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Effect of Process Parameters on Print Density in Offset Print

Sanjay Sharma [1] * , Dr. Akshay V. Joshi [2]

1. Lecturer, Department of Printing Technology, Kalaniketan Polytechnic College, Jabalpur, M.P, India
sanjay.meenal@gmail.com ,

2. Assistant Professor, Savitribai Phule Pune University, Pune, Maharashtra, India

Abstract: Offset printing's great quality and affordability make it a popular choice for commercial printing assignments involving big volumes of paper. Print density is an important characteristic that affects picture sharpness, colour consistency, and overall visual appeal, among many others that impact print quality. This research delves into the impact of many process factors on print density in offset printing. These parameters include ink film thickness, composition of the fountain solution, printing pressure, blanket and plate conditions, and press speed. The best density and the absence of flaws like scumming and toning are achieved by keeping the ink-to-water ratio in check. Additionally, print density levels were directly affected by variations in printing pressure, which had a substantial effect on ink transfer efficiency. Additional factors that contribute to a consistent density distribution include the properties of the blanket surface and the correct maintenance of the printing plates. Changing the press speed affected production efficiency, however the impact on print density was small yet noticeable because of how the dynamic ink behaved. In general, print density and quality may be enhanced by standardising and closely monitoring these characteristics. To successfully manage important process parameters and achieve improved print outputs, integrated quality control systems are essential in offset printing, according to this study.

Keywords: Offset printing, print density, ink-water balance, printing pressure, process parameters, ink film thickness

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INTRODUCTION

The printing process known as offset printing, which is often referred to as offset lithography, is used for the production of packaging, magazines, brochures, books, and newspapers. The idea that oil and water are incompatible is the foundation upon which it is built. A image that has been inked is first moved from a plate to a rubber blanket, and then it is transferred to the printing medium, which is often paper. This is the beginning of the process. Offset printing is the most cost-effective alternative for big print runs because to its speedy speed, outstanding image quality, and cheap unit cost. Offset printing is also the most cost-effective method.

A significant aspect that determines the visual quality and consistency of the printed product is the print density, which is one of the most critical variables. The amount of darkness or brightness of the printed picture is referred to as the print density. There is a direct association between the print density and the output's colour depth, detail clarity, and aesthetic appeal. Maintaining a consistent and appropriate print density is essential to achieving quality standards, ensuring that customers are satisfied, and reducing the amount of waste that is produced by printing.

When it comes to offset printing, the print density is affected by a variety of process factors. These include, but are not limited to, the following: the thickness of the ink layer, the viscosity of the ink, the printing pressure, the conditions of the plate and blanket, the speed of the press, as well as the pH and conductivity of the fountain solution. To ensure that the printing circumstances remain constant and that the ink transfer remains homogenous throughout the entire print run, it is necessary to handle these elements with precision. Even little variations in these elements may lead to variations in print coverage, colour fidelity, mottling, or ghosting. These variations can be caused by several reasons.

As printing technology continues to progress and the demand from customers for quality printed goods continues to climb, it is becoming more critical to comprehend and optimise these process factors. Press operators and quality assurance workers still need to have a comprehensive understanding of how each parameter impacts print density, despite the fact that quality control and press automation have made it possible to monitor and modify print settings in real time. The major purpose of this study is to investigate the ways in which various aspects of the offset printing process influence the print density characteristics. The primary objective of the research is to shed light on how each component contributes to or subtracts from optimal print density in order to enhance print uniformity, increase printing efficiency, and reduce the number of errors that occur during the printing process.

OBJECTIVE

1. To determine how ink viscosity, fountain solution pH, press speed, and printing pressure affect offset printing print density.
2. To Optimise these settings to minimise print faults and maintain uniform colour density throughout printed material for high-quality print output.

METHODOLOGY

- Using components like photos, a step wedge, vignettes, surface/reverse, line elements, a control strip, and solid patches across the sheet, a customised monotone test form was created.
- A computer-to-plate was shown to the test form at a predefined screen rule.
- On 130 GSM coated paper, cyan ink was used for printing.
- An impartial trial was conducted in a press room setting.
- This trail's performance was meant to correspond with the outcomes following DOE.
- Full factorial DOE for four parameters—alcohol percentage, machine speed, pressure, and ink tack—was carried out in the first phase.
- Two values, Low (1) and High (2), are assumed for Tack and Pressure in relation to the baseline.
- The L*a*b ΔE values were measured on the printed sheets.
- To determine the optimal set of parameters minimising the colour difference, the DOE was examined.
- In order to confirm the DOE's analysed findings, the optimal variable combination was rerun. This was done at regular intervals to further check for consistency.

Process Parameters:

This experiment is comprised of four different parts. There were two different degrees of variation for the variables that included the speed of the machine, the pressure, the amount of alcohol, and the ink thickness. The validation of the solution and the construction of a transfer function (regression) are both facilitated by this.

Table 1: Offset Process Variables

S. No.	Factors	Low Level	High Level
01	S P ' SI O N	4000	6003
02	Ink lad(	1	2
03	Alcohol %	6	10
04	Nip Pressure	1	2

PRODUCTION RUN AND BASELINE

Manufacturing runs on coated paper (130 GSM) were carried out with the assistance of a Heidelberg offset printing machine over a period of several days. A pressure of 0.03 mm, 220 ink tack, 8% alcohol, and a machine speed of 6,000 impressions per hour were the specific parameters that we used. For the goal of providing a starting point for the ΔE, this exercise was designed to be carried out.

Table 2: Baseline data for ΔE

Production run	ΔE
P1	1.31
P2	1.32
P3	1.30
P4	1.32
P5	1.32
Base line	**1.31**

Considering the fact that the data acquired from the manufacturing run on coated paper revealed a mean ΔE value of 1.31, it was deemed suitable for use as a baseline. A goal was established to reduce the ΔE to its minimum.

COLOR DIFFERENCE ANALYSIS (ΔE)

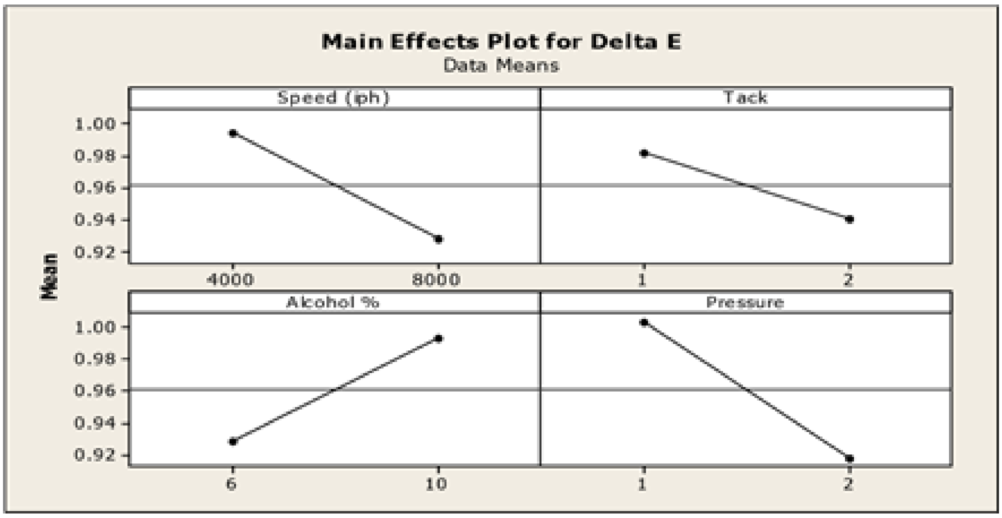

Figure 1: Effect of Process Variables on ΔE

The figure that represents the significant effect demonstrates that the least amount of change in E was achieved by lowering the proportion of alcohol while simultaneously raising the speed, ink tack, and pressure. According to the plot, each of the components is significant, as seen by the slopes of their respective slopes. differences in ink transfer happen as a result of a longer contact duration at lower printing rates, which leads to higher dwell time in the nip, where the ink spreads out more. This causes a bigger ΔE, which is produced by differences in ink transfer. When the speed is raised, the ink creates a bigger shear rate and concurrently suffers a high shear stress, which causes it to become more resistant to spreading once it has been transferred onto the substrate. Consequently, a drop in the value of ΔE is seen as the speed rises. A breakneck speed is achieved by the dispersion of ink with a lesser tack. The ink's viscosity has a direct correlation to the amount of tack it achieves. As a result of the lower tack ink's increased dispersion and uneven ink lay down, the density changes across the transferred areas throughout the transfer process. Consequently, a lower tack results in a greater ΔE value being created. Because the ink with a higher tack was dispersed uniformly over the printed page, the ΔE value was lower than it would have been otherwise considered. Stable emulsification, which takes place at lower alcohol percentages and results in consistent ink lay down across the sheet, is related with improved print quality. This is in contrast to unstable emulsification, which takes place at higher alcohol percentages and may result in uneven ink lay down over the sheet. Because of the decreased alcohol concentration, the ink film thickness (IFT) was uniform over the whole transferred area, which resulted in a reduction in the value of ΔE during the process. By raising the printing pressure, which in turn increases the force that is being applied to the NIP, it is possible to obtain a more equal dispersion of ink throughout the surface. When printing with a greater pressure, the colour difference was less visible than it would have been otherwise.

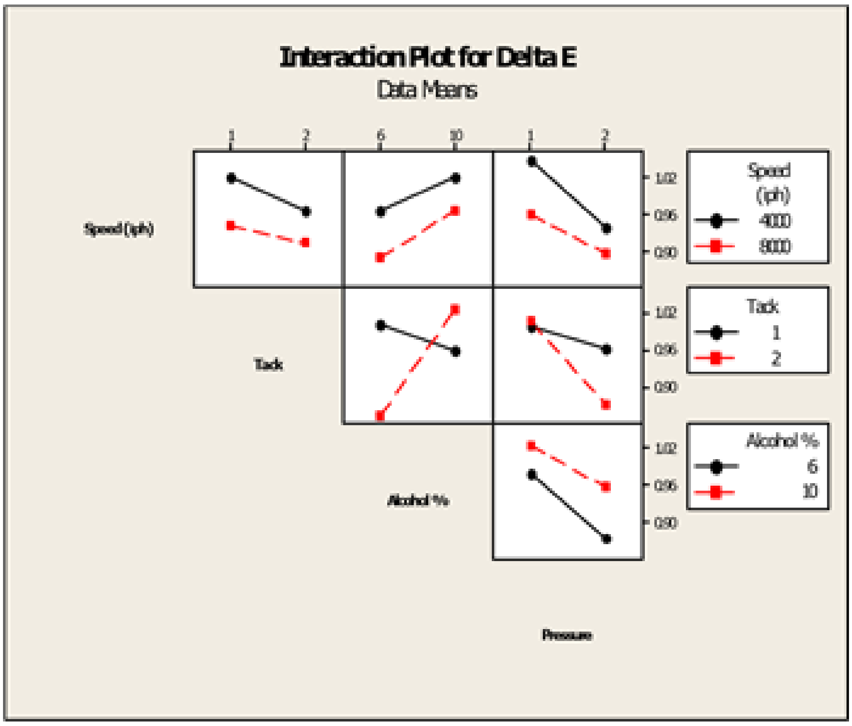

Figure 2: Interaction Plot of Process Parameters on ΔE

According to the interaction graphs, the lowest ΔE is reached when the reaction is carried out at a speed of 8000 iph, with two ink tacks, two pressures, and 6% alcohol. The slightly skewed lines that highlighted the interaction of speed with ink tack, alcohol percentage, and pressure showed that there was a little degree of interaction since they exposed the interaction. In addition, there were lines that were slightly asymmetrical due to the interplay between pressure and alcohol percentage. The fact that the interaction between ink touch, alcohol percentage, and pressure reveals an out-of-parallel state makes it abundantly evident that there is a significant link between these three factors.

STATISTICAL ANALYSIS FOR ΔE

Table 3 Estimated Effects and Coefficients for ΔE

Term	Effect	Coef	SE Coef	T	P
Constant		0.96125	0.008515	112.89	0.000
Speed(iph)	-0.06625	-0.03313	0.008515	-3.89	0.001
Tack	-0.04125	-0.02062	0.008515	-2.42	0.025

Alcohol%	0.06500	0.03250	0.008515	3.82	0.001
Pressure	-0.08625	-0.04312	0.008515	-5.06	0.000
Speed*Tack	0.01250	0.00625	0.008515	0.73	0.471
Speed*Alcohol%	0.01125	0.00563	0.008515	0.66	0.516
Speed*Pressure	0.02250	0.01125	0.008515	1.32	0.201
Tack*Alcohol %	0.10875	0.05438	0.008515	6.39	0.000
Tack*Pressure	-0.04750	-0.02375	0.008515	-2.79	0.011
Alcohol%*Pressure	0.02125	0.01062	0.008515	1.25	0.226

Summary of Model

S = 0.0481688 PRESS = 0.113139
R-Sq = 84.45% R-Sq(pred) = 63.89% R-Sq(adj) = 77.05%

A measurement of the error probability that is associated with accepting the results in their current state is referred to as the p-value. In spite of the fact that pressure has a large impact on ΔE, the p- and t-values indicate that all of the input parameters show significance. In order to demonstrate the relative significance of each element to the response (ΔE), the coefficients are used. Additionally, the pressure coefficient (-0.04312) and the speed coefficient (-0.03313) have the greatest impact on the value of ΔE.

Table 4: ANOVA (Analysis of Variance) for ΔE

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Main Effects	4	0.142037	0.142037	0.035509	15.30	0.000
Speed (iph)	1	0.035112	0.035112	0.035112	15.13	0.001

Tack	1	0.013612	0.013613	0.013613	5.87	0.025
Alcohol %	1	0.033800	0.033800	0.033800	14.57	0.001
Pressure	1	0.059512	0.059512	0.059512	25.65	0.000
2-Way Interactions	6	0.122587	0.122587	0.020431	8.81	0.000
Speed (iph)*Tack	1	0.001250	0.001250	0.001250	0.54	0.471
Speed(iph)*Alcohol%	1	0.001012	0.001013	0.001013	0.44	0.516
Speed (iph)*Pressure	1	0.004050	0.004050	0.004050	1.75	0.201
Tack*Alcohol %	1	0.094612	0.094612	0.094612	40.78	0.000
Tack*Pressure	1	0.018050	0.018050	0.018050	7.78	0.011
Alcohol %*Pressure	1	0.003612	0.003612	0.003612	1.56	0.226
Residual Error	21	0.048725	0.048725	0.002320		
Lack of Fit	5	0.019925	0.019925	0.003985	2.21	0.104
Pure Error	16	0.028800	0.028800	0.001800		
Total	31	0.313350				

There is a substantial relationship between the p-values of all the main components in the ANOVA table 4 for ΔE on coated paper and the α value of 0.05. This indicates that all of the components are significant. Both the adjusted sum of square (Adj SS) and the sequential sum of square (Seq SS) are statistical measures that demonstrate the relationship between each component and the response (ΔE). The pressure parameter was the one that had the most significant influence among the model parameters, with a Seq SS value of 0.059512. Due to the fact that pressure has a much higher F-statistic value, it may be inferred that it has a substantial influence on the amount of ΔE. The F-statistic may be obtained by dividing the factor mean square (MS) by the error mean square (MS). This will give you the factor mean square. As shown by the larger F-statistics with $P<0.05$, the analysis of variance (ANOVA) table 4 reveals that all the parameters (speed, ink tack, alcohol percentage, and pressure) had a significant influence on the coefficient of determination (ΔE) at the 95% confidence interval. It is possible to assess how well the model fits the data by calculating the R-Sq., which is calculated by dividing the regression sum of squares by the total sum of squares. As shown by the high coefficient of determination (R-Sq.), the model was able to account for 84.45% of the variability in the data. It is possible to use the adjusted R-Sq to assess the degree to which models with different numbers of predictors do a good job of explaining data. Including existing components will only result in an increase in value if they improve the model's ability to accommodate the anticipated change. The model greatly improved as a result of the use of four components, as shown by the adjusted R-Sq value of 77.05%. There is a statistically significant relationship between the model's four-factor regression and the fact that the difference between R-Sq and Adjusted R-Sq is less. With the use of the projected error for sum of squares (PRESS) statistics, we are able to get the R-Sq. (predicted), which demonstrates how well the model forecasts responses for information that is relatively recent. It is anticipated that the model will have a maximum R-Sq. value of 63.89%.

CONCLUSION

This research illustrates the crucial impact that factors like as ink viscosity, fountain solution pH, press speed, and printing pressure have in determining print quality. The study was conducted to investigate the influence of process parameters on print density in offset printing. A consistent ink transfer, greater picture sharpness, and enhanced colour consistency are all possible outcomes that may be achieved by the appropriate management and optimisation of these parameters. Based on the findings, it seems that even little differences in these characteristics may lead to considerable variations in print density, which can result in defects such as mottling, ghosting, or poor colour reproduction. Therefore, in order to achieve high-quality and consistent print results in offset printing, it is vital to maintain a printing environment that is both balanced and regulated.

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