



Research on the Influence of Digital Printing Quality

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November 7, 2019

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Abstract— Paper performance has an important impact on the quality of printed matter. This paper mainly studies the correlation of paper surface performance and digital printing quality in digital printing. The experiment selected two types of five kinds of paper, ordinary printing paper (coated paper, offset paper, white cardboard) and digital printing special paper (digital color exciting paper, highlight digital printing paper). Through the measurement and control of paper surface performance and printing quality. Discussed the correlation effects of whiteness, gloss and smoothness performance on the correlation of $L^*a^*b^*$ color gamut, solid density and relative contrast. The mathematical model relationship between paper performance and digital printing quality is established. The standardization of printing quality provides a basis for discussion.

Keywords—digital printing, surface properties, quality

I. INTRODUCTION

The characteristics of flexible digital printing technology, variable reproduction and on-demand printing has become a new development direction of the printing industry. Paper is the most used substrate in the digital printing process, and its own performance and quality have extremely important impact on the stability of the printing process and the quality of the printed matter. Printing enterprises must not only maximize the cost savings in the printing process, reduce the rejection rate of printed matter, reduce the failure of printing machines, and enhance the market competitiveness of printing enterprises, but also meet the changing personality needs of customers. so ,how to ensure the continuous stability of the quality of digital printing is a very important topic of discussion. starting from the angle of paper performance , focusing on the causal relationship and correlation between paper performance indicators and digital print quality indicators, aiming to establish a mathematical model relationship between paper performance and digital printing quality factors, and providing the support basis for research the standardization of digital printing quality.

II. EXPERIMENT

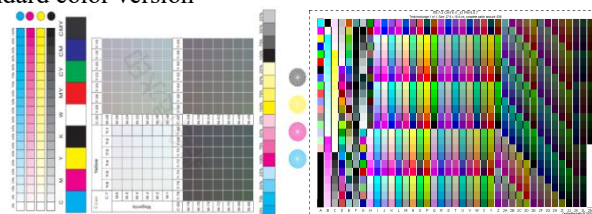
A. Experimental conditions

Hardware equipment: PN-488 whiteness meter, PN-8ST smoothness tester, X-rite exact advanced spectrophotometer, Konica Minolta C1060 digital press, X-Rite i1iO+i1Publish pro2 color measurement kit

Software equipment: Founder Changliu software, ProfileMaker pro software, Matlab software

Experimental sample: ordinary printing paper (157g/m² coated paper, 70g/m² offset paper, 180g/m² white cardboard), Digital printing paper (97g/m² digital color exciting paper , 200g/m² highlight digital printing paper)

Experimental printed manuscript: test version, IT8.7/3 standard color version



a (test version) b (IT8.7/3 standard color version)
Figure 1. Experimental printed manuscript

B. Experimental design

Paper surface performance test: Each sample is cut into nine 100×100mm small samples for measurement, three for whiteness, three for gloss, and three for smoothness. Each sample was measured three times, and the measurement results were expressed as the average of all the measurement results.

Print density and chromaticity detection: use Founder Fluency software to import the test version and IT8.7/3 standard color version drawn in the early stage of the experiment. Each time corresponding to different papers, printed by Ke Mei C1060 electrostatic digital printing machine All proofs, one type of proof each time, three sheets of each type of paper.

Select the solid density color block and the 75% dot density color block on the test version, and measure with the X-rite exact advanced spectrophotometer (measuring the light source condition as D50, 2° viewing angle), and obtain the four-color solid density value and relative contrast. value.

Use the color measurement kit X-Rite i1iO+i1Publish pro2 to measure the chromaticity of 928 patches in the standard color card (measured by the light source D50, 2° viewing angle), and obtain the $L^*a^*b^*$ values of all the color patches. And generate an ICC profile, which is converted into a device's $L^*a^*b^*$ color gamut by Profile Maker pro software.

C. Data measurement

1) Paper performance measurement

TABLE I. Whiteness measurement

Paper	Whiteness			
	one	two	three	average
Coated paper	102.1	101.8	102.0	102.0
Offset paper	95.7	95.1	96.6	95.8
White cardboard	100.8	100.5	100.5	100.6
digital color exciting paper	102.0	101.5	101.7	101.7
highlight digital printing paper	104.8	103.4	103.3	103.8

In the whiteness surface performance, the whiteness values of the five papers are similar, and the whiteness value of the coated paper in the ordinary printing paper is higher than that of the digital color exciting paper in the digital printing paper, but the other two ordinary printings paper whiteness values are lower than digital printing paper. The whiteness values are arranged from large to small: highlight digital printing paper > coated paper > digital color exciting paper > white cardboard > offset paper.

TABLE II. Gloss measurement

Paper	glossiness/85°			
	one	two	three	average
Coated paper	58.4	59.7	58.2	58.77
Offset paper	2.8	3.2	2.6	2.87
White cardboard	5.6	5.4	5.7	5.67
digital color exciting paper	10.8	10.8	10.5	10.7
highlight digital printing paper	63.4	63.9	61.5	62.93

In gloss surface performance, the gloss of the coated paper in ordinary printing paper is higher, but still lower than the gloss of highlight digital printing paper. The gloss of digital color exciting paper is lower, but still higher than the offset paper and white cardboard. The glossiness values are arranged from large to small: highlight digital printing paper > coated paper > digital color exciting paper > white cardboard > offset paper.

TABLE III. Smoothness measurement

Paper	smoothness (s)			
	one	two	three	average
Coated paper	236.5	248.0	245.8	243.4
Offset paper	20.5	18.5	32.8	23.9
White cardboard	28.3	25.3	26.3	26.6
digital color exciting paper	91.5	96.5	104.0	97.3
highlight digital printing paper	293.8	297.5	302.0	297.8

In smooth surface performance, the smoothness of coated paper in ordinary printing paper is higher, but lower than the highlight digital printing paper. The smoothness of digital color exciting paper is lower, but higher than offset paper and white cardboard in ordinary printing paper. The smoothness values are arranged from large to small: high-gloss digital printing paper > coated paper > digital color laser paper > white cardboard > offset paper.

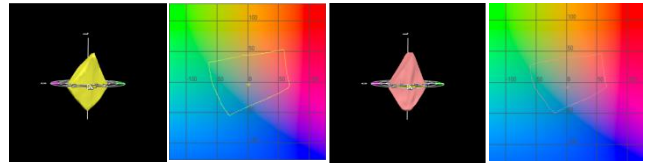
2) Density and chromaticity measurements

TABLE IV. Field density measurements

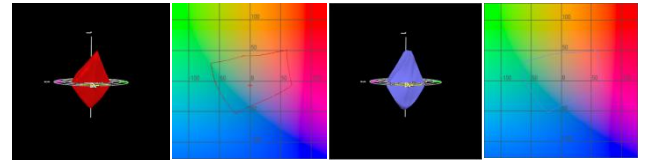
color	C	M	Y	K
Coated paper	1.6536	1.5896	0.9849	1.8436
Offset paper	1.2331	1.2619	0.8349	1.3907
White cardboard	1.3587	1.3801	0.8841	1.5338
digital color exciting paper	1.3740	1.4110	0.8893	1.6187
highlight digital printing paper	1.6775	1.5895	0.9787	1.8193

TABLE V. Calculated relative contrast measurement

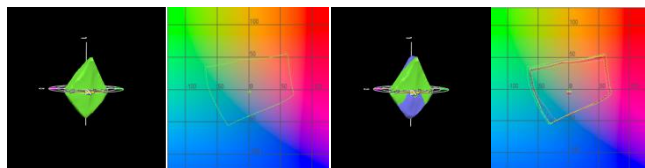
color	C	M	Y	K
Coated paper	33.8%	35.3%	29.3%	34.8%
Offset paper	22.5%	27.3%	23.6%	25.3%
White cardboard	27.7%	32.1%	23.4%	30.1%
digital color exciting paper	28.7%	33.6%	28.7%	32.4%
highlight digital printing paper	35.6%	36.3%	30.7%	39.2%



(a) Coated paper three / two-dimensional color gamut map
(b) Offset paper three / two-dimensional color gamut map



(c) White cardboard three/two-dimensional color gamut map
(d) Digital color exciting three/two-dimensional color gamut map



(e) Highlight digital printing three / two-dimensional color gamut map
(f) Five types of paper three / two-dimensional contrast color gamut map

Figure 2. Comparison of L*a*b* color gamut between digital printing paper and ordinary printing paper

D. Correlation between paper properties and print quality parameters

1) Study on the relationship between surface properties and solid density

The whiteness, glossiness, and smoothness of the five types of sample sheets were taken as the independent variables x_1 , x_2 , and x_3 , respectively, and the measured field density of the black ink is taken as dependent variable DK for correlation analysis.

The calculated correlation coefficient r is shown in the

following table:

TABLE VI. Calculated values of correlation coefficient of field density of whiteness, gloss, smoothness and black ink

Correlation coefficient(r)	x ₁	x ₂	x ₃
D _K	0.89681	0.93497	0.94130

Since r is greater than 0 and less than 1, the whiteness, gloss, and smoothness of the paper are all positively correlated with the solid density of the black ink.

After demonstrating the correlation between the whiteness, gloss and smoothness of the paper and the field density of the black ink, the whiteness value, the gloss value and the smoothness value of the five types of sample paper were respectively used as independent variables to measure the field density of the black ink. Density was used as the dependent variable, and the data was fitted using Matlab software. The fitted image is shown in Figure 3. The fitting equation is as follows.

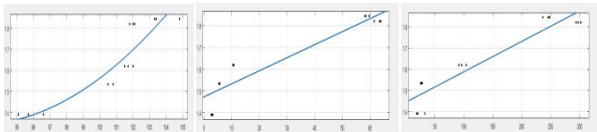


Figure 3. Whiteness / Glossiness / Smoothness - Black ink field density fit image

$$D_K = 0.005815x_1^2 - 1.0995x_1 + 53.35161 \quad (1)$$

$$D_K = 0.005897x_2 + 1.473 \quad (2)$$

$$D_K = 0.00143x_3 + 1.444 \quad (3)$$

In the same method, the green, magenta and yellow inks were analyzed according to the above steps, and the images were fitted to the models Figure 4 Figure 5 and Figure 6 , and the fitting equations are as follows.

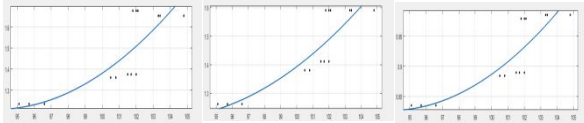


Figure 4. Whiteness-Cyan/Magenta/Yellow ink field density fit image

$$D_C = 0.00445x_1^2 - 0.8346x_1 + 40.34 \quad (4)$$

$$D_M = 0.002504x_1^2 - 0.4582x_1 + 22.17 \quad (5)$$

$$D_Y = 0.001565x_1^2 - 0.2936x_1 + 14.6 \quad (6)$$

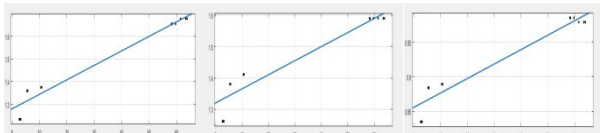


Figure 5. Gloss-Cyan/Magenta/Yellow ink field density fit image

$$D_C = 0.006389x_2 + 1.279 \quad (7)$$

$$D_M = 0.004481x_2 + 1.32 \quad (8)$$

$$D_Y = 0.002089x_2 + 0.8555 \quad (9)$$

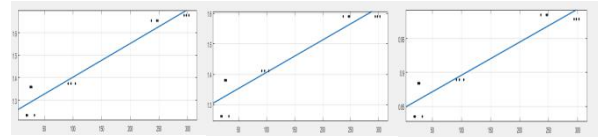


Figure 6. Smoothness -Cyan/Magenta/Yellow ink field density fit image

$$D_C = 0.001502x_3 + 1.252 \quad (10)$$

$$D_M = 0.001063x_3 + 1.3 \quad (11)$$

$$D_Y = 0.0004885x_3 + 0.8471 \quad (12)$$

2) Study on the relationship between surface properties and relative contrast

TABLE VII. Calculated values of whiteness, gloss, smoothness, and black ink relative contrast correlation coefficient

Correlation coefficient(r)	x ₁	x ₂	x ₃
K _K	0.94757	0.84023	0.82699

The same method, according to the above steps to analyze, whiteness, gloss, smoothness and contrast images of cyan, magenta, yellow, black ink relative contrast are shown in Figures 7.8.9, the equation is calculated as follows Shown.

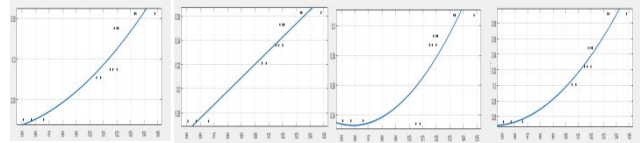


Figure 7. Whiteness-Cyan/Magenta/Yellow/Black ink relative contrast fit image

$$K_C = 0.001031x_1^2 - 0.1896x_1 + 8.931 \quad (13)$$

$$K_M = 0.01121x_1 - 0.8007 \quad (14)$$

$$K_Y = 0.001209x_1^2 - 0.2317x_1 + 11.34 \quad (15)$$

$$K_K = 0.001501x_1^2 - 0.2828x_1 + 13.58 \quad (16)$$

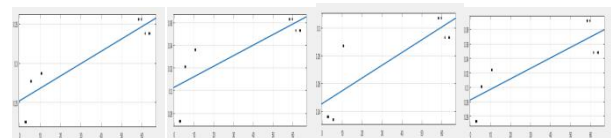


Figure 8. Glossiness -Cyan/Magenta/Yellow/Black ink relative contrast fit image

$$K_C = 0.001576x_2 + 0.2522 \quad (17)$$

$$K_M = 0.0009299x_2 + 0.303 \quad (18)$$

$$K_Y = 0.0009184x_2 + 0.2455 \quad (19)$$

$$K_K = 0.001452x_2 + 0.2827 \quad (20)$$

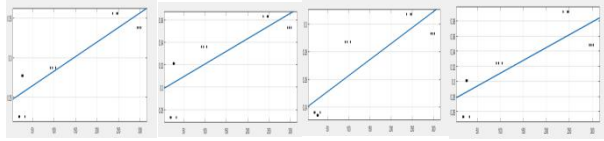


Figure 9. Smoothness -Cyan/Magenta/Yellow/Black ink relative contrast fit image

$$K_C=0.0003701x_3+0.2456 \quad (21)$$

$$K_M=0.0002259x_3+0.2981 \quad (22)$$

$$K_Y=0.0002315x_3+0.2395 \quad (23)$$

$$K_K=0.0003395x_3+0.2768 \quad (24)$$

E. Conclusion

1) Relationship between paper properties and print density

a) According to the correlation analysis, there is a positive correlation between whiteness, gloss and smoothness and solid density. It is calculated from the correlation: correlation between solid density and smoothness > correlation of gloss > correlation of whiteness. According to the regression analysis, the whiteness is non-linearly related to the filed density of each ink color, and the glossiness and smoothness are linearly related to the filed density of each ink color. According to the obtained regression equation, the degree of correlation between each ink color and whiteness is obtained. For: black ink > cyan ink > magenta ink > yellow ink, the degree of correlation with gloss and smoothness are: cyan ink > black ink > magenta ink > yellow ink.

b) According to the correlation analysis, there is a positive correlation between whiteness, gloss and smoothness and relative contrast, which is calculated by correlation: correlation between relative contrast and whiteness > correlation of gloss > correlation of smoothness. According to the regression analysis, the relative contrast between whiteness and ink is linearly correlated. The relative contrast between whiteness and other inks is quadratic nonlinear correlation. The relative contrast between gloss and smoothness and each ink color is linearly correlated; According to the obtained regression equation, the degree of correlation between each ink color and whiteness is: black ink > yellow ink > cyan ink > magenta ink,

the degree of correlation with gloss is: cyan ink > black ink > magenta ink > yellow, the degree of correlation between ink and smoothness is: cyan ink > black ink > yellow ink > magenta ink.

2) Relationship between paper performance and print color

As can be seen from the L*a*b* gamut plots plotted on the measurement data, all types of paper have relatively similar gamut shapes but different gamut volumes. Offset paper has the smallest color gamut and the lowest whiteness, gloss and smoothness in all papers; high gloss digital printing paper has the highest color gamut and the highest whiteness, gloss and smoothness in all papers; Overall, the gamut difference between the yellow space and the green space is more obvious, and there is no significant difference in all the papers in the blue space gamut. It can be seen that in the range of color expression (i.e. the color gamut space size), highlight digital printing paper > coated paper > digital color exciting paper > white cardboard > offset paper.

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