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INFLUENCE OF THE DIFFERENCE ELECTRIC CHARGE ENERGY TRANFER INK TO PAPER IN DIGITAL PRINTING

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Abstract: *By integrating light and static electricity to form a passive electrostatic image on an image unit covered with a light conducting substance, the electrophotography principle is applied to digital printing. and employ powder ink with a charge or toner on both the recording unit's image and non-image areas. Static electricity also causes the image to transfer to the printed material. The quality of the image that is conveyed and received depends on the electric charge energy. This study's objectives were to examine how the electric charge energy difference in a digital press image impacts the color value. By changing the electric charge's five levels to -10, -5, 0, +5, and +10, evaluate the color difference value, and selected each of electric charge energy value to improve color quality of digital printing.*

Key words: electrophotography, electric charge energy (ECE), color gamut

1. INTRODUCTION

Electrophotography is the most widespread of nonimpact-printing technology that exists. The principle of electrophotography printing is a direct printing process where image information in the form of electronic signals is converted to a latent electrostatic field stored on a photoconductive dielectric material (Johnson, 1992). The latent charged image, stored on the photoreceptor, is inked with dry toner particles and then transfers directly or via intermediate belt to the paper. Inking takes place by inking units that transfer the fine toner particles in a noncontact manner to the photoconductive drum through electric potential differences (electric fields) and thus image becomes visible (Sardjeva & Mollov, 2013). That latent image is made visible by depositing charged colorant particles on the field pattern and then made permanent by fixing (Johnson, 1992).
The principle of electrophotography printing is achieved by using light and static electricity to create images. There are the following principles;
1. Use a recording unit coated with an optical material or photoconductor material. (photoconductor) that is a semiconductor It is a semiconductor and has dielectric properties, i.e., it is both a conductor and an insulator depending on the light exposure conditions. Will conduct electric chart and allow to flow through it but when there is no light or when in the dark is an insulator or conducts less electric. Before the image is formed on the recording unit electrical charge must be applied to the surface of the recording unit first.
2. Light projection on the recording unit to form the initial image electrostatically. When the recording unit is exposed to light with high sufficient energy. Particles in a semiconductor at the imaging surface at the uncovered locale are transformed by the light excitation of the peripheral electrons with higher energy until they take off the particle. This permits the exposed area to conduct power and the discharge from the area, such as permitting it to stream along the ground. As a result, the light-exposed region is not one or the other charged nor electrically unbiased (neutralized), and the un-covered region can either be a picture region or a non-image region, depending on the printer innovation. The regions that were not uncovered to light retained the same electrical charge. After light will occur within the image region on the recording unit It may be idle image which is undetectable to the bare eye and has electrostatic properties, that's may or may not have an electric charge depend
3. Electrostatic printing of pictures on substrates utilizing electrically charged inks. It may like a fine powder or liquid ink called toner transfer on the recording unit. The printing ink will selectively adhere to as it were the covered-up image zone by electrostatic constrain. Then a picture with toner that shows up to be obvious. This image is at that point transferred to print on a substrate, for the most on paper. Toner to be able to stay to the paper. It is caused by an electric charge that's inverse to

the electric charge on the toner on the back of the paper. But it causes attractive force to ink on the paper that's more grounded than suction drive to print ink on idle pictures. The toner can be transfer from the recording unit to adhere on the paper (Tungwichacharn, 1982).
In digital printing mostly used electrophotography method, toner is transferred to the paper base and then fused in place. The paper is usually uncoated, and the images are reasonably stable, because they are composed of pigment particles that are fused to the paper with a durable polymer binder material (Fogra, 2018).
The manufacturers of digital printing, on the other hand, use their own brands with different properties and features, generally of electrophotography printing uses a direct-current electric field (DC) to transfer toner from an image transfer belt onto paper. New technology to use an alternating-current electric field (AC), which produces a condition that enables toner to transfer easily to the concave portion of the paper (Ricoh, 2022).

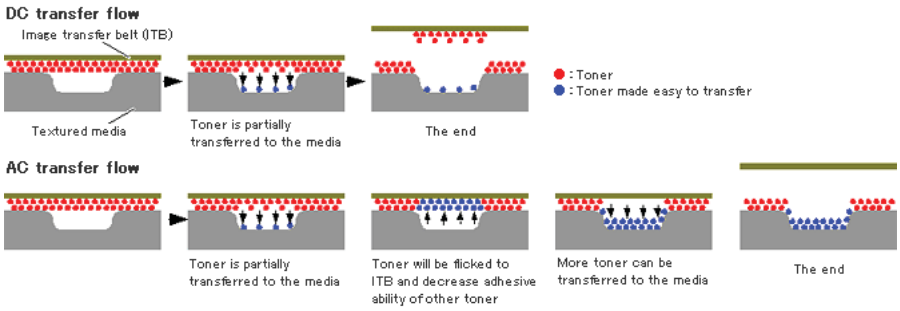


Figure 1: Flow image of DC transfer and AC Transfer

The objectives were to study the influence of different electric charge energy transfer of ink (toner) to paper in digital printing, and selective for improve color quality to be able to create a color gamut close to HDMCoated color data. For this study have been used test files as a characterization target for device profiling and for quality analysis. Used test chart for ISO 12642-2 / ANSI IT8.7/4 random were printed by the Heidelberg versafire EV, compared color reference from data for HDMCoated color data.

2. METHODS

2.1 Printing Substrates

The printing substrate in this study was used same nominal coated paper with 250 g/m^2 paper properties show as Table 1.

Table 1: Properties of substrate

Substrate	Properties			
	Type	Basic weight (g/m2)	Whiteness (%)	Color Value (L* a* b*)
Type1	Coated	250	81.63	92.70/-1.01/-0.06

2.2 Digital Printing

The digital printing as Heidelberg Versafire EV, delivers high quality and offers the possibility of reliable production of CMYK standard jobs, as well as the embellishment with the white special toners. The image quality is achieved to the resolution of 4,800 × 2,400 dpi. Enhanced toner transfer system for structured media (AC/DC) and controller by Prinect Digital Frontend (DFE).

2.3 The condition for examination (electric charge energy; ECE)

The objectives of this study were as follows:

- To study of the electrical charges energy that affect the quality of image transfer on digital printing, order the following conditions: ECE1 (-10), ECE2 (-5), ECE3 (0), ECE4 (+5) and ECE5 (+10)
- To study the color difference under conditions of electric charge energy for each color.
- To improve image quality consequence after analyze result to adjust electric charge energy.

2.4 Image transfer (electric charge energy: ECE)

This model for examination were adjust quality output of the electric charge energy for each color that shown in Table 2.

Table 2: The electric charge energy for each color.

Electric charge energy (ECE)	Black	Cyan	Magenta	Yellow
ECE 1 (-10)	-10	-10	-10	-10
ECE 2 (-5)	-5	-5	-5	-5
ECE 3 (0)	0	0	0	0
ECE 4 (+5)	+5	+5	+5	+5
ECE 5 (+10)	+10	+10	+10	+10

2.5 Test Chart

Reference test chart for ISO 12642-2 / ANSI IT8.7/4 random_S25 target, CMYK" for i1Pro amount 1,617 patches; this standard defines a data set of ink value combinations that may be used to characterize four-color process. While it is primarily aimed at process color printing with CMYK inks, it may also be used with any combination of three chromatic inks and a dark ink.

(a) IT874_Random_S25_P1_i1 (b) IT874_Random_S25_P2_i1 (c) IT874_Random_S25_P3_i1

Figure 2: Testchart IT8.7/4_Random_S25 for i1Pro

2.5 Colorimetric Testing

The evaluate of these colorimetric values of test chart after print on coated paper of prints for difference electric charge energy was measured by spectrophotometer EFI ES-2000. The colorimetric difference (ΔE) measured ΔE^*_{00} in L*a*b* the color data were measured under illuminant D65, 2° standard observers. shown equation below;

$$\Delta E_{00} = \sqrt{\left(\frac{\Delta L'}{K_L S_L}\right)^2 + \left(\frac{\Delta C'}{K_C S_C}\right)^2 + \left(\frac{\Delta H'}{K_H S_H}\right)^2 + R_T\left(\frac{\Delta C'}{K_C S_C}\right)\left(\frac{\Delta H'}{K_H S_H}\right)} \quad (1)$$

Table 3: Evaluation according the total color difference (ΔE)

ΔE value	Assessment
0 - 1	Unnoticeable difference
1 – 2	Very little difference
2 - 3.5	Middle difference
3.5 – 5	Noticeable difference
>6	Unacceptable (strong difference)

3. RESULTS

After the experiment, all samples were subjected to colorimetric testing by spectrophotometer EFI ES-2000 Model i1Pro of each sample were performed by Prinect Color Toolbox 12.0 to obtained color value for comparison and created La/Lb diagram graphs of the color difference. And improve quality printed of color reproduction by adjust electric charge color for quality transfer.

3.1 The Color value comparison

The color data from test chart; ISO 12642-2 / ANSI IT8.7/4 random_S25 was measured by spectro-photometer EFI ES-2000 model i1Pro with Prinect Color Toolbox 12.0. In test chart combination of color patch of single, double and triple color combination are there. This paper was assessed total color data and total color difference (ΔE^*_{00}).
The result of these test chart it is determine the color difference of digital printing, and then compared data between HDMCoated color data with samples; was compared different electric charge energy in the color values data. The color difference of each sample these show in Table 4 and Figure 3.

Table 4: Color difference between HDMCoated color data and Samples on coated paper.

ECE	Black	Cyan	Magenta	Yellow	Red	Green	Blue
ECE 1 (-10)	3.4	2.74	2.07	29.44	2.22	2.7	2.56
ECE 2 (-5)	3	1.37	1.79	1.43	1.36	1.92	3
ECE 3 (0)	4.48	1.21	1.25	1.4	2.18	1.93	2.68
ECE 4 (+5)	3.34	1.96	3.21	1.79	2.71	3.73	5.29
ECE 5 (+10)	4.5	3.04	4.43	2.76	5.12	7.57	9.05

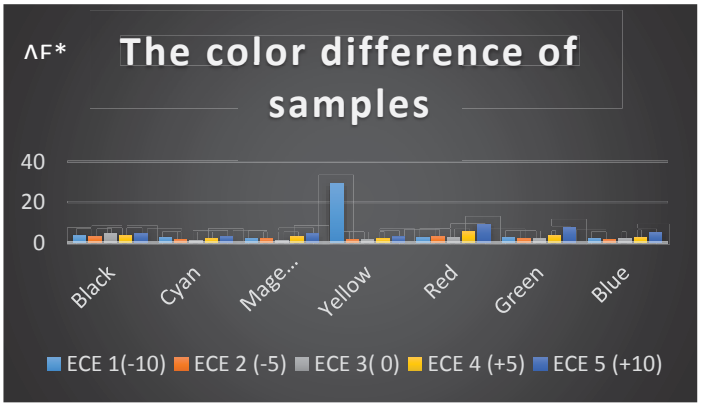
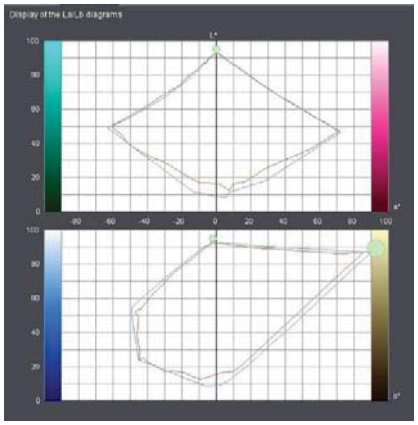


Figure 3: Compare for color difference (ΔE^*_{00}) between HDMCoated and Samples

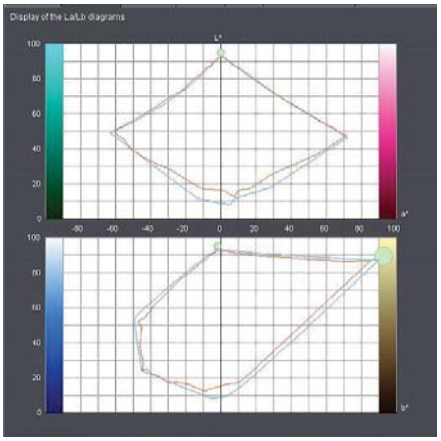
In Table 4 and Figure 3 show color difference (ΔE^*_{00}) between HDMCoated color data (reference) compare with five samples that founded as ΔE of each sample under condition as; Black for ECE2 has the color difference (ΔE) lowest is 3.0. cyan and magenta have the lowest color difference for ECE3 are 1.21 and 1.25 respectively and yellow has the lowest color difference for ECE3 is 1.40. At color combination represent to red green and blue; red and green lowest color difference for ECE2 and lowest of blue for ECE1.

3.2 The La/Lb diagrams Comparison

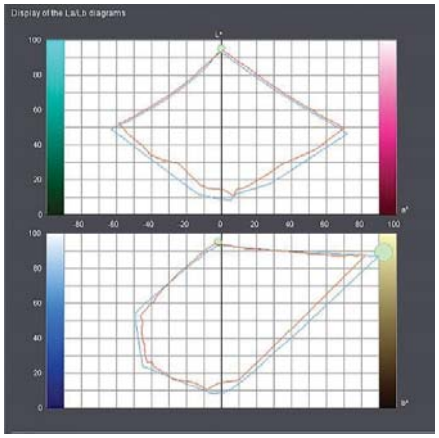
In order were compared the difference color gamut La/Lb diagrams comparison on coated paper by Prinect Color Toolbox 12.0 of Heidelberg manufacturer are shown in Figure 4. These La/Lb diagrams represent HDMCoated data (blue line) and samples (red line) of difference electric charge energy.



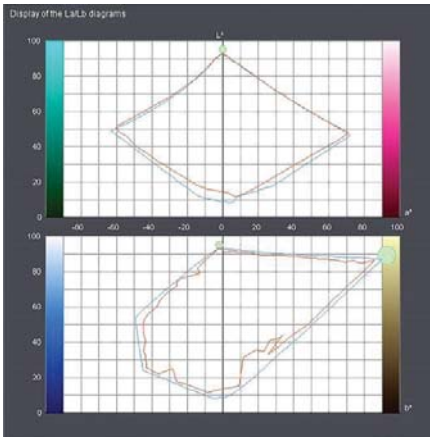
(a) Display of the La/Lb diagrams; ECE3 (0)



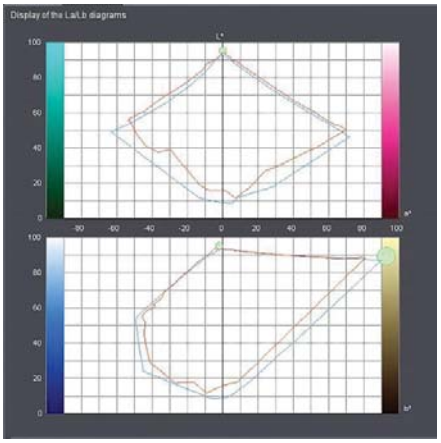
(b) Display of the La/Lb diagrams; ECE2 (-5)



(c) Display of the La/Lb diagrams; ECE4 (+5)



(d) Display of the La/Lb diagrams; ECE1 (-10)



(e) Display of the La/Lb diagrams; ECE5 (+10)

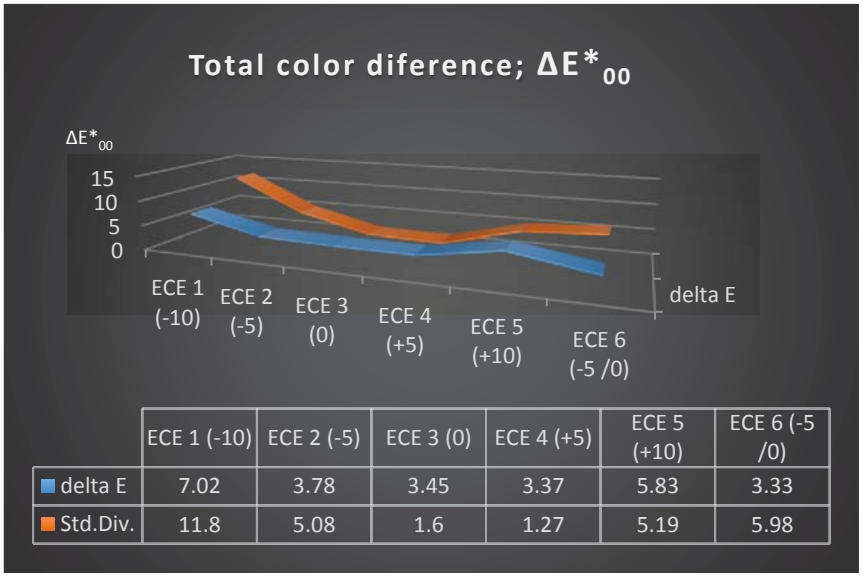
Figure 4: Compared the La/Lb diagrams and ΔE of each color from Heidelberg Versafire EV

The results of comparison between HDMCoated color data with samples. The color gamut of HDMCoated is larger when compared other samples the Δa*/ Δb* for ECE 3 (0) can produced color tone similar the reference data. But the samples for ECE3 (a) cannot produced green/red color gamut almost equal to the reference data.

In the Figure 4 for the ECE2 (b) can be show color gamut about of yellow and blue nearby than ECE3 (a) and ECE1 (d) cannot to produced red and green that not as good enough. For ECE4 (c) and ECE5 (e) cannot to produced red/green yellow and blue similar color gamut of HDMCoated.

3.3 Improve quality printed of color reproduction by adjust electric charge color for quality transfer

After analyzed we founded the cyan and yellow for ECE2 (-5) have lowest color difference. By adjust electric charge energy of quality transfer for improve quality output of color reproduction as black is 0, cyan is -5, magenta is 0 and yellow is -5 the result show in Table 5 and Figure 5.
The results of these test chart it is determined the color gamut of digital printing, and then compared data from samples under conditions; different electric charge energy was compared the color values data between HDMCoated color data with samples. The total color difference of each sample these show in Figure 5,6.



	ECE 1 (-10)	ECE 2 (-5)	ECE 3 (0)	ECE 4 (+5)	ECE 5 (+10)	ECE 6 (-5 /0)
delta E	7.02	3.78	3.45	3.37	5.83	3.33
Std.Div.	11.8	5.08	1.6	1.27	5.19	5.98

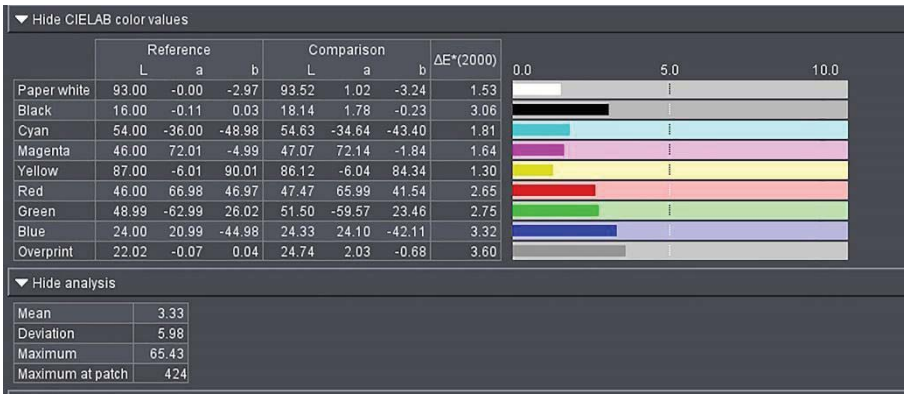
Figure 5: Compared for total color difference (ΔE^*_{00}) between HDMCoated and Samples

In Figure 5 show total color difference between HDMCoated color data with five electric charge energy on coated paper. At ECE 3 we adjusted electric charge energy at zero has the total color difference (ΔE*) lowest is 3.45 and when analyzed data we adjusted electric charge energy (ECE6) as black and magenta is zero and cyan and yellow are -5. After compared between HDMCoated and new ECE 6 by Prinect Color Toolbox 12.0 the total color difference of ECE6 is 3.33 that lower ECE 3 the result show in Figure 6.

	Reference L	Reference a	Reference b	Comparison L	Comparison a	Comparison b	ΔE*(2000)
Paper white	93.00	-0.00	-2.97	92.61	0.74	-1.60	1.71
Black	16.00	-0.11	0.03	18.97	1.59	-3.54	4.48
Cyan	54.00	-36.00	-48.98	53.29	-34.01	-45.89	1.21
Magenta	46.00	72.01	-4.99	47.11	73.02	-3.55	1.25
Yellow	87.00	-6.01	90.01	86.56	-7.36	84.92	1.40
Red	46.00	66.98	46.97	48.11	63.79	42.00	2.68
Green	48.99	-62.99	26.02	49.94	-61.74	21.77	1.93
Blue	24.00	20.99	-44.98	22.19	22.10	-42.85	2.18
Overprint	22.02	-0.07	0.04	31.07	4.64	-3.10	9.43

Mean	3.45
Deviation	1.60
Maximum	9.65
Maximum at patch	682

(a) CIE report and analysis color difference (e) of ECE 3 (0)



(b) CIE report and analysis color difference (e) of ECE 6 (0/-5)
Figure 6: Display the total color difference (ΔE^*_{00}) from Prinect Color Toolbox 12.0

In Figure 6 that show about of CIELAB color values report between HDMCoated with samples: ECE 3, ECE 6 (change electric charge of cyan and yellow to -5 and still black and magenta is 0 (ECE6)). Consequently, the total color difference (ΔE*) of sample to decrease to 3.33.

4. DISCUSSION

Dry toners consist of pigments embedded inside polymer beads. The fusing phase of the electro-photographic process melts the polymer beads to the surface of the paper (Ordant, 2019).
Toner is transmitted from an image transfer belt onto sample (coated paper) that was employed with a direct-current electric field when electrophotography printing is functionalized (DC). In order toner from the belt onto the paper, new digital printing technology uses an alternating-current electric field (AC). The samples (ECE6) showed a slight reduction in ΔE^*_{00} (0.12 for cyan and yellow was adjusted). In comparison, the overprint (CMY) samples, which show similar the HDMCoated data in ΔE^*_{00} (5.83). While ECE 6's deviation value deviates from the distribution's average (5.98).

5. CONCLUSIONS

For all ink combinations, the electric charge energy had an impact on how accurately the colors in the test chart and its overprints were reproduced. The Heidelberg Versafire EV prints from digital printing at ECE6 are better at reproducing color. Future analyses should functionalize each substrate's unique characteristics, and it is anticipated that doing so will bring color value closer the output target and apply so boost the reaction of the other substrate

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