The influence of trapping percentage to color reappearance

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Abstract:
The variation of ink trapping percentage is one of the primary factors which influence the reappearance of printing color. Making use of the experimental methods, this paper analyzes quantitatively the relationship between trapping percentage of the intermediate color and color difference. It puts forward the fluctuant tolerance of the trapping percentage in 4-*colour process printing and the mostly influencing factors of the trapping percentage. The conclusions can be used to guide the printing process control.*

Key words: *Trapping percentage*; *Color reappearance*; *Color gamut*; *Color difference*;

1 Introduction

Through the prepress stage, a color image is splitted into four-color halftone dots of yellow, magenta, green and black. In the press stage, the four-color halftone dots are overprinted one by one to reproduce the synthesis of color image. Because the area and location of the four-color dots are not same, there will be two possibly relative positions of the four-color dots after they are overprinted. One is juxtaposed; the other is that some or all of the dots are superposed. Because the trapping of yellow, magenta, green and black is followed by mixed principles of subtractive process to produce new color, 16 colors of white, yellow, magenta, green, red, green, blue and different types of black will be created in the four-color overlay region, and then multifarious colors are produced from some of the 16 kinds of juxtaposed colors by mixed principles of additive process[1]. Therefore, the effect of 4-colour process printing is not only involved in primary color, dots area, but also involved in the result of trapping.

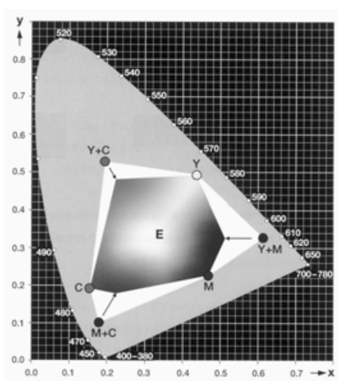

Fig.1 *Gamut of bad trapping*

The effect of trapping is evaluated through compared a reference that ink is printed on paper directly with the characteristics performance of ink trapped on another kind of ink that has been printed on the paper. If the trapping ink is evenly distributed and the coordinate value of trapping color in color space is in proper location, the effect of the trapping is said well. If the effect of the trapping is bad, the trapping color of Y+C，M+C，Y+M is usually more shallow than the ideal trapping color, the hue of trapping color bias to the first primary colors, the reproduced color is difficult to achieve gray balance, and the reappeared Gamut is reduced. As shown in figure 1, the saturation of the trapping color Y + C, M + C, Y + M is inadequate, Gamut contracts. It inevitably lead to some higher saturation color irreproducible.

The effect of trapping is usually scaled by trapping rate. At present, almost all of the common printing controller strip and the density meter have the function of trapping rate detection. Among various methods to evaluate trapping effect, Preucil formula is the most commonly used[2]. The trapping rate of Preucil formula method is the ratio of the density of the post-printed color which transferred to the first-printed color and the density of post-printed color which printed on the paper directly[4], As shown in figure 2.

If $f_{D(2/1)}$ is the trapping rate of the second color on the first

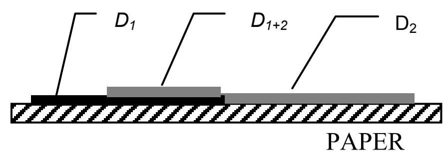

Fig.2 the density of different color field

color； $D_{(1+2)}$ is the total density that the second color ink traps on the first color ink measured by the complementary filter of the second color . D_1 is the density of the first color that is printed in the paper and measured by the complementary filter of the second color. D_2 is the mainly density of the second color that is printed in the paper. The relationship between them can be expressed by the following formula:

$$f_{D(2/1)} = \frac{D_{(1+2)} - D_1}{D_2} \times 100\% \qquad (1)$$

According to the additive principle of density, $D_{(1+2)} - D_1$ is the trapping color density minus the first color density. That is equal to the main density ($D_{2,1}$) of the second color that traps on the first color. The ratio of $D_{2,1}$ and D_2 reflects the comparison of the second color trapping on the first color and the second color printing on the paper directly.

People know that intermediate color red, green and blue have an important impact on the color reproduction. In addition of the primary color yellow, magenta, cyan density, intermediate color red, green and blue mainly depend on the scale of trapping rate. With the change of the ambient temperature, the fluctuation of fountain solution, the accumulation of paper powder on the blanket and other many factors, even the density of primary color solid area maintain unchanged, there could be changes of trapping rate in printing process to affect the intermediate color reproduction, and then affect the correct color reproduction. So controlling trapping rate is important. However, the precise date of trapping rate in the printing process has not been reported yet. This paper studies how much does the change of trapping rate affect the reproduction of the intermediate color, and gets tolerance limit of trapping rate in printing process. This will be a certain guiding significance to ensure color reproduction steadily.

2 The chromatic evaluation method for the effect of trapping

Because the effect of trapping affects color reproduction of print, color difference can be considered to evaluate the effect of trapping. But in this method, the first of all need a standard trapping color. Because the trapping color is affected by trapping rate, paper, ink, printing technology, and many other factors, in industrial production, it's usually difficult to give a standard value of trapping color. Therefore, this method is only applicable to standard printing conditions. The general production in China is not really practical.

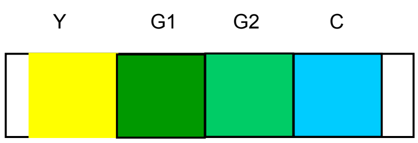

Fig.3 *trapping proof*

In this experiment, using IGT AIC2-5 Printability Tester, a test proof shown in figure 3 can be got in a trapping test. In order to evaluate trapping effect of the intermediate color G1and G2 by color difference, the following steps must be adopted. First, measure the spectral reflectance of the two primary colors Y and C , then calculate the chromaticity of the ideal trapping color G in the condition of the ideal trapping which means the second color ink traps on the first color ink is as same as it prints on the paper directly, and treat the ideal trapping color as standard trapping color. Second, measure the chromaticity of the actual trapping color G1, G2, got color difference by compared the actual trapping color with the ideal trapping color. Third, measure the trapping rate of the actual trapping color G1, G2, and then analyze the relationship between the trapping rate and the chromatism, study the change of trapping rate how to affect color reproduction, as well as an acceptable fluctuant range of the trapping rate.

The formula to calculate the chroma value of the ideal trapping color is as follows:

$$\begin{aligned} X_{10} &= K\sum_{\lambda}\frac{\rho_1(\lambda)\rho_2(\lambda)}{\rho_w(\lambda)}S(\lambda)\bar{x}_{10}(\lambda)\Delta\lambda \\ Y_{10} &= K\sum_{\lambda}\frac{\rho_1(\lambda)\rho_2(\lambda)}{\rho_w(\lambda)}S(\lambda)\bar{y}_{10}(\lambda)\Delta\lambda \\ Z_{10} &= K\sum_{\lambda}\frac{\rho_1(\lambda)\rho_2(\lambda)}{\rho_w(\lambda)}S(\lambda)\bar{z}_{10}(\lambda)\Delta\lambda \end{aligned} \tag{2}$$

In this formula, K is an adjustable factor, its value is:

$$K = \frac{100}{\Sigma S(\lambda)\bar{y}_{10}(\lambda)\Delta\lambda} \tag{3}$$

$S(\lambda)$ is the relative spectral power distribution of light source. Because D_{65} standard lighting is used in this experiment, $S(\lambda)$ is the relative spectral power distribution of D_{65} light.

$\rho_1(\lambda)$ is the spectral reflectance of the first color ; $\rho_2(\lambda)$ is the spectral reflectance of the second color ; $\rho_w(\lambda)$ is the spectral reflectance of the white paper.

$\bar{x}_{10}(\lambda)$ 、 $\bar{y}_{10}(\lambda)$ 、 $\bar{z}_{10}(\lambda)$ are CIE 1964 supplementary standard colorimetric observer. Tristimulus values that are calculated through the formula (2) can be turned into CIE1976 L^* a^* b^* by formula (4).

$$\begin{aligned} L^* &= 116(Y_{10}/Y_0)^{1/3} - 16 \\ a^* &= 500\left[(X_{10}/X_0)^{1/3} - (Y/Y_0)^{1/3}\right] \\ b^* &= 200\left[(Y_{10}/Y_0)^{1/3} - (Z_{10}/Z_0)^{1/3}\right] \end{aligned} \tag{4}$$

X_{10} 、 Y_{10} 、 Z_{10} are tristimulus values of the sample color; X_0 、 Y_0 、 Z_0 are tristimulus values when a completely diffusely reflected surface is exposed under CIE standard illuminant and then diffusely reflects to the eyes of observers.

Compared L^* a^* b^* of the ideal trapping color with L_a^* a_a^* b_a^* that is measured from experimental proof ,CIE 1976 L^* a^* b^* color difference can be calculated through the formula (5).

$$\Delta E_a = \sqrt{(L_a^* - L^*)^2 + (a_a^* - a^*)^2 + (b_a^* - b^*)^2} \tag{5}$$

Trapping effect that is described by the color difference can directly reflect the difference between actual trapping color and the ideal trapping color. Compared color difference with trapping rate, we can analyze the relationship between them.

However, as the light absorption and reflection of ink is not entirely consistent with the theoretical calculation, especially, the tristimulus values of the ideal trapping color is calculated as we think the post-printed ink is completely transparent. But actually, even under ideal trapping, the real tristimulus values of the actual trapping color are different from the ideal values that are calculated. In addition, when we do the trapping experiment many times, we can't maintain the primary colors exactly same in different proof, so the calculated tristimulus values of the ideal trapping color aren't same in different test proof. Therefore, such an analysis about the relationship between color difference and trapping rate has a relative significance.

3 experiment

3.1 *Experimental Material*

157g/m^2 coated paper；Tianshi ink made in Tianjin Toyo Ink Co. Ltd: TGS-429 Offset gloss sky blue, TGS-238 Offset gloss middle yellow, TGS-128 Offset gloss peachblow.

3.2 *Experimental equipment*

AIC2-5 Printability Tester; X-rite 938 Spectrophotometer

3.3 *Experimental methods*

(1)Control quantity by pipette, distribute the yellow, magenta, cyan ink by inking unit and then transfer to the rubber disc. The solid density of yellow, magenta, cyan color is as far as possible in accordance with national standards, and as far as possible to maintain stability in the course of experiments.

(2)Do trapping experiment by AIC2-5 Printability Tester and get experimental proof like Figure 3. The trapping rate can be adjusted by changing trapping interval time or adding a little ink compound in ink.

(3)Measure the density of the primary color and the trapping color by the density measurement function of the 938 - spectrophotometer, and then calculate the trapping rate.

(4)Measure the spectral reflectance of the white paper, two primary color with the spectral measurement function of the 938 – spectrophotometer(using D65 CIE standard illuminant and 10° field of vision)and then calculate L^* a^* b^* of the ideal trapping color according to the formula (2) (3) (4).

(5)Measure L_a^* a_a^* b_a^* of the trapping color of experimental proof with the 938 – spectrophotometer and then calculate color difference ΔE_a between ideal trapping color and actual trapping color according to the formula (5).

4 Results and Discussion

4.1 Yellow trapping on cyan

A test proof which has same primary color density but two different intermediate color (as G1,G2 shown in Fig.3)can be got by changing trapping intervals. But in different experimental proof, it is impossible to get completely consistent primary color density. Therefore, different experimental proof has different ideal trapping color values after measurement and calculation. The experimental results are shown in Table 1:

Table 1: trapping rate and color difference of yellow traps cyan

Proof number	Ideal trapping color			Left trapping field		Right trapping field	
	L^*	a^*	b^*	color difference	trapping rate	Color difference	Trapping rate
1	44.21	-52.00	29.76	14.51	0.736	5.16	0.989
2	43.72	-56.50	27.10	9.90	0.809	4.13	1.034
3	42.47	-58.96	26.94	13.62	0.689	12.54	0.733
4	43.79	-53.53	27.19	14.57	0.663	5.25	0.913
5	45.22	-56.39	25.14	24.07	0.448	2.33	0.966
6	42.00	-56.80	19.37	44.29	0.177	35.63	0.306
7	46.07	-56.45	28.70	19.63	0.551	8.92	0.820

Setting trapping rate to be x-axis and color difference to be y-axis, the dates of trapping rate and color difference of various trapping field can be depicted on the coordinates map，as shown in Fig.4. It can be seen from the scattered location that there are approximate linear relationship between the trapping rate and color difference. Using MATLAB software, according to least squares fitting the relationship between the trapping rate and the

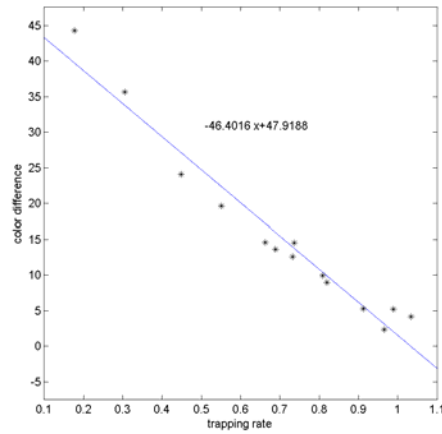

Fig.4 the relationship between trapping rate and color difference of yellow traps cyan

color difference, we can get formula (6):

$$y = -46.4016x + 47.9188 \tag{6}$$

Generally, the tolerance of color difference of the intermediate color should be within the sum tolerance of color difference of the two colors which participate in trapping [4]. According to the Chinese National Standards GB / T 17934.2-1999 [5], the tolerance of color difference of solid during printing process is: cyan-2.5, magenta-4, yellow-3. So, the tolerance of green which is trapped by yellow and cyan should be controlled within 5.5. The fluctuant tolerance of trapping rate of green which can be calculated by formula (7) is 12%.

$$\Delta x = \frac{\Delta y}{-46.4016} \tag{7}$$

In actual production, due to the ink rheological reasons, the general sequence arrangements of four-color printing are black, cyan, magenta and yellow. The trapping effect on black has relative subordinate. The trapping effect which has a significant impact on color reproduction is yellow trapping on cyan, yellow trapping on magenta, magenta trapping on cyan.

4.2 yellow trapping on magenta

Values of trapping rate and color difference of yellow trapping on magenta can be got by similar methods like above. As shown in Table (2):

Table 2: trapping rate and color difference of Yellow traps cyan

Proof number	Ideal trapping color			Left trapping field		Right trapping field	
	L^*	a^*	b^*	color difference	trapping rate	color difference	trapping rate
1	41.52	53.40	46.41	19.65	0.626	5.47	0.934
2	41.71	54.50	44.80	20.28	0.697	12.41	0.787
3	41.57	53.57	46.67	22.65	0.548	4.62	0.914

4	43.72	53.53	50.81	37.64	0.292	20.28	0.625
5	41.70	54.75	47.84	27.38	0.533	11.72	0.889

According to least squares fitting the relationship between the trapping rate and the color difference, as shown in Fig.5, we can get formula (8) when we Set trapping rate to be x-axis and color difference to be y-axis:

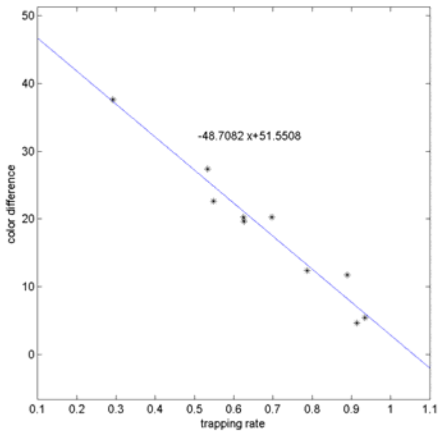

Fig.5 the relationship between trapping rate and color difference of yellow traps magenta

$$y = -48.7082x + 51.5508 \quad (8)$$

According to the Chinese National Standards GB / T 17934.2-1999, the tolerance of color difference of magenta solid during printing process is 4, and yellow is 3. So, the tolerance of red which is trapped by yellow and magenta should be controlled within 7. The fluctuant tolerance of trapping rate of red which can be calculated is 14%.

4.3 magenta trapping on cyan

Values of trapping rate and color difference of magenta trapping on cyan can be got by similar methods like above. As shown in Table (3):

Table 3: trapping rate and color difference of magenta traps cyan

Proof number	Ideal trapping color			Left trapping field		Right trapping field	
	L^*	a^*	b^*	color difference	trapping rate	color difference	trapping rate
1	19.27	31.34	-56.03	28.77	0.357	12.52	0.670
2	21.97	32.24	-54.53	16.01	0.602	4.20	1.009
3	21.18	32.25	-52.58	15.14	0.638	5.10	0.871
4	18.71	32.97	-53.42	23.41	0.471	4.18	0.941
5	17.79	32.23	-51.84	23.33	0.500	5.65	0.881

According to least squares fitting the relationship between the trapping rate and the color difference, as shown in Fig.6, we can get formula (9) when we Set trapping rate to be x-axis and color difference to be y-axis:

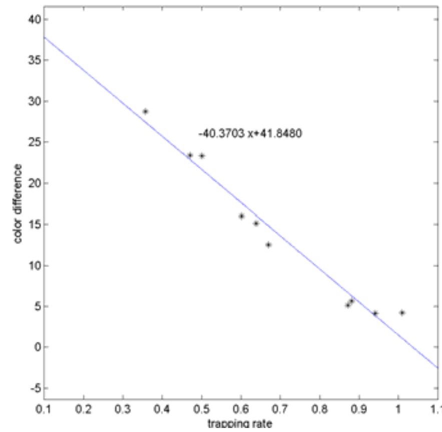

Fig.6 the relationship between trapping rate and color difference of magenta traps cyan

$$y = -40.3703x + 41.8480 \quad (9)$$

According to the Chinese National Standards GB / T 17934.2-1999, the tolerance of color difference of magenta solid during printing process is 4, and cyan is 3. So, the tolerance of red which is trapped by yellow and magenta should be controlled within 6.5. The fluctuant tolerance of trapping rate of blue which can be calculated is 16%.

5 Conclusions

During 4-colour process printing, even maintaining the density of primary color stable, due to the changes of other technical conditions of production, there could be trapping rate fluctuation which results in the changes of intermediate color, further, affects color gamut and color reproduction. This paper analyzes the relationship between trapping rate and color difference, gets the fluctuant tolerance of the trapping rate. In order to ensure the correct reproduction of the intermediate color In the course of printing, we need detect trapping rate and adjust printing process parameters in time to remain trapping rate stable. During printing process, the main adjustable parameters which affect the trapping rate are:

(1)The tack contrast between the first-printed ink and post-printed ink: increasing the tack of the first-printed ink, reducing the tack of the post-printed ink will raise trapping rate;

(2)The drying speed of the first-printed ink: quickening the first -printed ink will enhance trapping rate;

(3)The interval time between the first-printed ink and the post-printed ink: longer interval time will have higher trapping rate.

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