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A SURVEY OF PRINTABILITY RELATED ISSUES IN DRY TONER BASED DIGITAL PRINT ENGINES

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ABSTRACT

Printability has been a point of strong interest among customers and printers. Printability is the capability of printing press to print accurately along with the substrate combination as per predetermined standards without hampering the print quality. Many digital printers are suffering from the printability related problems due to the lack of knowledge of substrates characteristics. Objective of this paper is to analyse various substrate characteristics related factors and their combined influence on printability of the dry toner digital printing presses. For the better theoretical background work in this area, a printability model already has been developed to get aware of the prominent substrate surface characteristics which affect the printability of the presses. In the present work a survey of 50 digital printers of the northern region of India was carried out to understand the awareness of digital printers about the printability behaviour of dry toner based digital printing machines in relation to the cellulosic substrate characteristics. A questionnaire was prepared to identify the print quality related problems digital printers are facing in the northern region of India on the Likert Scale of 1-5. The degree of challenge posed by various characteristics of cellulosic substrates on dry toner digital printing presses has been examined by EFA (Exploratory Factor Analysis) tool using SPSS 11.5 version. Kaiser-Meyer-Olkin value is found 0.731 and Bartlett's test of sphericity values are found (0.000) which indicated that survey method used in the research work is highly feasible and significant. Gloss and Surface strength of paper has shown the maximum contribution towards printability problems, on the other hand, dimensional stability and moisture content characteristics have shown the minimum contribution towards the printability related issues. The Exploratory Factor Analysis used in this paper indicated that there are two learning key factors (LFKs) namely; Paper Printability Index-I and Paper Printability Index-II which leads to 67.20% of the total printability results.

KEYWORDS: - Print Quality, Dry Toner based Digital Printing Press, Curling, Heating, Moisture Content, Linting, Stiffness, Grain Direction, Exploratory Factor Analysis

INTRODUCTION

Printability means the interrelationship of a printing press in combination with the substrate that can result into accurate and high quality print output. Surface and structural characteristics of the substrate has direct influence on the printability of the presses. Printability is the term generally used in concert with the runnability which means how well a paper runs through the press without jam (Print Wiki). Printability is a general term refers to all the properties of paper that contributes to good quality of the printed matter (Singh & Rao).

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Printability in dry electro-photographic presses, commonly known as digital printing presses or laser printers, is affected by several factors. These factors can influence the quality, efficiency, and overall performance of the printing process. The ink, paper characteristics, fusing system, surrounding temperature and moisture conditions, image resolution and maintenance aspects of the DEP press have direct influence on the printability of papers. To achieve consistent printing and ensure good colour reproduction in digital proofing systems, it is essential to have well-defined and controlled paper properties. By considering and optimizing the optical properties of paper, printers can enhance the visual impact and quality of their printed materials (Thompson, 1998).

While special embossed finishes with specific patterns can add visual interest to printed materials, they can present challenges when used with most dry toner systems. Printing on these substrates can be notoriously difficult due to the intricate textures and uneven surfaces created by the embossed patterns. Achieving consistent and accurate toner adhesion and image quality can be more challenging on such substrates. It is important to consider the compatibility of the paper finish with the chosen printing technology, including dry toner systems. Some finishes may pose difficulties in terms of toner adhesion, image quality, and overall print performance. Careful evaluation and testing are necessary to determine the best combination of paper finish and printing technology for achieving optimal results (Evans, 2005).

A number of factors contributing to printability of paper in dry toner based digital printing presses have already identified with the help of literature review. From the literature 11 cellulosic substrate characteristics were identified which may cause the printability issues. From the literature total 11 factors; dimensional stability, heat resistance, surface strength, moisture content, curling tendency, gloss, grain direction, surface smoothness, linting (Bijender & Baral 2021).

REVIEW OF LITERATURE

There are different techniques used in digital printing which require different paper characteristics. Due to this, paper manufacturers face challenges in creating specific paper grades for specific digital printing processes. A variety of paper grades are manufactured to fulfil customer needs as well as requirements. Paper manufacturers should seek this opportunity and serve specific unique paper grades to printers (Gullichsen & Paulapuro, 2000).

To ensure optimal printing results, it is important to choose papers that are specifically formulated and designed for the type of digital printing technology being used. These papers are engineered to withstand the specific heat, pressure, and chemical interactions associated with the respective printing process. By selecting the appropriate paper for the specific printing technology, users can mitigate issues such as image clarity, ink seepage, and paper deformation, and achieve high-quality, well-fused prints (TGI Inc, 2007).

While there are several important characteristics to consider for successful printing, there is no universally agreed-upon set of characteristics across all printing areas. The choice of paper and its key characteristics largely depends on the specific application. While improvements can be made in the paper manufacturing process to address global issues, manufacturers must also produce paper that meets the needs of different groups within the printing community (Gamm et al., 2012).

The printability of a paper surface is influenced by various surface properties, including smoothness, uniformity, and the paper's ability to absorb ink. Generally, high print quality is associated with well-formed and smooth papers that are also compressible (Thompson, 1998). Several important surface properties of paper can impact printability, including roughness, formation, porosity, and permeability. Roughness and formation are external surface properties, while pore size, porosity, and permeability are considered internal surface properties (Wilson, 1997).

RESEARCH OBJECTIVE

In the present production digital printing market, among most of the printers, the per-impression cost is higher than conventional technologies after a specific point of a few hundred impressions. The major cost consists of contributions from toner/inks, paper, maintenance, press consumables, and depreciation of the equipment capital investment. With the increase in run length, this differential also increases, rendering digital production no longer feasible and viable. Most of the advantages of digital printing are becoming more widely experienced by the printers within the marketplace as the technology becomes popular. With the introduction of strong fusing system, the print quality of digital printing systems has become comparative to the offset and the trend is going on with rapid pace. For the short run applications most of the printers have already been migrated to the digital systems.

Higher print quality expectations from the printers also puts pressure onto paper manufacturers and suppliers because defects, poor toner fusion, non-uniformities, poor charging characteristics and mottle are no longer tolerated in the print market. Demand for the printability poses significant technical challenges for digital papers and as press speed increase; this becomes more of a challenge for papers. Printers need to take utmost care for various printability issues for the better print run and thereby overcoming possible print problems occurring in the pressroom. Objective of this paper is to analyse various substrate characteristics factors and their combined influence on printability of the dry toner digital printing presses.

RESEARCH METHODOLOGY

The research consists of 6 major steps i. e. preparation of questionnaire and google form; identification of dry-toner digital printers in northern part of India, sending the questionnaire to digital printers; collecting and examining the responses of printers; conduct of KMO and Bartlett’s test of sphericity, conducting EFA (Exploratory Factor Analysis), analyse the data and finally the interpretation of results. This study involved 50 digital printers situated in Northern part of India at New Delhi, Chandigarh and Ludhiana locations. The respondents had at least three years of experience in handling digital printing machines. The questionnaire instrument was filled in voluntarily by digital print professionals in online/offline mode.

Total 11 factors contributing to printability as explained in proposed review model (Bijender, Baral AK 2021) were utilized in the EFA (Exploratory Factor Analysis). As in the EFA, each item was score on a 5-point Likert scale, ranging the scale 1-5 i.e. (1= Very Low, 2= Low, 3= Medium, 4= High, 5= Very High). A number of techniques exist for finding most crucial factors involved in the research. Out of that most frequently used is the exploratory factor analysis. EFA helps in reducing the variables, by converting many variables into a single factor or more factors as obtained with the results. The factors obtained results into limited number of factors which consists of highly correlated factors. Framework of EFA (Jamil et al., 2015) is shown clearly in the figure given below: -

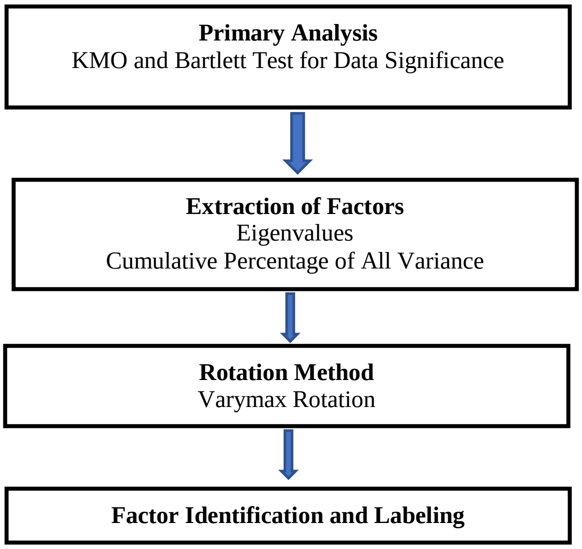

Fig.1. Framework of Sequence for Exploratory Factor Analysis (Jamil et al., 2015)

DATA COLLECTION & ANALYSIS

The data was collected by survey method. During the data collection stage, after getting the responses of the printers, KMO and Barlett's Tests are required to be conducted to check the feasibility of collected data for various factors. KMO is a test conducted to examine the strength of the partial correlation (how the factors explain each other) between the variables. KMO values closer to 1.0 are consider ideal while values less than 0.5 are unacceptable.

Kaiser-Meyer-Olkin (KMO) and Barlett's Test

During the analysis of response data, feasibility and significance of the study was evaluated with the help of Kaiser-Meyer-Olkin (KMO) and Barlett's test. The KMO value is found 0.731 and Bartlett's test of sphericity values are found (0.000) which indicated that exploratory factor analysis used in the research work is highly feasible and significant, as shown in table 1.

Table 1. KMO and Bartlett's Test for data significance

KMO and Bartlett's Test		
Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		0.795 (Feasible)
Bartlett's Test of Sphericity	Approx. Chi-Square	301.494
	df	55
	Sig.	0.000 (Significant)

The contribution of each printability factor was counted and summarized in the table 2. Gloss and Surface strength has shown the maximum contribution towards printability problems with the loading value of 0.912 and 0.907 respectively. Dimensional stability and moisture content characteristics have shown the minimum contribution towards the printability related issues with the loading values of 0.172 and 0.450 respectively.

Table 2. Exploratory factor analysis principal component loadings of print quality related issues

Communalities		
	Initial	Extraction
surfsmoothness	1.000	0.809
dimensional	1.000	0.172
Heatresist	1.000	0.684
surfstrength	1.000	0.907
Moisture	1.000	0.450
Curling	1.000	0.770
Gloss	1.000	0.912
graindirect	1.000	0.473
Fluffing	1.000	0.870
Stiff	1.000	0.630
Dynamic	1.000	0.718

Further, Principal Component Analysis was conducted keeping in aim of getting major Learning Key Factors (LKF) and finally; identification and labelling of factors based on the higher loading factor for each component were also held out. The extraction communalities for this data set were found significant. The contribution of each printability factor was counted and summarized in the table 2.

RESULTS & DISCUSSION

For any research to be significant the eigenvalues more than 1 are called acceptable and total variance score for different factors is required to be performed for the factor extraction. It is used to find out the optimal number of components useful to describe the data. The higher the cumulative amount of score variance, the less information will be missed out (lost).

Refer to Table 3, the number of factors revealed are only two (2) being the eigenvalue greater than 1. The first eigenvalue was equal to 4.362, and contributes to 37.33 % of the variance in the data. The eigenvalue 3.031, corresponding to the second factor, contributes to 67.21% of the variance in the original data.

Table 3. Eigen values of key factors contributing to the results

Total Variance Explained									
Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	4.362	39.657	39.657	4.362	39.657	39.657	4.106	37.329	37.33
2	3.031	27.555	67.212	3.031	27.555	67.212	3.287	29.883	67.21
Extraction Method: Principal Component Analysis.									

Finally, 11 components by Principal Component Analysis with Varimax rotation was produced which indicated the two learning key factors (LKF) as shown in Table 4. Total seven items were loaded onto Factor-1, were labelled as “Paper Printability Index-I” which includes five factors i.e., surface strength, gloss, fluffing, surface smoothness and moisture content.

Table 4. Rotated component matrix of the key factors contributing to the results

Rotated Component Matrix[a]		
	Component	
	1	2
Surfstrength	0.942	
Gloss	0.937	
Fluffing	0.933	
Surfsmoothness	0.892	
Moisture	0.614	
Dynamic		0.823
Curling		0.811
Heatresist		0.796
Stiff		0.770
Graindirect		0.644
Dimensional		0.414

Total of five items that were loaded onto Factor 2 were labelled as "Paper Printability Index-II" which includes factors like dynamic friction, curling, heat resistance, stiffness grain direction and dimensional stability.

CONCLUSION

From the Exploratory Factor Analysis (EFA) of print quality related problems, it has been concluded that; for print quality and printability problems, the most contributing and impacting factors are substrate gloss and surface strength. With the EFA, total five factors were loaded into Learning Key Factor-1 labelled as "Paper Printability Index-I". Remaining six factors were loaded into Learning Key Factor-2, which is labelled as "Paper Printability Index-II". These terms are introduced in the research first time. The two learning key factor constructs i.e., Paper Printability Index-I: includes five factors i.e., surface strength, gloss, fluffing, surface smoothness and moisture content and "Paper Printability Index-II" includes six factors i.e., dynamic friction, curling, heat resistance, stiffness grain direction and dimensional stability. These two Learning Key Factors (LKFs) account for 67.20 % of printability results to be produced in dry toner-based digital printing presses. Printers need to take care of all above paper characteristics which result into optimum print quality. Printers need to strictly follow the user manual and take care of all above factors for optimizing the printability and print quality results.

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