SCREENING PATTERN EFFECT ON PRINT USING FLEXOGRAPHY AND SCREEN PRINTING

Synopsis submitted by

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Synopsis

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Title of the Thesis: Screening pattern effect on print using flexography and screen printing

This thesis examines screening pattern effects on print using flexography and screen printing. Screening involves converting continuous tone images into halftones consisting of a series of dots of varying size or spacing. Main types of screening are AM, FM and Hybrid. The quality and visual output of flexography and screen printing are significantly affected by the choice of screening pattern. In flexography printing, anilox roller looks like screen and in screen printing, screen mesh also looks like screen. There is huge effect of these screen-like anilox roller and screen mesh on print quality. Nowadays, the flexography printing is widely used for packaging and label printing and the screening pattern directly affects tonal range, image clarity, color consistency and the overall print appearance as well as print quality. The screening pattern is a critical factor in the flexography printing that affects everything from image fidelity to print consistency, considering the substrate characteristics, anilox roller, halftone dot shape and ink which ensures optimal print performance. In screen printing, the screen mesh count and dot size also influence the amount of ink deposited.

From literature review of related published research papers, it has been observed that different print quality parameters like solid ink density, dot gain, print contrast and hue error are affected by the input parameters like anilox screen ruling, screen mesh count, paper roughness, types of screening, types of dot shapes etc. both in flexography and screen printing. Research gap has been noticed in this area and objective has been set accordingly.

The objectives of this research are:

1. To print an ideal grey scale step wedge of dot coverage varying from 5% to 100% with AM, FM and Hybrid dots considering different anilox roller screen rulings onto different grades of substrates using flexography printing.

2. To print an ideal grey scale step wedge consisting of both AM and FM dots varying from 5% to 100% considering different screen mesh rulings onto different grades of substrates using screen printing.

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3. To study and analyze the prints of flexography and screen printing.

Taguchi Grey Relational Analysis, Box Behnken Design and Machine Learning are used to analyze the various print quality parameters such as solid ink density, dot gain, print contrast and hue error.

In single color flexography printing process, the effect of process parameters such as anilox roller ruling, paper surface texture and AM halftone dot shapes like round and square in the highlight, middle-tone and shadow areas of the print are evaluated based on the output responses such as dot gain, print contrast, solid ink density and hue error. The process parameters are selected at various levels such as anilox roller ruling at 700 lpi, 1000 lpi and 1300 lpi, the paper substrate of both coated and uncoated grade with surface roughness of 36 ml/min and 182 ml/min respectively, the halftone dot shapes of square and round shapes, the halftone dot percentages at 30%, 50% and 70% respectively that represents the highlight, middle-tone and shadow areas in the reproduction. The experiment was conducted by printing an ideal grey scale step wedge of dot coverage varying from 5% to 100% with both AM square and AM round dots. The printing process executed in flexographic printing machine, OMET LAB230 Iflex (Printing speed – 35 m/min, Nip pressure – 3 mm) with black colour uv ink. Each element of the specified samples of printed sheets are subjected to visual analysis with a Digital microscope (LEICA, S8APO) followed by the quantitative optical property measurement using Spectro-densitometer (X-Rite Spectro Eye and TECHKON GmbH Spectro Dens). Total of 12 numbers of experimental runs with different combinations of paper grades, halftone dot shapes and anilox roller rulings are employed in the experiment to investigate its influence on the final print quality.

The print quality evaluation is based on the assessment of solid ink density, dot gain, hue error and print contrast using Taguchi's Grey Relational Analysis method. Based on the Taguchi's GRA score, the optimal solution for the high print quality is prioritized. Considering the results of Taguchi's grey relational analysis, it has been observed that optimum print quality is obtained when print is taken on coated paper adopting 700 lpi anilox roller screen rulings if the image is made of round dot where dot gain is taken as a factor affecting print quality. It is also found that if hue error is considered as print quality index, optimum result can be obtained on uncoated paper using square dot but it behaves differently in different percentage dot areas so far as print contrast is concerned, coated paper printed with 700 lpi screen ruling will produce highest print quality. As a whole, 700 lpi anilox roller

screen ruling will produce highest print quality on coated paper if the image is composed of round dots.This experiment aims to distinguish the influence of substrate, halftone dot shape and anilox cell ruling in the final print quality of flexography printing process. Also, it demonstrates the scope of applying Taguchi's Grey Relational Analysis in the printing field to find out an optimal solution for the multiple criteria-based decision making activities.

In single color screen printing, the impact of AM and FM screen ruling in screen printing under the condition such as printing of a test target on both coated and uncoated paper with three different types of screen mesh count are assessed. The change in print quality according to the screen mesh count are focused here, because the screen mesh count is one of the key elements in screen printing that influences the ink flow through the mesh as well as the excellence of stencil image or halftone dots over the mesh. Under three different screen mesh count, the impact of AM and FM halftone in the print quality on both coated and uncoated paper grades are evaluated in the analysis part. The print quality assessment parameters taken as solid ink density, dot gain, hue error and print contrast at 30%, 50%, & 70% tonal areas of the print. Twelve different combinations of input variables such as coated and uncoated substrate, AM and FM halftone dots, 100 lpi, 120 lpi and 140 lpi screen mesh counts are employed at different print trials. The printing work was executed in screen printing machine ATOM 1520, APL Machinery Pvt. Ltd with black ink. The printing pressure, room temperature and ink parameters are kept constant throughout the printing process. After printing, the printed samples were subjected to the visual inspection by Digital microscope (LEICA, S8APO) and the quantitative optical property measurement by Spectro-densitometer (such as X-Rite Spectro Eye & TECHKON GmbH Spectro Dens). The print quality assessment and ranking of each experiment are done by Taguchi's Grey Relational Analysis which is a best method to implement in the decision making process of quality control.

It has been found that the screen printing quality is dependent on the screen mesh count. Printing with a high screen mesh count on smooth surface paper will give the best result in screen printing. The AM dots will work better in the middle-tone region with a good tonal value transition from highlight to shadow region. It has also been found that the FM dots are also capable to give the vibrant color especially at the solid density regions than that of AM dots but fail to reproduce the middle tone densities with a smooth tonal transition. A huge shift of tonal value has been observed at the middle-tones for FM dots. The accurate reproduction of FM dots in screen printing is dependent on the mesh count and some other

crucial factors like adaptation with proper stencil making process, adhesion with screen mesh, squeegee pressure, ink parameters etc. The printing on uncoated paper with low mesh count will lead to high dot gain and it is a poor choice for high quality precision works.

The print quality assessment and optimization of process parameters associated with the flexography printing process based on Design of Experiment (DoE) was carried out by one of the most efficient quadratic models in Response Surface Methodology called Box Behnken Design. The experimental approach that designated three factor inputs such as three kinds of anilox roller screen rulings, three grades of paper substrates with different smoothness and three levels of halftone dot percentages. The dot gain and print contrast are taken as the output responses that denote the degree of accomplishment of print quality. After printing and measurements and data collection, the Box Behnken Design (BBD) is implemented here for the optimization of process parameters with proper employment of analytical approach such as ANOVA and regression analysis. The results found the suitability of BBD model and regression analysis in selecting the parameters to get the better print in flexography. The value of VIF (Variance Inflation Factor) in regression analysis is found below 1.5 that indicates the less occurrence of multi-collinearity in the regression model. It is also found that the roughness of paper surface, anilox roller screen rulings and dot percentage influence the dot gain and print contrast.

This study examines the evaluation of print quality and process parameter optimization related to the screen printing process using Design of Experiment (DoE) conducted by Box Behnken design, one of the most effective quadratic models in Response Surface Methodology. Three types of screen meshes, three classes of paper substrates with varying smoothness, and three degrees of halftone dot percentages were among the three factor inputs identified by the experimental methodology. The output responses that indicate the level of print quality are the dot gain and print contrast. A grey scale image is printed using three different grades of paper substrate and three different screen meshes using screen printing process. The image is halftoned with FM dots.

The dot gain and print contrast responses were recorded throughout a total of fifteen experimental runs. Minitab 17 software was used to carry out the BBD, and regression and graphical analysis were performed. The graphical analysis was done to find relation among parameters that affect print contrast and dot gain. Using surface, contour, interaction, main effect and other plots, the outcome was thoroughly analyzed.

It has been observed that the screen mesh ruling plays a major role in the occurrence of dot gain in screen printing. It has been found that higher the screen mesh ruling, higher will be the dot gain especially for FM halftone dots. The mesh opening size must be capable to carry each individual halftone dots of the stencil for the accurate result in printing; otherwise, the dot loss over the screen mesh will occur and it further causes dot gain and also it will influence the print contrast too. The undesirable tonal shift from highlight to middle-tones and immediately to the shadow areas were also observed with the screen printing result with FM dots. Also, the dot gain and print contrast were found to be influenced by the surface roughness level of the substrates used. The roughness of the surface can accelerate the rate of ink absorption and increase of dot gain. In the present work, a substrate with smoother surface finish and a higher screen mesh ruling would be the ideal levels of process parameters which may be used with the screen printing in order to get a good quality print.

This research work is focused on to integrating the machine learning possibilities with single color flexography print quality evaluation and to establish a machine learning algorithm in python to evaluate the print quality as dot gain as the output response. The data analysis and performance evaluation are done using the supervised machine learning approaches such as linear regression, decision tree regression and random forest regression algorithms. The experimental trials are executed with three input variables such as paper substrates with two different roughness levels, anilox rollers with three different screen rulings and square shaped AM halftone dots. After measurements and data collection, the input datasets for the machine learning algorithms are created from the readings up to 114 print trials. The split ratio of training to test dataset is taken as 7:3. The collected data are inputted to the python programme to process with machine learning algorithms. Loss functions like MSE, RMSE, MAE and R^2 are generally used to assess the performance of various machine learning techniques. It has been observed that random forest regression is comparatively better out of the three machine learning techniques considered in single color prints.

This research work focuses on using machine learning algorithms in the prediction of dot gain related to four color flexography printing process. The process parameters are selected at various levels such as anilox roller ruling at 900 lpi and 1200 lpi, the paper substrate of both coated and uncoated grade with surface roughness of 76 ml/min and 109 ml/min, the halftone dot shape of square shaped AM dot, the halftone dot percentages at 30%, 50% and 70% respectively that represents the highlight, middle-tone and shadow areas in the reproduction.

For data analysis and performance evaluation, machine learning techniques such as linear regression, decision tree regression, random forest regression, XG (Extreme Gradient) boost regression, SVM (Support Vector Machines) regression and neural network algorithms were used. The machine learning algorithms employed the readings of 100 print trials of input data sets for every color (cyan, magenta, yellow and black). It is expected that the split ratio of the training to test dataset is 7:3. The collected data is fed into the python program which processes it using machine learning techniques. The findings of this research work demonstrate that out of all the machine learning algorithms used in this investigation, neural network methods had the highest accuracy considering the loss functions.

Also, the implementation of machine learning algorithms in the prediction of hue error associated with four color flexography printing was done. The experimental process variables are chosen as two levels of anilox screen ruling, two grades of paper substrates with different surface texture and a total of 100 steps AM halftone square dot percentages with 4% intervals for each process colors. The algorithm is developed with python machine learning technique to assess the output response of a flexography print in terms of hue error. Different approaches of machine learning methods such as linear regression, decision tree, random forest regression, XG boost regression, SVM regression and neural network algorithm are used for data analysis and performance assessment. The readings of 100 print trials of input datasets for each color were used with the machine learning algorithms. The training to test dataset split ratio is assumed to be 7:3. The python software receives the gathered data and uses machine learning methods to process it. From the loss functions analysis, it is found that Neural Network machine learning can predict hue errors with better accuracy in all the process colors such as cyan, magenta, yellow and black in comparison to other methods considered. It has also been found that printing sequence of yellow, cyan, magenta and black promotes minimum chances of hue error variations.

Prediction of image quality using three different machine learning algorithms has been done in single color prints in screen printing process. In black and white prints, input parameters which vary are screen mesh ruling, paper roughness, dot percentage and halftone screening type. The experimental data were fed to train the system and the output response as dot gain was found. The split ratio of training to test dataset was taken as 7:3. The collected data were given as input to the python program to process different machine learning algorithms. From the loss functions of different machine learning techniques, it has been noticed that random

forest regression (RF) gives better output in comparison to linear regression (LR) and decision tree regression (DT) in single color screen prints.

The major contribution of the research work is that the different models like Taguchi Grey Relational Analysis and Box Behnken Design are generally not considered in flexography and screen printing quality evaluation. But these models as well as Machine Learning have been applied as far as possible in accomplishing of this research work. This can open a completely new avenue in assuring and predicting the print quality. Besides, it is to be mentioned that the results obtained using Taguchi Grey Relational Analysis, Box Behnken Design and Machine Learning are more or less consistent to attain the research goal.

Future Scopes

This research work in flexography printing may be extended by varying the different parameters such as halftone dot shapes, anilox roller cell shapes, cell angles, cell depth, varying ink viscosities, the printing speed, different surface textures of the substrates, printing atmospheric conditions etc. and their effects on the print quality.

This research work in screen printing may be extended by varying the different parameters such as halftone dot shapes, screen mesh rulings, varying ink viscosities, squeegee angles, squeegee profiles, different substrates and also the printing speed.

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