Light Fastness of Heat Transfer on Polyester Blend Fabrics

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Abstract

This research project was designed to compare color performance of different transfer papers on cotton/polyester blend fabrics using heat transfer printing process. Digitally printed textile technology and heat transfer processed have advantages of ease of color reproduction of several colors, reduced post processing, and low equipment investment and maintenance. New developments in paper carrier have made it possible to transfer and fix inks on the fabrics more effectively. However, the light fastness of heat-transferred colors is not well defined. The purpose of this experimental study was to examine the light fastness of cotton/polyester blend fabrics with heat transfer printing. A digital four-color test chart including a test target and photographic images was designed for this study. The designed test target was first printed onto three different commercially available transfer papers by using a ink-jet printer. The printed transfer images were then press transferred using a SwingMan 15© heat transfer press. A Q-Sun Xenon test chamber was employed to evaluate light fastness based upon AATCC Test Method. The transferred color patches were measured using the X-Rite i1iO spectrophotometer. The color performance was quoted as color difference (ΔE) in CIE color space.

Introduction

The thermal dye transfer printing method has been expanding into an increasing number of applications, for example, heat transfer on the cotton/polyester blend fabrics. In the heat transfer printing process, the required image is first printed onto a heat transfer paper (can be done by either screen printing or ink-jet printing) using dye inks which comprise sublimation dyes. The heat transfer paper is brought into intimate contact with textile, through a heated press. The heat transfer paper releases a color dye when heated, and the dyes sublime and diffuse into the fabric, permanently coloring it. Ink-jet printing technology and heat transfer processed have advantages of ease of color reproduction of several colors, low equipment investment and maintenance, and quick output digital image data[1-4].

From the customer's point of view, textile printing is expected to provide good image durability. The light stability of prints is of particular importance and the improvement of the photo stability of heat transferred prints is an important goal. Light fastness is the resistance of colorant to fading under exposure to light. The most important factors in determining the light fastness are the ink, media, the ink/media interactions, and light source. Colorant and its inherent photo stability, binder, solvent and other ingredients affect the light fastness of the ink. The properties of heat transfer media such as pH, chemical composition of the media surface, location of colorant within the media, and formulation additives have impact on the light fastness of heat transfer prints. The environment such as light source and light intensity affect the image performance[5-10]. The interaction of the heat transfer media/fabric with the colorant definitely can alter the light fastness of a heat transfer print. Careful selection of the colorant/ink system and the media is needed to improve the light fastness of heat transfer prints in order to provide the print performance required by the end user.

Initial developments in heat transfer printing focused primarily on the development of dye sublimation inks. New developments in manufacturing heat transfer media have made it possible to match the exiting pigment-based ink sets, which are expected to provide better light fastness. However, the light fastness of heat-transferred colors on cotton/polyester blend fabrics is not well defined. The objective of this study was to evaluate the impact of colorants and transfer papers used in heat transfer on cotton/polyester blend fabrics. In this study, the light fastness properties of three commercially available heat transfer papers, printed with two major ink-jet ink sets (dye sublimation and pigment) were explored.

Experimental

In order to examine the light fastness properties of cotton/polyester blend fabrics with heat transfer printing, sets of printed samples were prepared. A digital four-color test chart including Cyan (C), Magenta (M), Yellow (Y), Red (R), Green (G), and Blue (B) solid colors, six continuous-tone color images, and a test target consisting of 288 color patches evenly sampled in the CIELAB color space, was designed for this study. This color target was formatted as a TIFF format and printed on three different commercially available transfer papers (denoted as A, B, and C) on two different printers with printing resolution of 360 dpi. Two ink jet printers with major ink-jet ink technologies were investigated in this work: an Epson Stylus Pro 4880 printer with ArTainium dye sublimation inks and an Epson Stylus Pro 9600 printer with UltraChrome pigmented inks. The printed transfer images were then pressed on the 50/50 cotton/polyester fabrics (white T-shirts) using the SwingMan 15© heat transfer press. Heat transfer settings were 375 to 400°F for heat press temperature and 30 seconds for dwell time. Light fastness tests were accomplished by exposing the prints to artificial sunlight for 25, 50, 75, 100, 200 and 300 hours with a Q-Sun Xenon lamp equipped with a Daylight-Q filter. Test chamber was used at irradiance settings of 0.68 $W/m^2/nm$ at 340nm (noon summer sunlight) and 63°C for black standard temperature (BST).

The color values in CIE L*a*b* color space of each transferred color patch were measured before, during and after exposure using the X-Rite i1iO spectrophotometer (D65/10° standard illuminant). Results of accelerated light fastness tests for the different printer/ink/substrate sets were interpreted in terms of change of color gamut volume and color difference. The color gamut is the range of colors that a particular combination of printer, ink, and print media can achieve. Higher volumes indicate the possibility of making more color combinations[11-14]. Color performance was quoted as color difference (ΔE_{CMC}). The ΔE_{CMC} was developed for the textiles industry by the CMC (Color Measurement Committee of the Society of Dyes and Colorists of Great Britain) in 1984. In this study, ΔE_{CMC} (2:1) was calculated from the difference in shade between the original transferred color patches and the color patches after light exposure. The formula for

CMC ($l{:}c$) is as follows[15]:

$$\Delta E = \left[\left(\frac{\Delta L^*}{l S_L} \right)^2 + \left(\frac{\Delta C^*}{c S_C} \right)^2 + \left(\frac{\Delta H^*}{S_H} \right)^2 \right]^{1/2} \quad (1)$$

Where S_L = function of L
S_C = function of C
S_H = function of H and C
l, c = correction factors which can be chosen so that the calculated numbers correspond to optical values for certain matching conditions or certain samples.

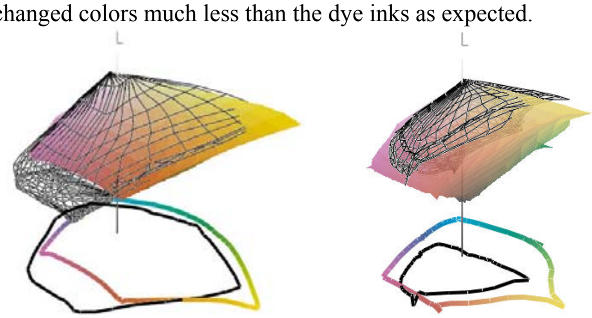
Color Gamut Analysis

The color gamuts of the output combinations were compared using ColorThink 3.0 Pro software. Table 1 shows gamut volume results before and after exposure. Before exposure, transfer paper C provided a larger color gamut, compared to other transfer papers. After exposure, however, transfer paper C cannot protect colorants against environmental influences properly with dye sublimation inks. The color gamut of dye sublimation inks was larger than that of the pigment-based inks in terms of gamut volume. After 300 hours exposure, the gamut volume of dye sublimation inks dropped up to 90-97%, and the colors were visually observed to fade almost completely. As expected, pigment-based inks provided better light fastness. At the end of exposure, the gamut volume of pigmented inks dropped about 33-40%.

Table 1. Gamut volume results before and after exposure.

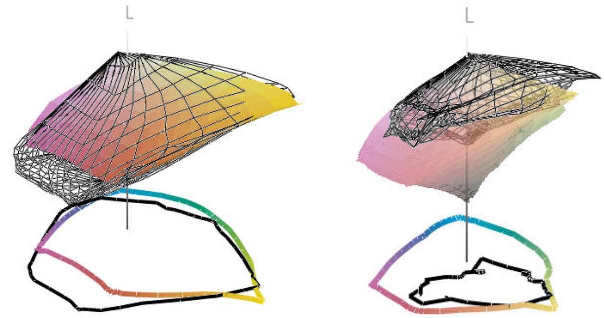
Ink Type	Transfer Paper	Original	300 Hours	Decrease [%] After 300Hrs exposure
Dye Sublimation	A	233,123	20,040	91.4
	B	211,462	17,160	91.8
	C	249,523	7,401	97.0
Pigment	A	189,412	115,935	38.8
	B	178,988	105,747	40.9
	C	189,570	126,940	33.0

The gamut volumes before and after exposure for each output combination are also graphically compared. The axis represents the CIELab color space: from "–*a*" (green) to "+*a*" (red) and from "–*b*" (blue) to "+*b*" (yellow) colors. As shown in Fig. 1 to 3, there are some saturated colors that the dye sublimation inks can achieve and pigmented inks cannot. Before exposure, dye sublimation inks tended to have a greater color gamut in magenta and red areas, while the color gamut of pigmented inks was larger in the yellow, green, and blue regions. After 300 hours exposure, color gamuts of tested output combinations reduced in size. The pigmented inks changed colors much less than the dye inks as expected.



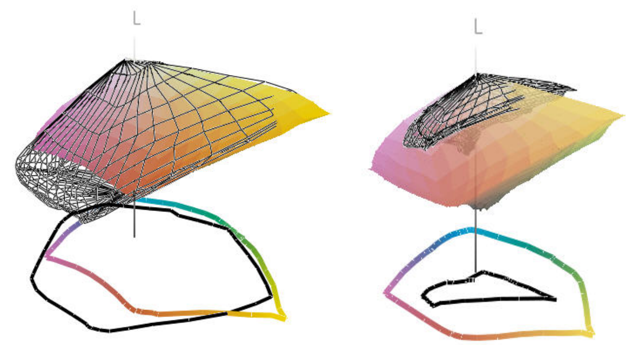
Before exposure After 300 hours exposure

Figure 1. The gamut volumes before and after exposure for transfer paper A: dye sublimation (wireframe) vs. pigment (true color).



Before exposure After 300 hours exposure

Figure 2. The gamut volumes before and after exposure for transfer paper B: dye sublimation (wireframe) vs. pigment (true color).



Before exposure After 300 hours exposure

Figure 3. The gamut volumes before and after exposure for transfer paper C: dye sublimation (wireframe) vs. pigment (true color).

Light Fastness Tests

Figure 4 illustrates color changes in cotton/polyester blend fabrics after light exposure for 300 hours. As shown in **Figure 4**, the transfer paper C with pigmented inks combination was the most stable chromophore, whereas the transfer paper C with dye sublimation inks combination was the least stable.

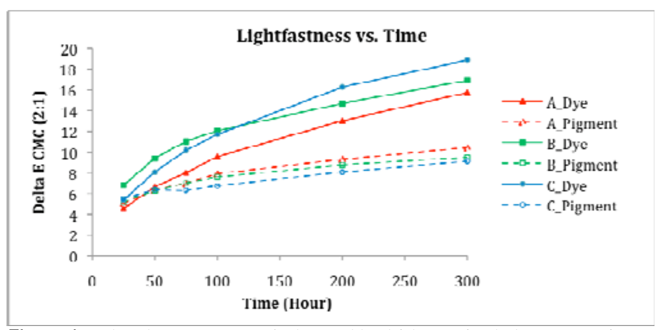


Figure 4. Color changes in cotton/polyester blend fabrics after light exposure for 300 hours.

Table 2 summarizes the color changes of primary and secondary colors before and after 300 hours exposure. For the dye sublimation inks, yellow ink had better light fastness (the overall ΔE_{CMC} values were all less than 1.0), while the secondary color blue had poor fade resistance (with ΔE_{CMC} value of over 12). For the pigmented inks, cyan and magenta pigmented inks had excellent fade resistance (ΔE_{CMC} values were in the range of 0.7-1.9), while red, green, and yellow colors had poorer light fastness.

Table 2. Summary of primary and secondary color changes before and after exposure.

Ink Type	Transfer Paper	Color	L*a*b* value Before exposure			L*a*b* value After 300 Hours exposure			ΔE_{CMC} (2:1)
			L*	a*	b*	L*	a*	b*	
Dye Sublimation	A	C	64.0	-32.9	-4.3	81.4	-5.6	-1.3	14.8
		M	52.9	58.6	-4.6	72.1	32.7	-7.7	13.0
		Y	83.4	-8.1	78.1	88.3	-9.8	49.9	9.6
		R	47.5	61.2	35.2	58.7	46.3	16.2	11.3
		G	58.8	-40.7	24.4	78.8	-12.0	19.1	15.3
		B	33.9	14.7	-40.0	66.5	12.5	-18.0	21.4
	B	C	64.8	-31.5	-3.9	87.2	-4.1	2.3	16.6
		M	53.9	57.1	-6.5	80.8	21.7	-6.3	17.8
		Y	84.0	-8.4	76.0	91.6	-10.0	51.7	8.6
		R	48.3	59.2	32.5	69.6	35.1	12.0	15.4
		G	61.4	-39.2	25.7	84.5	-10.1	22.4	16.5
		B	37.2	13.6	-38.8	73.3	12.1	-15.6	22.7
	C	C	64.2	-34.3	-3.3	85.9	-2.8	0.9	17.2
		M	54.0	60.2	-5.5	78.2	21.9	-6.1	17.6
		Y	84.0	-8.5	77.5	88.6	-9.4	41.3	12.1
		R	47.4	60.7	37.0	69.0	32.3	7.7	19.0
		G	58.0	-41.5	27.9	82.6	-8.3	18.2	18.0
		B	31.4	16.2	-41.0	69.1	13.4	-15.6	25.7
Pigment	A	C	60.5	-30.8	34.1	61.3	-29.6	-36.1	1.3
		M	55.6	46.2	13.7	57.6	44.3	-14.4	1.2
		Y	84.8	-0.4	2.0	86.5	-3.1	64.1	8.6
		R	52.2	41.7	5.6	54.4	39.9	27.8	11.5
		G	55.6	-42.4	2.2	57.1	-41.0	23.2	8.2
		B	39.3	5.7	35.0	41.0	2.3	-32.6	2.9
	B	C	58.1	-30.7	-38.1	59.7	-30.4	-38.7	0.8
		M	55.7	48.0	-16.5	58.4	45.4	-13.9	1.9
		Y	84.2	-0.6	82.7	86.9	-1.4	48.8	10.8
		R	51.3	41.7	34.0	54.5	41.9	13.0	15.4
		G	53.0	-42.7	30.8	55.7	-38.1	-0.1	14.9
		B	39.0	5.3	-36.1	40.9	1.6	-32.7	3.3
	C	C	60.8	-30.1	-35.9	61.3	-28.8	-35.9	0.7
		M	56.6	45.1	-15.9	58.4	43.2	-14.4	1.3
		Y	84.5	0.2	89.3	85.7	-0.1	66.6	7.0
		R	53.4	39.9	41.1	55.1	38.9	27.9	8.8
		G	54.0	-41.3	37.1	55.6	-37.5	17.6	8.7
		B	39.7	5.0	-36.2	41.6	1.5	-32.6	3.2

Figures 5 to 10 present ink color changes (in the a*, b* chroma diagram) with fading for cyan, magenta, yellow red, green, and blue colors, respectively. For the cyan and magenta dye sublimation inks (solid line), examination of the data shows that most of the average ΔE resulted from the Δa^* shift, while the b* values of the yellow dye sublimation ink dropped with increasing exposure. Color was visually observed to fade almost completely. Cyan and magenta pigmented inks (dashed-line) provided good fade resistance, where a* and b* values of the samples nearly kept its original values with time. Yellow ink had poorer light fastness (with ΔE values of 7 to 11), compared to cyan and magenta inks.

For the secondary color red, it was observed that printed with dye sublimation inks, a* and b* values of the samples respectively dropped and there was a shift toward green. When pigmented inks were transferred on the fabrics, most of the average ΔE resulted from the Δb^* shift. **Figure 9** shows that increasing exposure resulted in a trend to less a* values for the secondary color green. It shows that color changes of dye sublimation inks were greater than that of pigmented inks. For the secondary color blue, some color shifts occur during fading processes. When dye sublimation inks were transferred on the fabrics, the secondary color blue deteriorated rapidly in the presence of light. The color blue initially shifts toward red, and then shifts toward blue and green. At the end of exposure, the ΔE values of blue color were over 20. The use of pigmented inks, on the other hand, exhibited linear changes and shift toward green.

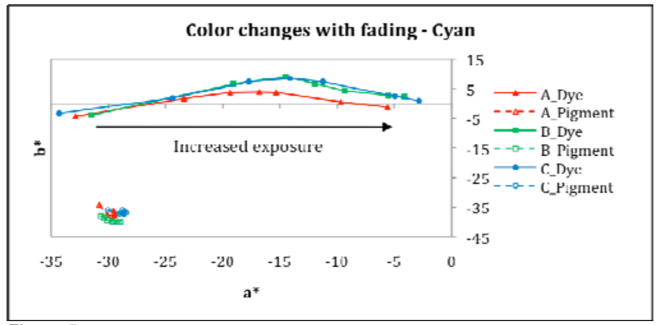


Figure 5. Color changes with fading for the cyan ink.

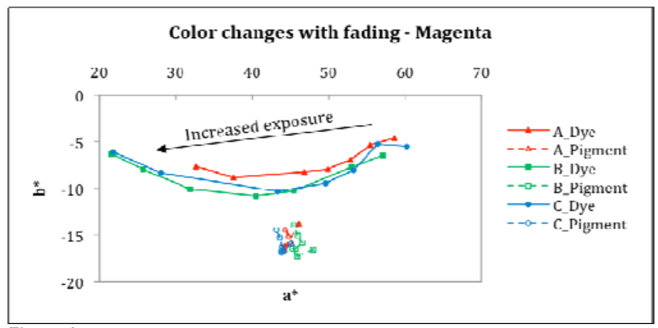


Figure 6. Color changes with fading for the magenta color.

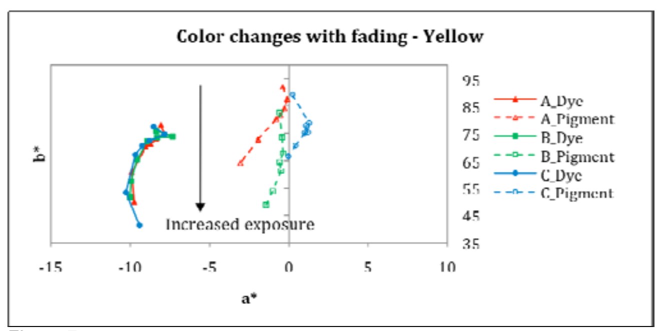


Figure 7. Color changes with fading for the yellow color.

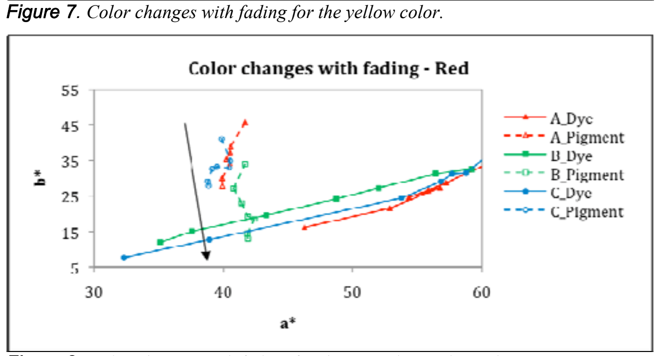


Figure 8. Color changes with fading for the secondary color red.

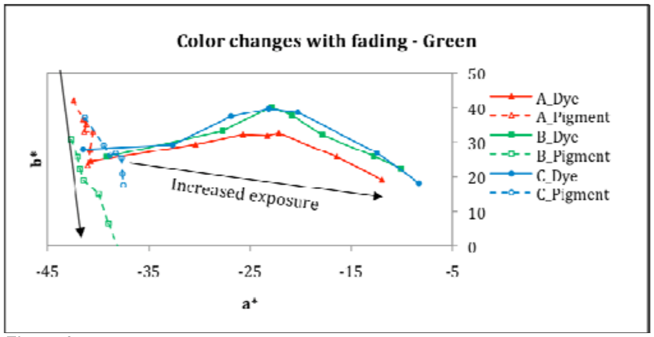


Figure 9. Color changes with fading for the secondary color green.

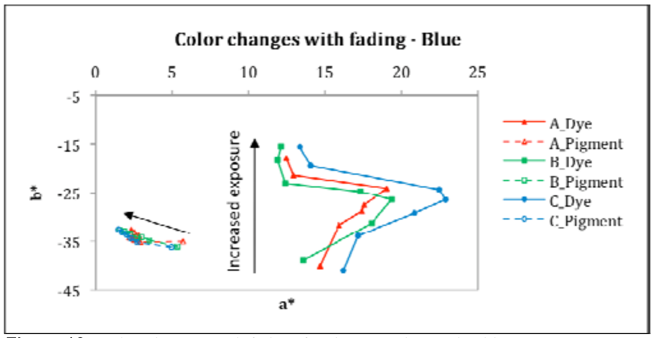


Figure 10. Color changes with fading for the secondary color blue.

Conclusions

The light fastness performance of transferred images on cotton/polyester blend fabrics is determined by the ink, transfer paper, fabrics, and the ink/media/fabrics interaction. The tested transfer papers behaved differently when worked with different types of ink. It was found that the transfer paper C with pigmented inks combination provided the most stable chromophore. However, the transfer paper C with dye sublimation inks combination was the least stable.

Dye sublimation inks yielded high color density and sharp image with the downside of poor fade resistance. Before light exposure, dye sublimation inks tended to have a greater color gamut in magenta and red areas, compared to pigmented inks. After 300 hours exposure, the gamut volume of dye sublimation inks shrunk and the gamut volume dropped to 90-97%. The colors were visually observed to fade almost completely. As expected, pigmented inks tended to produce more permanent and durable images but lower gamut volume. At the end of exposure, the gamut volume of pigmented inks dropped about 33-40%.

Some of the colorimetric changes were observed during fading processes. For the dye sublimation inks, the color shift was even more significant in the blue area, whereas yellow ink had better light fastness. Although pigmented inks were less prone to light fading, they were not immune from this effect. It shows that red, green, and yellow colors had poor light fastness, while cyan and magenta pigmented inks showed an overall lower fading rate over time.

The optimization of inks and media to achieve excellent light fastness is complicated. Careful selection of inks and media is needed to improve the light fastness of heat transfer on cotton/polyester blend fabrics.

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