Research on the Relationship between Properties of Printing Paper and UV Inkjet Printing Quality

Zhang Jing[1,2], Chen Guangxue[1,]; 1. State Key Laboratory of Pulp and Paper Engineering, South China University of Technology; 2. College of Arts, South China Agricultural University; Guangzhou, China*

Abstract

As an environmental printing method, UV inkjet printing is becoming a hot research topic and has great prospects for development. The purpose of this paper was to integrate theory with practice to analyze the relationship between printing paper and UV inkjet printing quality. This could make press worker determinate rationally printing paper and improve the printing quality. In this paper, kinds of paper surface characteristic (including whiteness, glossiness, roughness, Permeability, absorbent) were measured. Printing tone and color reproduction results of these papers were experimented. Different prints parameters were tested with saturation, hue error, gray scale and coloration efficiency. Data of the paper parameters and prints parameters were calculated separately by Principal Components Analysis (PCA) with software. Then, the equation between paper parameters and paper quality synthetic value was obtained on the basis of the tested data. The equation between prints parameters and prints quality synthetic value was obtained in the same way. Linear regression was used to find the correlation between line combination of print quality synthetic value(y-axis) and paper quality synthetic value(x-axis). Paper printability prediction equation is derived according to the curve. It was shown that the results can provide valuable reference for the evaluation of the quality of printing papers and improving color reproduction, and can be used as one of the basis to guide the production.

Introduction

The performance of the paper is the key element for the print quality, which is a hot issue in recent years. Paper properties such as optical properties, evenness, absorbency, smoothness, etc. may significantly affect the printing process and the printing quality. In the past, the printability of the paper were often discussed separately, Fewer considered the relevance of these properties of paper. Studies have shown that the independent properties of the paper may not fully reflect the merits of the print quality, we should be more concerned with the comprehensive printability of paper.

In this paper, some properties of paper and the corresponding parameters of print quality were tested, and then the measured data were analyzed by the use of mathematical statistical methods and software. A model was established for the performance of paper associated with the print quality parameters. This model can be used to predict the UV inkjet printability of the paper[1].

Experimental Materials and Instruments

Experimental Papers

UV inkjet printer can print color on a variety of materials, so nine different types of paper (1#~9#) were used not just inkjet paper.

Experimental Instruments and Methods

Paper surface characteristic (including whiteness, glossiness, roughness, Permeability, absorbent) were measured by the use of X-Rite 530 Spectrophotometer, NOVO GLOSS TM(Statistical Glossmeter), L & W PPS Tester, L & W Air Permeance Tester, Paper Cobb Absorbency Tester. Digital UV inkjet printer was used for printing output. Different prints parameters were tested with saturation, hue error, gray scale and coloration efficiency by the use of X-Rite 530 Spectrophotometer.

Experimental Results and Analysis

The Equation between Paper Parameters and Paper Quality

Data of the paper parameters including whiteness (X1,%), glossiness (X2,0~100), roughness(X3,μm), permeability (X4,ml/min) and absorbent (X5,g/m^2) were calculated by Principal Components Analysis (PCA) with software SPSS[2,3]. The tested data and result were are shown in table 1,2 and 3.

Table 1: Tested data of the paper parameters

Paper	X_1	X_2	X_3	X_4	X_5
1#	99.75	57.56	3.156	303.5	101.702
2#	89.2	65.64	2.147	0.265	19.968
3#	99.27	5.84	3.698	507.1	50.876
4#	103.01	5.82	5.356	793	62.844
5#	102.32	10.58	3.866	877.9	36.758
6#	100.5	7.68	5.443	711.9	68.064

Table 2: Total Variance Explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	3.771	75.418	75.418	3.771	75.418	75.418
2	1.051	21.028	96.446	1.051	21.028	96.446
3	0.120	2.400	98.845	0.120	2.400	98.845
4	0.054	1.083	99.929	0.054	1.083	99.929
5	0.004	0.071	100.00	0.004	0.071	100.00

©2013; Society for Imaging Science and Technology

Table 3: Component Matrix

	Component				
	1	2	3	4	5
X_1	-0.974	0.011	0.183	0.135	0.022
X_2	0.807	0.575	0.080	0.106	-0.030
ZX_3	0.963	0.146	0.204	-0.095	0.028
ZX_4	0.970	-0.143	-0.155	0.119	0.031
X_5	-0.552	0.824	-0.121	-0.038	0.021

According to the principle, the number of principal components was determined. Two principal components were extracted from the five variables. The specific equations were as below.

$$Prin1=-0.501*X_1+0.415*X_2+0.496*ZX_3+0.499*ZX_4-0.284*X_5 \quad (1)$$

$$Prin2=0.011*X_1+0.561*X_2+0.142*ZX_3-0.139*ZX_4+0.804*X_5 \quad (2)$$

It is obvious that from the above analysis the strengths and weaknesses of the paper could not be identified, so the first and second principal component and composite score needed to be calculated for evaluation. Data standardization and harmonization should be done first, and then according to Table 2 and 3 the equation between paper parameters and paper quality could be achieved as below.

$$M=0.782*Prin1+0.218*Prin2=-0.39*X_1+0.447*X_2+0.419*ZX_3+0.36*ZX_4-0.047*X_5 \quad (3)$$

The equation could help us to calculate the integrated value of the performance of paper, the results were shown in table 4.

Table 4: The integrated value of the performance of paper

Paper	the integrated value
1#	-17.785
2#	-4.7972
3#	-38.352
4#	-40.417
5#	-36.763
6#	-38.854

the Equation between Prints Parameters and Prints Quality

Under the same conditions the tested papers were used for UV inkjet output. In this paper, saturation, hue error(%), gray scale (%)and coloration efficiency(%) were measured from the spot color C,M and Y[4].

The tested data were shown in table 5, 6 and7. Coloration efficiency is the combined effect of hue error and gray scale. The greater hue error and gray scale were, the lower the coloration efficiency was. Comparing the three primary colors ink, we would find that the yellow ink on each paper presented minimal color difference, followed by the magenta ink, the performance of the cyan ink was the worst. This result was due to the surface properties of the paper.

Table 5: Tested prints parameters from primary color C

Paper	Primary color C			
	saturation	hue error	gray scale	coloration efficiency
1#	33.684	39.775	39.925	48.128
2#	33.47	32.475	40.925	49.483
3#	39.633	36.475	33.85	54.086
4#	46.336	36.5	28.775	58.226
5#	46.718	38.05	28.225	58.12
6#	46.152	36.2	28.65	58.436

Table 6: Tested prints parameters from primary color M

Paper	primary color M			
	saturation	hue error	gray scale	coloration efficiency
1#	67.944	48	25.475	56.639
2#	68.596	48.725	23.35	57.976
3#	72.027	41.65	23.225	60.787
4#	71.726	42.575	23.35	60.333
5#	70.657	42.35	24.4	59.592
6#	69.594	40.275	25.075	59.837

Table 7: Tested prints parameters from primary color Y

Paper	primary color Y			
	saturation	hue error	gray scale	coloration efficiency
1#	67.488	9.9	19	76.991
2#	73.609	10.325	15.775	79.877
3#	74.379	7.925	18.05	78.703
4#	74.817	7.75	18.025	78.798
5#	74.391	8.3	18	78.597
6#	71.014	5.625	22.1	75.709

According to Table 5,6 and 7, the equation between prints parameters and prints quality could be achieved as below in the same way mentioned before[5].

$$N_C=0.764*Prin3+0.236*Prin4=0.454*Y_{C1}+0.096*ZY_{C2}+0.447*ZY_{C3}+0.473*Y_{C4} \quad (4)$$

$$N_M=0.749*Prin5+0.251*Prin6=$$

$0.445*Y_{M1}+0.211*ZY_{M2}+0.461*ZY_{M3}+0.41*Y_{M4}$ (5)

N_Y=0.731*Prin7+0.269*Prin8=

$0.463*Y_{Y1}-0.171*ZY_{Y2}+0.388*ZY_{Y3}+0.46*Y_{Y4}$ (6)

The equations could help us to calculate the integrated value of the print quality in the same way, the results were shown in table 8.

Table 8: The integrated value of the print quality

Paper	the integrated value			
	primary color C	primary color M	primary color Y	average
1#	38.079	53.5	66.704	52.761
2#	38.624	54.341	70.873	54.613
3#	43.601	57.022	70.681	57.101
4#	48.604	56.702	70.927	58.744
5#	48.727	55.921	70.639	58.429
6#	48.62	55.548	67.731	57.3

The result of table 8 was specific values, it's easy and intuitive to compare the value of the size. The larger the value was, the better printability the corresponding paper would achieve. In addition, we found that the performance of paper changed for output the three primary colors. For example, paper 6# could get a better color reproduction results for print the primary color C, paper 3# could get a better color reproduction results for print the primary color M, paper 4# could get a better color reproduction results for print the primary color Y.

a Predicted Model For Print Quality

It was mention before that we had achieved the equation between paper parameters and paper quality and the equation between prints parameters and prints quality. Further more, we calculated the integrated value of the performance of paper and the integrated value of the print quality.

Linear regression was used to find the correlation between line combination of the integrated value of the print quality (y-axis) and the integrated value of the performance of paper(x-axis),the result was shown in figure 1[5].

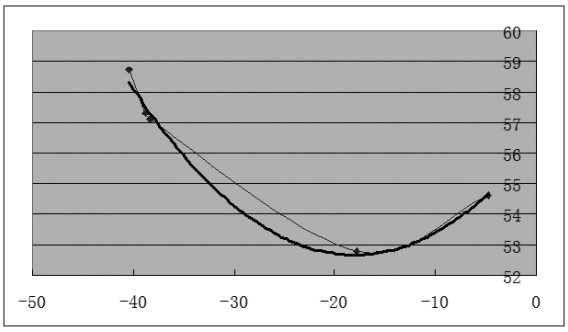

***Figure 1**. fitting curve by use of linear regression*

Paper printability prediction equation was derived according to the curve by the use of EXCEL software.

$N = 0.0113*M^2 + 0.4089*M + 56.353$

$=0.0113*(-0.39*X_1+0.447*X_2+0.419*ZX_3+0.36*ZX_4-0.047*X_5)^2 + 0.4089*(-0.39*X_1+0.447*X_2+0.419*ZX_3+0.36*ZX_4-0.047*X_5) + 56.353$ (7)

To test the accuracy of the model, another three type of paper were measured, the tested data was shown in table 9. The integrated value of the print quality could be predicted by calculating the paper printability prediction equation, the results were shown in table 9 too.

Table 9: Tested data of the paper parameters and the predicted values

Paper	X1	X2	X3	X4	X5	N
7#	98.55	7.46	6.101	824.5	31.292	56.471
8#	98.18	10.94	4.719	457.8	40.576	55.956
9#	76.11	10.02	5.132	747.4	57.482	53.719

It could be determined that paper 7# would have a better performance in color reproduction. This result was consistent with the actual measurement.

In fact, it was more difficult to judge the good or bad of the performance of paper if only by artificially. Because each parameters of paper were higher and lower, it's too subjective to integrate with a great deal of parameter only by the judgement of human, while the use of this method could be a convenient, fast, objective and accurate judgment[6].

Conclusion

Although UV inkjet is still a relatively new technology, it has experienced growth in a number of markets. UV inkjet technology is being adopted by many printers looking to increase their capabilities. UV offers users many benefits, including quick turnaround time and the ability to print directly on a substrate. The purpose of this paper was to integrate theory with practice to analyze the relationship between paper and UV inkjet printing quality. This could make press worker determinate rationally printing paper and improve the printing quality.

Different types of paper have a larger difference in color reproduction. Even if the same ink was used, the same ink thickness was exerted, the color reproduction including color difference, gray scale, coloration efficiency and the color gamut was not the same if it was printed on different types of paper. The surface properties of paper affect the color of the print ultimately[7].

Subjective judgment of color reproduction requires experience and is easy to generate errors. In this paper, a predicted model for print quality was achieved by linear regression. It was shown that the results can provide valuable reference for the evaluation of the quality of printing papers and improving color reproduction, and can be used as one of the basis to guide the print production.

©2013; Society for Imaging Science and Technology

Acknowledgements

*Corresponding author. E-mail: chengx@scut.edu.cn.

References

[1] He Xiaoqun, Multivariate Statistical Analysis (China Renmin University Press, BeiJing, 2008) pg. 152.
[2] Zhu Xingyu, Chen yongqiang, SPSS Multivariate Statistical Analysis Method and its Application (Tsinghua University press, BeiJing, 1999) pg. 251.
[3] Zhang Lijun, Ren Yinghua, Multivariate Statistical Analysis Experiment (China Statistics, BeiJing, 2009) pg. 102.
[4] Li Ying, "Influence of Surface Characteristics of Paper on Printing Color Reproduction," Jour. Packaging Engineering, 31, 25 (2010).
[5] Zhang Lin, Zhang Meiyun, Yang Junping, "Study on the Prediction Model of Paper Printability," Jour.China Printing and Packaging Study, 11, 330 (2010).
[6] Chen Shuanglian, Chen Guangxue, Qu Zhencai, et al., "Study on the Prediction Model of Paper Printability in Ink-jet Printing," Jour. Transactions of China Pulp and Paper, 26, 9 (2011).
[7] Marius Pedersen, Nicolas Bonnier, Jon Y. H., et al., "Attributes of image quality for color prints," Jour. J. of Electronic Imaging, 19, 011016 (2010).

Author Biography

Zhang Jing , PHD candidate from South China University of Technology. Her work has focused on the imaging processing.

CHEN Guangxue, doctor, professor. Now, he works in South China University of Technology, Guangzhou, China. He is a member of Chinese Society for Image Science and Technology (CSIST) . His work focuses on color image process, digital printing technique and so on.