

# Research and Analysis on the Standardization of Gray Balance Data Based on Digital Printing

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## Abstract

*With the rapid popularization of the technology application about digital printing, the requirement of quality for digital pressworks becomes higher and higher. Thus, Gray balance plays an important role in getting better quality of pressworks. According to the method of theory and experiment combination, this article uses the gray balance equations and gets the control curves by the regression analysis, which provide the foundation for the gray balance control about digital printing. So the aim is that we can obtain the better quality of digital printing products.*

## 1. Summary

Digital printing applies gradually and abroad because it has several virtues that can attain the shorter printing cycle, realize 100% alterable info printing, fulfill individuation demand and carry out long-distance printing. The newest report (Chinese printing market .The next important chance of digital printing and workflow) of Info Trends company shows that digital printing technology applies rapidly. In terms of the estimate of retail sales of presswork, it's predicted that sale can increase to 5 billion\$ and annual growth rate is up to 66% by estimate.

With the rapid popularization of digital printing technology application, the requirement of quality for digital presswork becomes higher and higher. Gray balance plays an important role in getting better quality of presswork and is one of the necessary conditions of color reproduction. So if there is a lack of right gray balance, it will result in tone offset of the whole image.

This thesis refers to the method that traditional printing technology controls presswork quality and study the basic technology parameters that appraise the quality about digital printing .Under the digital printing condition, making use of the gray balance equations ,the control rule of gray balance is gained by linking regression method .Finally, the precision of regression polynomial and curves-fitting result are evaluated by the determination coefficients ( $R^2$ ).The curves of gray balance provide reliable evidence for the quality of digital printing.

## 2.Theory analysis

### 2.1 Technology principle of digital printing

There is two definitions about digital printing .One is non-impact printing(NIP) that there is no pressure during printing, so we can also call it non- plate printing. The other is NIP besides direct imaging printing. However the latter will not be considered in this paper.

This thesis mainly uses the equipment of Epson printer, so introduce to the micro piezoelectric technology as follows: the single nozzle among the printheads consists of the ink cavity

storing ink, ink-jet jaws, flexible components and multilayer piezoelectricity crystal. Fig 2-1 illustrates ink-jet printing work principle. The digital symbols about printing dictation are added to the multilayer piezoelectricity crystal, produce the electrode compress, bump the flexible components, then extrude ink in the cavity and spurt the ink drops from the ink-jet jaws. In the end, ink drops drip on the paper and form information.

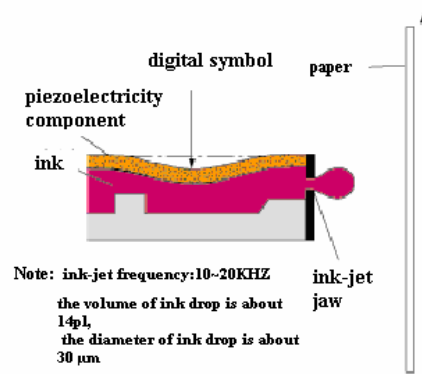


Fig2-1. Ink-jet printing work principle

### 2.2 Quality estimate of digital printing

There are many commonness between digital printing and offset print. They both use cyan(C), magenta(M), yellow(Y) color as primary colors and half-tone reproduction technology. Therefore, based on aforementioned reason, quality control of digital presswork can refer to traditional printing's. So, there are several important parameters as follows: reflective density, printing contrast, dot gains and trapping percentage. However, their core is gray balance.

#### 2.2.1 Gray balance

As we all know, the total density that process color inks trap is the sum of each primary ink density. When Y, M, C ink traps, they form neutral gray balance. That's to say, trapping density is the corresponding density of neutral wedge. Therefore, the gray balance equations can be described as follows:

$$\begin{cases} D_{eR} = f_{Ce}D_{CR} + f_{Me}D_{MR} + f_{Ye}D_{YR} \\ D_{eG} = f_{Ce}D_{CG} + f_{Me}D_{MG} + f_{Ye}D_{YG} \\ D_{eB} = f_{Ce}D_{CB} + f_{Me}D_{MB} + f_{Ye}D_{YB} \end{cases}$$

Where  $f_{Ce}$ ,  $f_{Me}$ ,  $f_{Ye}$  represent the ratio of C, M, Y ink respectively,  $D_{CR}$ ,  $D_{MR}$ ,  $D_{YR}$ ,  $D_{eR}$  represent C, M, Y ink and neutral density under red(R) filter respectively,  $D_{CG}$ ,  $D_{MG}$ ,  $D_{YG}$ ,  $D_{eG}$  respectively represent C, M, Y ink and neutral density under green (G)filter,  $D_{CB}$ ,  $D_{MB}$ ,  $D_{YB}$ ,  $D_{eB}$  respectively represent C, M, Y ink and neutral density under blue

(B)filter.

Next, the gray balance equations can be expressed as matrix and converted it into inverse matrix as follows:

$$\begin{bmatrix} f_{Ce} \\ f_{Me} \\ f_{Ye} \end{bmatrix}_i = \begin{bmatrix} D_{CR} & D_{MR} & D_{BR} \\ D_{CG} & D_{MG} & D_{BG} \\ D_{CB} & D_{MB} & D_{BB} \end{bmatrix}_i^{-1} * \begin{bmatrix} D_e \\ D_e \\ D_e \end{bmatrix}_i \quad (2.1)$$

Where  $f_{Ce}$ 、 $f_{Me}$ 、 $f_{Ye}$  represents the needed,  $D_{CR}$ 、 $D_{MR}$ 、 $D_{BR}$ ... $D_{YB}$  is called coefficient matrix,  $D_e$  represents neutral density. Ideally,  $D_{eR}=D_{eG}=D_{eB}=D_e$ ,  $i=1, 2, \dots, 30$ .

Then, the calculation equations of neutral density are described as follows:

$$\begin{cases} (D_{Ce})_i = (f_{Ce})_i (D_{CR})_i \\ (D_{Me})_i = (f_{Me})_i (D_{MG})_i \\ (D_{Ye})_i = (f_{Ye})_i (D_{YB})_i \end{cases} \quad (2.2)$$

### 2.2.2 Equivalent neutral density(END)

The visual density is combined with the monochromatic density, dot-area coverage and END to draw the color balance END relation curves between the monochromatic density and dot-area coverage. Relative gray balance data can be found by the curves.

Eq. (2.3) describes the relationship between Y, M,C dot area coverage and solid density as follows:

$$\begin{cases} a_{Ce} = [1 - 10^{-D_{Cs}/n}] / [1 - 10^{-D_{Cs}/n}] \\ a_{Me} = [1 - 10^{-D_{Ms}/n}] / [1 - 10^{-D_{Ms}/n}] \\ a_{Ye} = [1 - 10^{-D_{Ys}/n}] / [1 - 10^{-D_{Ys}/n}] \end{cases} \quad (2.3)$$

Where,  $a_{Ce}$ 、 $a_{Me}$ 、 $a_{Ye}$  represents the corresponding C,M,Y dot area coverage when forming END respectively,  $D_{Cs}$ 、 $D_{Ms}$ 、 $D_{Ys}$  represents solid density of C,M,Y ink respectively,  $n$  represents the corrected coefficient.

## 3. Experiment

### 3.1 Experiment equipment and material

Experiment Apparatus: Epson stylus pro7600, Gretag-Macbeth Spectro Scan, X-rite528.

Experiment Material: UltraChrome™ Ink From Epson Company, Glazed Printing Paper From Lucky Group (260gsm).

Experiment Software: Best color Screen proof 4up, Gretag-Macbeth ICC Profile Bundle Pro, Best Profile Keeper.

### 3.2 Test pictures of the experiment

Fig 3-1 is the 30 wedges of C、M、Y、BK that is used as the tool of linear calibration of color management system. The presumed dot area coverage of digital original are respectively as follows:

100%,95%,90%,85%,80%,75%,70%,65%,61%,56%,52%,48%,44%,40%,36%,32%,28%,24%,20%,17%,15%,12%,10%,8%,6%,4%,3%,2%,1%,0%.The ink density and dot area coverage of each gradient can be achieved from fig 3-1.In addition, gray balance

that the process color trapping forms can be used to evaluate the effect of gray balance.



Fig3-1. The gradient of C、M、Y、BK

Quantity of color that main purpose is to control the proper ink quantity of output is the incidental picture in Best Screenproof software. There is a four-color and 12 gradient (5%~100%) and ink quality controlling in the above picture.

This experiment uses the color target of Icc profile IT8.7/3, which includes 928 blocks.

### 3.3 Experiments and Aim

Firstly, printer must be calibrated linearly in order to define the quantity of inks. Secondly, after making sure the quantity of inks from each channel of printer, it will achieve the optimal output effect. Then, before the output ICC profile of the equipment is made, color management system is off. Then, the ICC file is imported into the color flow. When exchanging the types of paper every time, the printer must be calibrated linearly in order to make sure a reasonable linear profile. Last but not least, the printer prints the gradient of C、M、Y、BK with band thirty that uses as linear calibration and gains the better output effect of gray balance by the gray balance test bar. At the same time, all the parameters are measured. In terms of the above-mentioned, the output sample represents the current optimal output effect of the printer. So the measure data are more credible.

## 4. Result and analysis

### 4.1 Experiment result

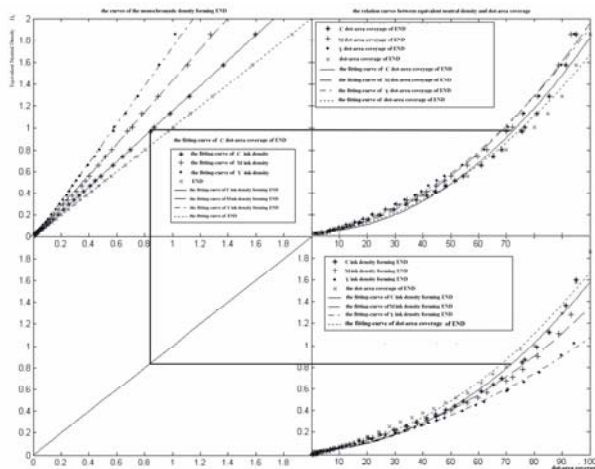
The measured density value of the 30 wedges of C,M,Y ink under R,G,B filter and the density of the 30 wedges of gray blocks are listed in tab 4-1.

Tab4-1 The density of the gradient

Presumed dot area coverage	C,M,Y ink density under R,G,B filter and gray blocks density									
	$D_{Rr}$	$D_{Gg}$	$D_{Bb}$	$D_{Rr}$	$D_{Gg}$	$D_{Bb}$	$D_{Rr}$	$D_{Gg}$	$D_{Bb}$	$D_e$
0	0.000	0.000	0.001	0.004	0.003	0.003	0.000	0.000	0.001	0.000
1	0.008	0.003	0.001	0.004	0.009	0.005	0.001	0.001	0.008	0.003
2	0.013	0.003	0.001	0.002	0.013	0.004	0.002	0.002	0.015	0.009
3	0.023	0.007	0.004	0.004	0.023	0.009	0.001	0.002	0.023	0.015
4	0.027	0.014	0.014	0.005	0.035	0.013	0.003	0.004	0.037	0.028
6	0.038	0.017	0.014	0.007	0.048	0.018	0.002	0.003	0.046	0.039
8	0.057	0.013	0.003	0.011	0.064	0.025	0.003	0.005	0.062	0.053
10	0.078	0.019	0.005	0.012	0.078	0.029	0.005	0.007	0.075	0.066
12	0.100	0.024	0.007	0.015	0.098	0.035	0.004	0.007	0.091	0.084
15	0.116	0.027	0.007	0.015	0.114	0.040	0.004	0.008	0.107	0.106
17	0.143	0.034	0.008	0.019	0.138	0.050	0.005	0.010	0.124	0.134
20	0.173	0.042	0.010	0.023	0.163	0.060	0.005	0.010	0.152	0.163
24	0.205	0.050	0.015	0.028	0.198	0.074	0.003	0.011	0.169	0.199
28	0.236	0.060	0.017	0.036	0.237	0.090	0.005	0.014	0.204	0.249
32	0.264	0.070	0.023	0.045	0.276	0.109	0.006	0.017	0.241	0.297
36	0.336	0.087	0.028	0.052	0.334	0.131	0.006	0.018	0.273	0.336
40	0.392	0.099	0.028	0.059	0.369	0.150	0.006	0.020	0.303	0.380
44	0.433	0.109	0.032	0.066	0.411	0.172	0.006	0.021	0.340	0.419
48	0.487	0.125	0.039	0.077	0.463	0.203	0.005	0.023	0.380	0.468
52	0.519	0.139	0.044	0.094	0.536	0.241	0.008	0.027	0.420	0.516
56	0.593	0.167	0.054	0.102	0.590	0.269	0.009	0.031	0.464	0.560
61	0.671	0.196	0.059	0.110	0.641	0.293	0.007	0.030	0.516	0.660
65	0.787	0.238	0.070	0.122	0.696	0.321	0.011	0.037	0.593	0.742
70	0.902	0.272	0.081	0.134	0.764	0.359	0.011	0.039	0.641	0.806
75	0.955	0.294	0.089	0.149	0.864	0.399	0.010	0.042	0.702	0.968
80	1.111	0.329	0.099	0.172	0.957	0.459	0.011	0.046	0.779	1.005
85	1.159	0.361	0.116	0.197	1.141	0.531	0.011	0.052	0.868	1.129
90	1.426	0.436	0.143	0.218	1.252	0.590	0.016	0.063	0.964	1.290
95	1.706	0.511	0.176	0.263	1.477	0.705	0.016	0.070	1.059	1.576
100	2.114	0.679	0.249	0.316	1.646	0.838	0.018	0.081	1.186	1.858

## 4.2 Analysis of gray balance

Making use of the testing samples of tab 4-1 and calculating the equations(2.1), (2.2), (2.3) respectively, the Y,M,C dot area coverage are obtained. Then the above data are made quadratic polynomial regression fitting by MATLAB software, so the fitting-curves of dot area coverage of process color ink that form neutral density are educed in the first quadrant of fig 4-1.The regression coefficients ( $R^2$ ), and adjusted determinant coefficients



( $R^2$ ) are shown in tab 4-2.

**Fig.4-1 The color balance END relation curves between the monochromatic density and dot-area coverage**

**Tab 4-2 The multiple correlation coefficients and regression function between the density and the original dot area coverage**

	Quadratic polynomial	$a_6$	$b_6$	$c_6$	$R^2$	Adj R-sq
C	$D_e = a_{61}F_c^2 + b_{61}F_c + c_{61}$	1.7974	-0.01921	0.04569	0.9860	0.9850
M	$D_e = a_{62}F_m^2 + b_{62}F_m + c_{62}$	1.7353	0.18452	0.03580	0.9935	0.9931
Y	$D_e = a_{63}F_y^2 + b_{63}F_y + c_{63}$	1.5453	0.34269	0.02681	0.9949	0.9945

By tab 4-2,  $R^2$  of C, M,Y ink are 0.986,0.9935,0.9949 respectively and close to 1,however, the adjusted  $R^2$  are still close to 1. Thus it can be seen that the quadratic polynomial regression fitting is notable and the precision of equations is very high.

**Tab 4-3The parameters and determination coefficients of linear regression expression**

	Regression line	$A_2$	$B_2$	$R^2$	Adj R-sq
C	$D_e = A_{21}D_{ce} + B_{21}$	1.1557	-0.000989	1.0000	0.9999
M	$D_e = A_{22}D_{me} + B_{22}$	1.4411	-0.009151	0.9994	0.9994
Y	$D_e = A_{23}D_{ye} + B_{23}$	1.7575	-0.020992	0.9979	0.9978

The data of C,M,Y ink density that forms gray balance are made linear regression fitting by MATLAB software, so the fitting-line of density of process color ink that form neutral density are educed in the second quadrant of fig 4-2. The regression coefficients ( $R^2$ ), and adjusted  $R^2$  are shown in tab 4-3..

By tab 4-3, determinant coefficient(  $R^2$  )of C ink is 1 and the adjusted determinant coefficient ( $R^2$ ) is 0.9999. Thus it can be seen that the result of linear regression fitting is special notable. However,  $R^2$  and the adjusted  $R^2$  of M,Y ink are close to 1,which the result of fitting is notable. In the end, the conclusion is that the precision of Y,M,C ink regression analysis is very high.

Draw a line that its slope is 1 in the third quadrant of fig 4-1 and the abscissa and the y-axis are both the monochromatic density. Making use of the construction method, some relative points can be found in the fourth quadrant by the relative points in the first and second quadrant. Next, the relative points found are fitted. Last, the fitting-curves of the monochromatic density and dot-area coverage are formed in the fourth quadrant. Fig 4-1 is the color balance END relation curves between the monochromatic density and dot-area coverage.

It can be seen from fig 4-1 that among Y, M, C ink density that forms END, C is biggest, M takes second place and Y is least. The sequence of Y, M, C dot area is the same as above-mentioned, too. However, M and Y dot area are closer. At the same time, it can be also seen intuitively the color balance END relation curves between the monochromatic density and dot-area coverage when formed definite END. For example, when the END is 1.0,C ink density is 0.869,M ink density is 0.713,Y ink density is 0.585,corresponding dot area of C ink coverage is 76.6%, dot area coverage of M ink is 72.30%, dot area coverage of Y ink is 72.30%. Finally, fig 4-1 can be used as the evidence that controls gray balance.

### 4.3 Analyze the effect factors of the gray balance data generally

The gray balance data are the evidence of color variation from color pictures reproduction, which are affected by many factors from digital printing as follows:

a. Inks and Toners. Because of their character of the chromaticity property is not the same. That's to say, If wanting to achieve the neutral color, different inks need the different C,M,Y density(or dot area coverage).At the same time, the variation of ink quantity will affect dot density.

b. Paper. Different types of paper posses different whiteness, so the ability that takes on color for different inks will not be same. As a result, different types of paper should choose different gray balance data.

c. The gray balance data are affected by dot gain, solid density, relative contrast (K) and so on. As dot gains during printing don't accord with the presumed, color emerges offset. Due to different solid density, color saturation is also different. K value is the technology parameter that control solid density and dot gain, therefore it reflects the inherence relation between solid density and dot gain. On the other hand, when the K value is maximum, the solid density reflects not only the optimal diversion and ratio of dot gain, but also the optimal color efficiency. Thus when the K value is maximal, the solid density can be the evidence of the gray balance data.

In addition, when calculating the values of the gray balance data, the equations (2.2) are based on the theory of density addition. Because the dots in highlights are juxtapositional, they have the better fitting. However, the dots in middle tones and shadows are both juxtapositional and superposable, middle tones and shadows don't have the better fitting. Thus these factors will lead to the problem that the numerical values superposition of the gray balance data will not be ideal.

## 5.Conclusions

At first, this thesis analyzes gray balance about digital printing in terms of Epson stylus Pro7600, digital proofing software, color management software and data processing software. Then, with the method described in this paper, the color balance END relation curves between the monochromatic density and dot-area coverage are obtained. In addition, among Y, M,C ink density that forms END,C is biggest, M takes second place and Y is least. That's to say, the sequence of Y,M,C dot area is the same as above-mentioned, too. But M and Y dot area are closer.

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