

# Effect of Process Parameters on Color Variation in Offset Print

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**ABSTRACT:** The offset printing process is widely used in commercial printing for short and long run jobs. The offset printing process is a composite procedure linking not only the printing machine but also the substrate, ink and their interaction. The offset printing process deals with the maximum number of variables amongst all other printing process. The slight variation in process parameter leads to variation in ink transfer, which results in differentiability. This leads to variation in color and gloss on printed surface, which can be termed as color difference and. Thus, it is necessary to understand and control the process parameter to deliver quality print. The study focuses to examine the effect of significant parameters such as ink tack, alcohol %, press speed and impression pressure on color variation. The color variation is gauged by variation in ink transfer, which is governed by color difference ( $\Delta E$ ). The spectrophotometer was employed to measure the color difference. A production runs were conducted on press to set a baseline for print defects and target was set to minimize them. A general full factorial design of experiments was generated for the above mentioned process parameters with two levels. The experimental data was analyzed by ANOVA, Main and Interaction plots to spot the optimal combination, which delivers quality print with minimized color variation. The optimized setting showed reduction in  $\Delta E$  by 40%.

**KEYWORDS:** Offset Printing, Color Difference

## I. INTRODUCTION

The goal of any printer is to deliver the job on time with quality and retain the customer. The consistency in the print characteristics within the job and between the jobs is also important to both printers and customers.

Paper and Board are majorly used substrate for commercial printing and packaging, which is widely printed by offset printing process. One of the foremost challenges faced by the printer is to control the shade variation in print both spatial and temporal for a given job. The inconsistent ink lay-down results in color drift in the print viz. side-to-side and sheet-to-sheet in solid and halftone. This leads to wastage of substrate and inks thereby reducing productivity and profitability of an organization. Optimizing the offset process variables may minimize the wastage. The optimization of the offset process involves identification of best combination of process variables to minimize color variation in the print.

## II. RELATED WORK

Rastko Milosevic et al [4] investigated the influence of different printing pressure levels between blanket and impression cylinders on sheet fed offset print quality. The printing was carried out on 115 GSM gloss coated offset paper at three different pressures viz. 0.12 mm - 0.10 mm (low pressure), 0.08 mm - 0.06 mm (medium pressure) and 0.07 mm - 0.04 mm (high pressure). The print quality parameters considered for evaluation were tone value increase (TVI), gray balance, solid-tone optical ink density, relative print contrast, color gamut and color difference ( $\Delta E$ ). The hardness of four blankets was 82 Shore A as measured by shore durometer PCE-DX- A. 200 sheets were printed on KBA Rapida 75 sheet fed offset machine at 7000 sheets/h with ink sequence being followed as black, cyan, magenta and yellow (KCMY). TVI values were measured at 10% to 90% patch while density was measured on horizontal control strip by TECHKON SpectroDens. Gray Control Strip was used for gray balance estimation while VIPTRONIC VIPDENS 2000 densitometer was used to determine the optical ink density on TV gray patches at 30%, 50% and 70% respectively while contrast was measured at 80% and 100% TV patch. ECI2002V CMYK PM 5.0.5 Test chart

# International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 5, May 2016

comprising of 1485 patches and Gretag Macbeth Spectrophotometer, Spectrolino was used for color gamut and color difference measurements. Color gamut differences and color deviations were evaluated using Chromix Color Think Pro 3.0 software. The color difference was calculated using  $\Delta E_{94}$  formula. The results showed higher TVI, dot gain values at higher pressure with black exhibiting the maximum and cyan as minimum. The optical gray balance was achieved at normal printing pressure while low printing pressure exhibited good contrast and lower TVI and color difference parameters. The high printing pressure level application during the offset printing process produced the highest color gamut volume and the highest solid tone optical ink density. The study concluded that, the low printing pressure level enables a better overall print quality result comparing to the other two printing pressure settings.

Vikas Solanki et al [14] performed an experiment on effect of ink sequence on sheet fed offset print quality. The experiment was performed on art paper. The printing was carried out in four color offset machine. The press room conditions were maintained at 45% relative humidity at 28°C temperature. The press runs were performed with ink sequence YMCK, MYCK, CMYK, KCMY and KYMC and print quality parameters such as density, lab values and contrast of different samples were measured by X-Rite 528 spectrophotometer. At various percentage of density (100, 90, 70, 40, 15 and 3), YMCK and MYCK sequence gives the maximum and minimum values for red and green color. KCMY gives the maximum density values for blue color and remaining all sequences has almost same value. Red color has almost same contrast in all the sequence, KYMC gives the minimum contrast value for green, violet, and purple color. CMYK sequence gives the maximum contrast value for violet and orange color. Brown color has no variation in all the sequence. KCMY gives the maximum contrast value for green and purple color. KYMC gives maximum contrast value for blue while YMCK gives minimum value for orange color. According to the value of  $\Delta E$  CMYK, MYCK, YMCK AND KYMC sequence are more suitable respectively for red, green, orange, and purple color. KCMY sequence was more suitable for blue, brown, and violet color. Similar experiment was conducted by Lubdha Lade on effect of ink color sequence on color gamut. The results revealed minimum  $\Delta E$  and maximum color gamut with KCMY.

### III. METHODOLOGY

- A Customized monotone test form was designed with elements such as images, step wedge, vignettes, surface/reverse, line elements, control strip and solid patches across the sheet.
- Test form was exposed to a computer-to-plate at a predetermined screen ruling.
- Cyan ink was used to print on 130 GSM coated paper.
- An independent trial was performed in and working press room environment.
- The performance of this trial was intended to correlates with results obtained after DOE.
- In the first phase, full factorial DOE for four parameters were performed, these parameters includes alcohol %, machine speed, pressure and ink tack.
- For Tack and Pressure, two levels are assumed with reference to the baseline as Low(1) and High(2).
- The printed sheets were measured for  $L^*a^*b$   $\Delta E$  values.
- The DOE was analyzed to identify the best combination of variables minimizing the color difference.
- The best combination of variables was re-run to verify the analyzed results from the DOE and further checked for consistency by re-running the best combination of variables at regular intervals.

#### Process Parameters:

The experiment consists of four factors. The factors such as machine speed, pressure, alcohol % and ink tack were varied at two levels. This further helps to build a transfer function (regression) for the response and validate the same.

# International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 5, May 2016

S. No.	Factors	Low Level	High Level
01	Speed (iph)	4000	8000
02	Ink tack	1	2
03	Alcohol %	6	10
04	Nip Pressure	1	2

**Table 1: Offset Process Variables**

## IV. PRODUCTION RUN AND BASELINE

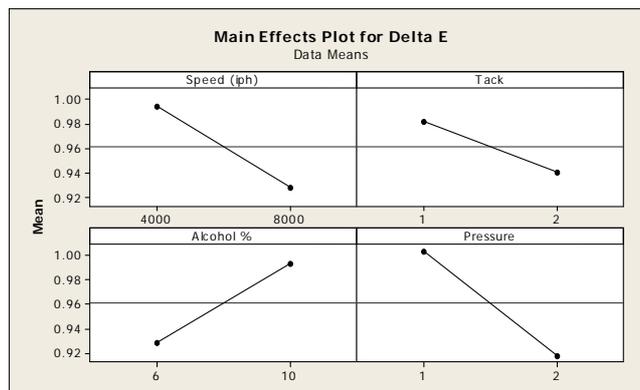
The production runs were conducted on the coated paper (130 GSM) for few days on a Heidelberg offset printing press. The parameters were set at 6000 impressions/hour machine speed, 220 ink tack, 8% alcohol and 0.03 mm pressure. The objective of carrying out this exercise was to define a baseline for the  $\Delta E$ .

Production run	$\Delta E$
P1	1.31
P2	1.32
P3	1.30
P4	1.32
P5	1.32
<b>Base line</b>	<b>1.31</b>

**Table 2: Baseline data for  $\Delta E$**

The data collected from the production run on coated paper showed mean  $\Delta E$  of 1.31, hence it was considered as baseline. The target was set to minimize the  $\Delta E$ .

## V. COLOR DIFFERENCE ANALYSIS ( $\Delta E$ )



**Fig 1: Effect of Process Variables on  $\Delta E$**

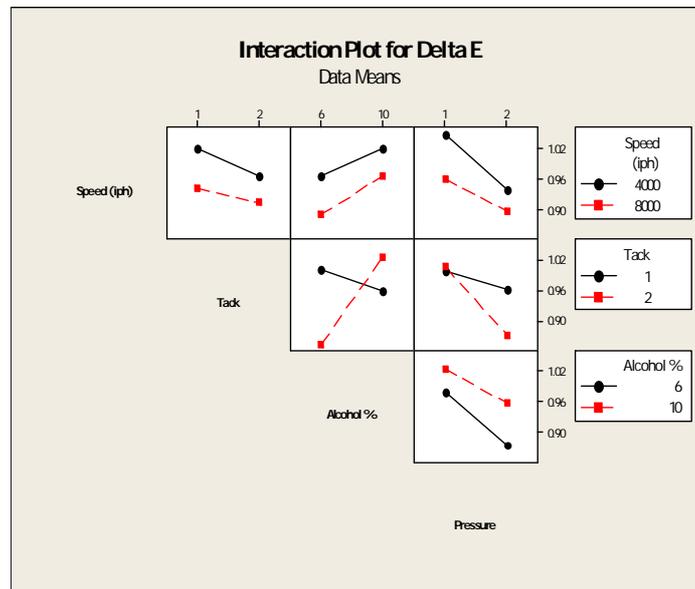
The main effect plot indicates that  $\Delta E$  was minimized at higher levels of speed, ink tack, pressure with lower level of alcohol%. The plot also indicates that all the factors are significant as represented by their slope. Lower printing speed corresponds to higher dwell time in nip where the spreading of ink is high due to prolonged contact period which results in variation in ink transfer thereby higher  $\Delta E$ . The higher speed develops more shear rate and concurrently high shear stress induced in the ink making it resistant to spreading after transfer onto the substrate. Thus,

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(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 5, May 2016

increase in speed shows lower  $\Delta E$  value. The spreading of ink with lower tack is a very rapid phenomenon. The lower tack corresponds to lower viscosity of ink comparatively. The lower tack ink spreads more and creates uneven ink lay down which results in variation in density across the transferred areas. Therefore, lower tack results in higher  $\Delta E$  value. The higher tack ink showed uniform distribution of ink across the printed sheet, which resulted in lower  $\Delta E$  value. The higher alcohol percentage shows unstable emulsification, which degrades the print quality while lower alcohol percentage shows stable emulsification, which results in even ink lay down across the sheet. The lower alcohol percentage showed uniform IFT (Ink Film Thickness) across the transferred area which resulted in lower  $\Delta E$ . The higher printing pressure applied ensure larger degree of force acting in NIP which helps in even ink transfer across the area. Therefore, higher printing pressure applied showed lower color difference.



**Fig2: Interaction Plot of Process Parameters on  $\Delta E$**

The interaction plots indicate that the lowest  $\Delta E$  is obtained at 8000 iph speed, 2 ink tack, 2 pressure with 6% alcohol. The interaction of speed with ink tack, alcohol% and pressure showed slightly skewed lines which indicate the slight degree of interaction. Also, the interaction with alcohol% with pressure showed slightly skewed lines. The interaction of ink tact with alcohol% and pressure shows out of parallel state which indicates the significant interaction between them.

## VI. STATISTICAL ANALYSIS FOR $\Delta E$

**Table 3 Estimated Effects and Coefficients for  $\Delta E$**

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

## International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 5, May 2016

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%

The p-value represents the probability of error involved in accepting the observed results. The p- and t-values suggest that all the input parameters are significant but pressure has a paramount effect on  $\Delta E$ . The coefficients indicate the relative importance of each factor to the response ( $\Delta E$ ). The coefficient of pressure (-0.04312) and speed (-0.03313) indicates a greatest impact on  $\Delta E$ .

**Table 4: ANOVA (Analysis of Variance) for  $\Delta E$**

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				

The ANOVA table 4 above for  $\Delta E$  on coated paper indicates that all the main factors are significant as the p-values are below  $\alpha$  value of 0.05. The Sequential sum of square (Seq SS) and adjusted sum of square (Adj SS) indicates the relative importance of each factor with response ( $\Delta E$ ). The pressure had highest Seq SS of 0.059512 which indicates its greatest impact in model. The relatively higher F-statistic value for pressure indicates that the factor has paramount influence on  $\Delta E$ . F-statistic provides an indication of the calculated by dividing the factor mean square (MS) by the error MS. The larger F-statistics with  $P < 0.05$  from the ANOVA table4 confirms the significance of all factor i.e., speed, ink tack, alcohol%, and pressure on  $\Delta E$  at 95% confidence interval. The R-Sq. indicates how well the model fits the data and is calculated by dividing regression sum of squares by total sum of squares. The higher percentage of coefficient of determination (R-Sq.) indicates that 84.45% of the variability could be explained by the model. The adjusted R-Sq. is a useful tool for comparing the explanatory power of models with different numbers of predictors. The value increase only if the adding existing factors improve the model to expected change. The adjusted R-Sq of 77.05% indicates that significant improvement of the model by using four factors. As it evident by R-Sq. and Adjusted R-Sq has lower difference between them indicating that significant regression of the model by using four factors. The R-Sq. (predicted) indicates how well the model predicts responses for new observations and is calculated from predicted error for sum of squares (PRESS) statistics. The highest R-Sq. (predicted) of 63.89% indicates that the model

# International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 5, May 2016

predict new observations nearly as well as it fits the existing data. Also, smaller PRESS value of 0.113139 indicates better predictive ability of model. The lack of fit with  $\alpha > 0.05$  indicates that the data fits well in the model. The lack of fit value of 0.104 represents the accuracy of the model.

## VII. CONCLUSION

The analysis for  $\Delta E$  revealed significance of all the main factors i.e., press speed, ink tack, alcohol% and pressure in minimizing print  $\Delta E$ . The best settings as extracted from the interactions plot for  $\Delta E$  on coated paper was at 8000 press speed, 2 ink tack, 6% alcohol and 2 pressure. The optimized setting resulted in reduction of  $\Delta E$  by 40%. The ANOVA table4 for  $\Delta E$  showed higher than 81% for R-Sq, 77% for R-Sq adjusted and 69% for R-Sq predicted which explains the ability of model to explain variability and make efficient predictions for new observation. The  $\Delta E$  was reduced by 40% for coated paper at 8000 press speed, 2 ink tack, 6% alcohol and 2 pressure.

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