal results (Beck, 2016).

PP-White and PP-Clear are two commonly used polypropylene substrates in flexography. PP-White has an opaque surface, offering high ink receptivity and consistency in print quality. In

contrast, PP-Clear is transparent, presenting unique challenges due to its smooth surface and light-transmitting properties. These differences significantly impact the behaviour of inks and print quality metrics (Ravindran & Prakash, 2020).

Three key parameters are central to assessing print quality in flexography: -

Tone Value Increase (TVI): Indicates how much the printed tone deviates from the intended tone, influencing tonal accuracy.

Solid Ink Density (SID): Measures the density of ink coverage, reflecting the substrate's ability to hold ink consistently.

Print Contrast (PC): Represents the relationship between highlights and shadows, determining the sharpness and vibrancy of the print (Sharma, 2018).

This paper examines these parameters to compare the performance of PP-White and PP-Clear substrates used for the flexographic printing.

2. RESEARCH OBJECTIVE

The main objective of this research is to analyse and compare the performance of PP-White and PP-Clear substrates in flexographic printing, focusing on three critical print quality parameters:

- Tone Value Increase (TVI); to evaluate how substrate properties affect tonal reproduction.
- Solid Ink Density (SID); to assess the substrates' capability to hold ink and deliver consistent coverage.
- Print Contrast (PC); to determine the substrates' influence on the sharpness and vibrancy of prints.

3. RESEARCH METHODOLOGY

In our methodology, to ensure the reliability of the results, we printed a total of 30 samples for each substrate i.e., PP-White and PP-Clear are under consistent printing conditions. These samples were taken across different print runs to account for any potential variation during the process. Once the samples were printed, we measured the key print quality parameters i.e., Tone Value Increase (TVI), Solid Ink Density (SID), and Print Contrast (PC) are using a calibrated spectrophotometer. For each set of 30 samples, the average values of TVI, SID, and PC were calculated. These averages were then compared between the two substrates to assess their performance in a more controlled and objective manner. By calculating the mean values and standard deviations, we were able to minimize the impact of any outliers and ensure a fair comparison of print quality between the PP-White and PP-Clear substrates.

Materials and Equipment: -

- Printing Press: Ultraflex UFO UV Graphics flexography printing press.

- Inks: UV-based inks.
- Substrates: PP-White and PP-Clear films.
- Testing Tools: Spectrophotometer for colorimetric analysis and print quality evaluation.

Procedure: -

- Preparation of Test Charts: A standardized test chart with halftones and solid patches was designed to evaluate tonal reproduction and density.
- Controlled Printing Environment: Printing was performed under identical conditions, including consistent pressure, speed, and UV drying parameters.
- Data Collection: Spectrophotometric measurements were taken from the test prints to analyse TVI, SID, and PC for each substrate.
- Comparative Analysis: The collected data were compared to identify significant differences between the substrates.

4. DATA COLLECTION & ANALYSIS

It measured the 30 printed samples of both PP-White and PP-Clear substrates using a calibrated spectrophotometer. The spectrophotometer was used to capture precise data for TVI, SID, and PC across the printed areas. Measurements were taken at multiple points for each sample to ensure consistency. The collected data were then organized and averaged for further analysis and comparison between the two substrates.

Table 1: Comparative Averages of SID on PP-White and PP-Clear Substrates

	Cyan	Magenta	Yellow	Black
Average SID of PP-White	1.33	1.82	1.12	2.09
Average SID of PP-Clear	1.30	1.75	0.99	2.07

From the data in Table 1, the average SID for PP-White is 1.33 for Cyan, 1.82 for Magenta, 1.12 for Yellow, and 2.09 for Black. In comparison, PP-Clear shows average SID values of 1.30 for Cyan, 1.75 for Magenta, 0.99 for Yellow, and 2.07 for Black.

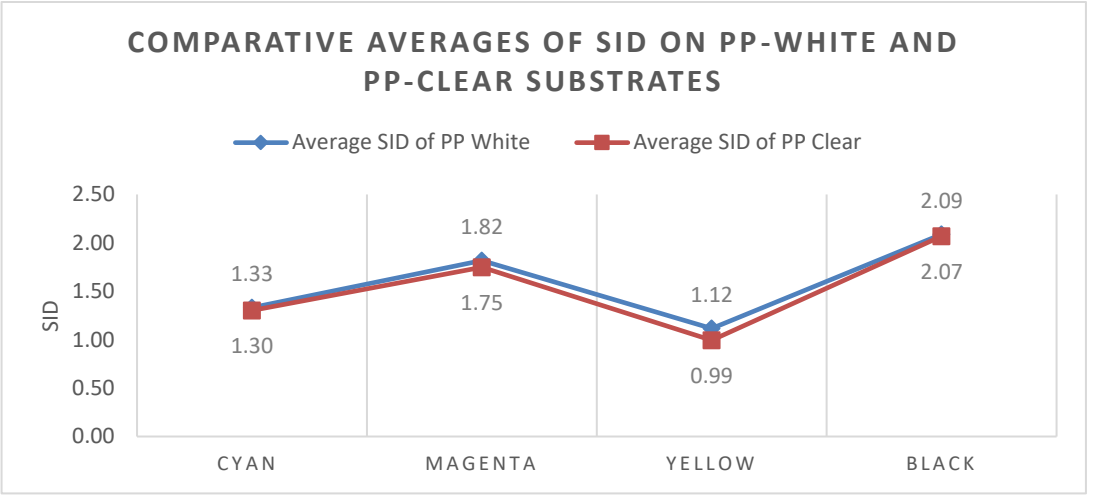

Fig 1, Comparative Averages of SID on PP-White and PP-Clear Substrates

The largest difference in SID between the two substrates is seen in the Yellow channel, where PP-White (1.12) is noticeably higher than PP-Clear (0.99), indicating a better ink density on PP-White.

Table 2: Comparative Averages of TVI (%) at 50% on PP-White and PP-Clear Substrates

	Cyan	Magenta	Yellow	Black
Average TVI (%) of PP-White	23.36	23.59	21.32	27.61
Average TVI (%) of PP-Clear	28.99	30.16	27.75	33.93

Table 2 presents the comparative averages of Tone Value Increase (TVI) at 50% for PP-White and PP-Clear across four Colour channels. The data reveals that PP-Clear has higher TVI values than PP-White in all Colour channels. For example, Cyan on PP-Clear shows a TVI of 28.99%, compared to 23.36% on PP-White.

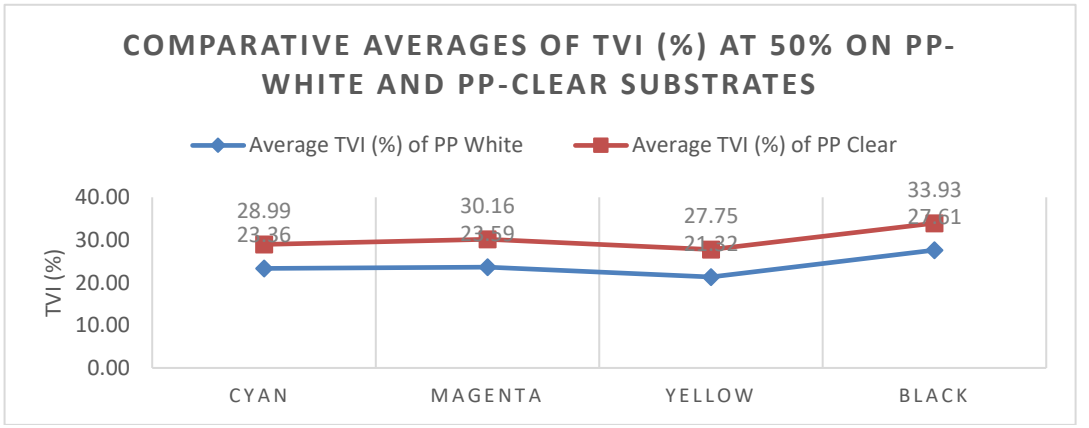

Fig 2, Comparative Averages of TVI (%) at 50% on PP-White and PP-Clear Substrates

This trend is consistent for Magenta (30.16% vs. 23.59%), Yellow (27.75% vs. 21.32%), and Black (33.93% vs. 27.61%). These results suggest that PP-Clear exhibits greater tonal increase, leading to potential differences in print quality and colour reproduction.

Table 3: Comparative Averages of PC on PP-White and PP-Clear Substrates

	Cyan	Magenta	Yellow	Black
Average PC % of PP-White	39.53	39.93	39.48	40.30
Average PC % of PP-Clear	34.72	35.02	34.56	36.17

Table 3 presents the comparative averages of Print Contrast (PC) for PP-White and PP-Clear substrates across four Colour channels. The data shows that PP-White consistently has higher PC values than PP-Clear in all channels. For example, the average PC for Cyan on PP-White is 39.53, compared to 34.72 on PP-Clear. This trend is also observed in Magenta (39.93 vs. 35.02), Yellow (39.48 vs. 34.56), and Black (40.30 vs. 36.17). These results indicate that PP-White produces higher print contrast, resulting in sharper and more vibrant prints compared to PP-Clear.

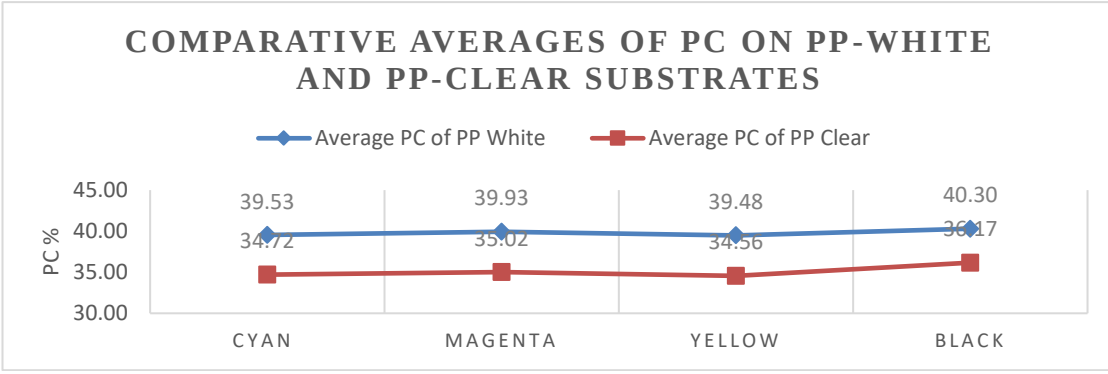

Fig 3; Comparative Averages of PC on PP-White and PP-Clear

5. RESULT AND DISCUSSIONS

Tone Value Increase (TVI):

PP-White exhibited a more consistent tonal reproduction curve, with lower TVI values compared to PP-Clear, which showed higher tonal distortion, particularly in midtones.

Solid Ink Density (SID):

PP-White achieved higher and more uniform SID values, indicating better ink holdout and coverage. In contrast, PP-Clear displayed lower SID due to its smoother surface and transparency, which impacted ink absorption.

Print Contrast (PC):

PP-White provided superior print contrast, contributing to sharper image reproduction and

vibrant Colours. PP-Clear struggled with achieving high contrast, resulting in muted prints.

The study confirms that PP-White outperforms PP-Clear in maintaining consistent print quality metrics, making it a preferred choice for high-precision applications.

6. CONCLUSION

This comparative analysis of PP-White and PP-Clear substrates highlights the significant influence of substrate properties on print quality in flexography. PP-White demonstrated superior performance in TVI, SID, and PC, making it more suitable for applications requiring precise tonal reproduction and vibrant prints. The findings serve as a valuable reference for optimizing substrate selection in the printing industry, particularly for UV-based flexography systems.

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