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CORRELATION OF VARIOUS ATTRIBUTES OF PRINT SUBSTRATES AND DRY ELECTROPHOTOGRAPHIC (DEP) PRINT ENGINES FOR POSSIBLE REDUCTION OF PRINT DEFECTS WITH SPECIAL REFERENCE TO SUBSTRATE RUNNABILITY

Bijender[1], Anjan Kumar Baral [Ph. D. 2]

1. Assistant Professor, Department of Printing Technology, Guru Jambheshwar University of Science & Technology, Hisar
2. Professor, Department of Printing Technology, Guru Jambheshwar University of Science & Technology, Hisar

ABSTRACT

Runnability has been a point of strong attention among most of the dry toner based digital printers. Runnability is the capability of substrate to run smoothly from infeed to outfeed unit during the printing work. But most of the digital printers are suffering from the runnability problems due to the lack of knowledge of substrates characteristics contributing to the runnability. For the better theoretical background work in this area, a runnability model already has been developed to get aware of the prominent surface characteristics of substrates contributing to the runnability problems. In the present work a survey of digital printers of the North India was carried out to understand the awareness level of digital printers about the runnability behaviour of dry toner based digital printing machines in relation to the cellulosic substrate characteristics. A questionnaire was prepared to identify the runnability 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 0.795 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. The Exploratory Factor Analysis used in this paper indicated that there are two major factors namely; Paper Runnability Index-I and Paper Runnability Index-II which leads to 65.9% of the total runnability results.

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

INTRODUCTION

Runnability is the ability of paper to smoothly move through the press without jamming during the printing. Poor runnability of a press can cause downtime, waste, and reduced productivity. Various factors can affect runnability include paper properties such as roughness, stiffness, and moisture content, toner adhesion, and fuser oil contamination etc.. Paper edge quality, curling capability, stiffness, moisture level and heat handling capability contribute to runnability of the paper in dry toner based digital printing [M Leon 2014]. The paper finish influences the paper quality in digital print production [Ataeefard, Maryam 2014]. With the literature review, a runnability model has been prepared and it has been observed that grain direction, static electricity, linting and dimensional stability are other key points that affect the runnability of the paper substrates in dry toner based digital printing process [Bijender, Baral AK 2021].

Dry toner electro-photographic digital printing is a widely used technology for high-quality printing in various industries. However, it is not without its challenges. One of the main issues is primarily runnability followed by the printability during the print run. Various scientific studies have used EFA to addresses the problem of analysing the structure of interrelationships (correlations) between a large number of variables, defining a set of latent dimensions, called factors (Hair et al., 2009). In the present work EFA is being used to find out the correlation of various variables affecting runnability in dry toner electro-photographic presses.

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REVIEW OF LITERATURE

Pekka Kettunen and Pekka Kärenlampi (2018) examined the relationship between paper properties and runnability issues in dry toner electro-photographic printing. The authors found that paper roughness, stiffness, and moisture content significantly affect runnability. They recommend using papers with lower roughness, higher stiffness, and optimal moisture content for better runnability.

Keiichi Nakamoto et al. (2019) investigated the impact of fuser oil contamination on paper runnability in dry toner electro-photographic printing. The authors found that fuser oil contamination can also cause paper jams and misfeeds, leading to decreased productivity and increased waste. They recommend regular cleaning of the fuser unit and replacing the contaminated fuser oil to improve runnability.

Oshima et al. (2019) revealed the factors affecting toner adhesion to paper in dry toner electro-photographic printing, which can cause toner offset and paper jams. The authors found that toner adhesion is influenced by paper surface roughness, toner particle size, and fuser temperature. The author recommended using papers with smoother surfaces, smaller toner particle sizes, and appropriate fuser temperature settings to improve toner adhesion and runnability.

Olivier Arnould et al. (2020) focused on improving the runnability of dry toner electro-photographic printing on coated papers, which are often more challenging to print on due to their smooth surfaces. The authors found that paper surface roughness and coating structure significantly affect runnability. They recommend using papers with higher roughness and a more open coating structure to improve runnability and reduce jams.

All above discussion proves that runnability issues in dry toner electro-photographic digital printing presses can be caused by various factors, including paper properties, fuser oil contamination, toner adhesion, and coated paper surfaces.

RESEARCH OBJECTIVE

A number of factors contributing to runnability of paper in dry toner based digital printing presses have already identified with the help of literature review [Bijender, Baral AK 2021]. Objective of this paper is to analyse various factors which affect the runnability in dry toner based digital printing presses and to correlate the factors with cellulosic substrate (paper) characteristics using EFA (Exploratory Factor Analysis).

RESEARCH METHODOLOGY

The research consists of 6 major steps i. e. preparation of questionnaire and Google Forms; 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) to analyse the data and finally the interpretation of results.

DATA COLLECTION & ANALYSIS

Participants

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.

Measure and Procedure

Total 11 factors contributing to runnability as explained in proposed review model (Bijender, Baral AK 2021) shown in Table.2 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).

Exploratory Factor Analysis

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 (Nur Izzah Jamil et al.) is shown clearly in the figure given below: -

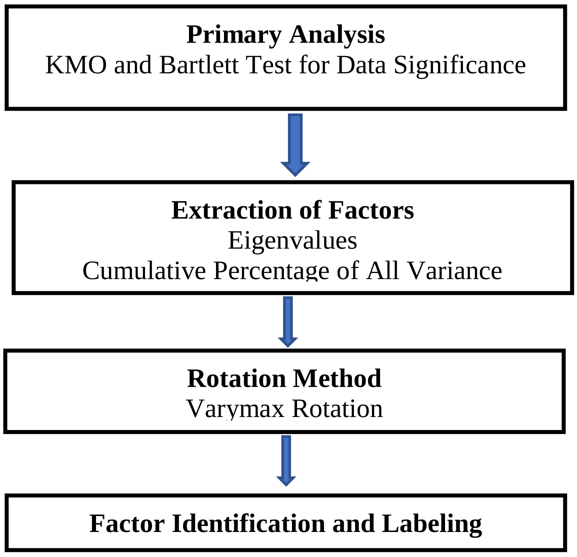

Fig.1. Framework of Sequence in EFA (Exploratory Factor Analysis) [14]

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

KMO and Barlett's Tests are required to be conducted to check the feasibility of collected data for various factors. More KMO values and smaller values of Bartlett's test results that the factor analysis is quite feasible. If values of KMO are above 0.5 and values of Bartlett's test are below 0.05, it indicates that data is highly correlated. As shown in the Table 1, KMO value was found 0.795 and (.000) of the Bartlett's test suggests that factor analysis is found significant for present research.

Principal Component Analysis

Further, Principal Component Analysis was conducted keeping in aim of getting major Learning Key Factors. 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 (Table 2).

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

KMO and Bartlett's Test		
Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.795 (Feasible)
Bartlett's Test of Sphericity	Approx. Chi-Square	301.494
	df	55
	Sig.	.000 (Significant)

Table 2. Exploratory factor analysis principal component loadings

Sr. No.	Factors Contributing to Runnability	Abbreviation Used	Loading
1.	Dimensional Stability	dimesionstability	.814
2.	Heat resistance	heatresistance	.403
3.	Surface strength	surfacestrength	.493
4.	Moisture content	moisturecontent	.502
5.	Curling tendency	curlingtendency	.743
6.	Gloss	gloss	.757
7.	Grain direction	graindirection	.583
8.	Surface smoothness	surfacesmoothness	.734
9.	Linting/fluffing	linting	.785
10.	Stiffness	stiffness	.730
11.	Static/Dynamic friction	friction	.708

RESULTS & DISCUSSION

Eigen Values

For any research to be significant 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 4.49, and contributes to 40.817% of the variance in the data.

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

Total Variance Explained									
	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
Component	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	4.490	40.817	40.817	4.490	40.817	40.817	4.133	37.573	37.573
2	2.763	25.114	65.932	2.763	25.114	65.932	3.119	28.359	65.932
3	.730	6.635	72.566						
4	.708	6.437	79.004						
5	.621	5.644	84.647						
6	.458	4.164	88.811						
7	.351	3.192	92.003						
8	.329	2.992	94.995						
9	.257	2.337	97.332						
10	.168	1.526	98.858						
11	.126	1.142	100.000						
Extraction Method: Principal Component Analysis.									

The eigenvalue 2.763, corresponding to the second factor, contributes to 25.114% of the variance in the original data. Hence, the total percentage of the total variance explained by two learning key factors extracted was 65.932% with the loss of around 34 % of the information (Table 3, Fig.2).

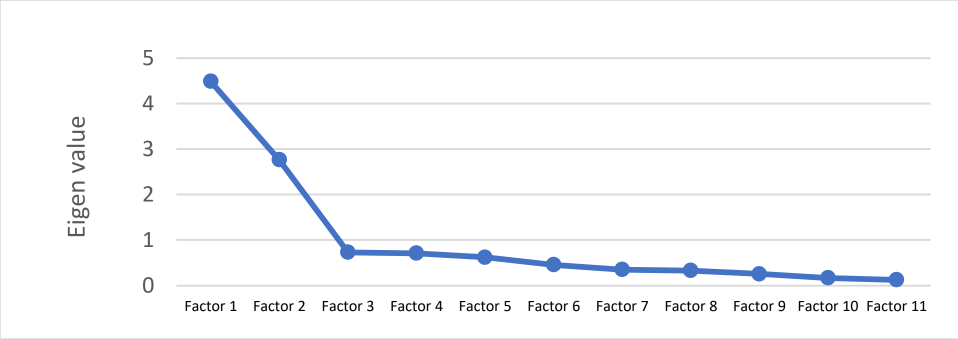

Fig.2. Eigen values of key factors contributing to the results

Rotated Component Matrix

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. Totally Seven items were loaded onto Factor 1 were labelled as "Runnability Index-I". Total of Three items that were loaded onto Factor 2 were labelled as "Runnability Index-II".

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

Rotated Component Matrix[a]		
	Component	
	1	2
stiffness	.844	
friction	.832	
dimesionstability	.818	
graindirection	.764	
moisturecontent	.698	
curlingtendency	.682	
heatresistance	.635	
linting		.873
surfacesmoothness		.847
gloss		.831
surfacestrength		.692
Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization.		

CONCLUSION

It has been resulted that paper surface strength, curling capability, stiffness, moisture content, heat handling capability, grain direction, static electricity, linting and dimensional stability are the major factors that affect the runnability of the paper substrates in dry toner based digital printing process. Results of EFA demonstrated that there are two learning key factors (LKFs) contributing to runnability of substrates in dry toner based digital printing engines derived from the data. The two constructs are Paper Runnability Index-I which include 7 factors i. e. stiffness, friction, dimensional stability, grain direction, moisture content, curling tendency and heat resistance and Paper Runnability Index-II which includes four factors i.e. linting, surface smoothness, gloss and surface strength. These two LKF account for 65.93 % of runnability results to be produced in dry toner-based digital printing presses.

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