Effects of Pretreatments on Print Qualities of Digital Textile Printing

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Abstract

Research presented in this paper addresses some preliminary attempts to establish the relationship between the pretreatment and the digital printing quality by the use of digital image analysis and optical microscopy. As in traditional textile printing, miss color, out of fit patterns, mottle, and color defects due to poor ink surface coverage can occur in digital printing. More specifically, defects in the digital printing of textile fabrics can be categorized into color-related issues (color gamut, color matching, light fastness, wash fastness and uniformity) and appearance-related issues (line definition, dot geometry, penetration, intensity and color registration). Woven and knitted cotton fabrics were treated with twelve formulations including ingredients like alginate, silicone and silica. Printed patterns were analyzed using an optical microscope and a digital image analysis to quantify the print qualities in terms of color-related metrics (L*a*b*) and appearance-related metrics (line width). Results show that digital textile printing quality on cotton fabrics can be optimized with appropriate pretreatments.

Introduction

A printed textile fabric can be produced by various methods. In the US, rotary screen (69%), flat screen (20%), transfer (10%) and roller (1%) printing are traditionally employed for the manufacture of printed fabrics. Current textile printing speeds are 30 to 60 yards per minute at a 65 inch printing width. The number of colors in a design can be up to 24. However, typical textile print designs have an 8-color pattern. Also, average lot sizes are 3,000 linear yards or longer.[1]

US textile markets are facing challenges from developing economies around world. The US Textile/Apparel Complex has adopted a demand activated manufacturing architecture (DAMA) to survive into the 21st century. This manufacturing strategy requires “quick response”, time-based competition, small lot sizes, large variety, and linkage into the supply chain.[2] It has been recognized that the textile printer can achieve these goals by employing digital printing technology. This provides minimizing printing lead time, quick sample printing and small lot size. Current digital textile printing based on ink-jet technology is limited to proofing and sample production. Further developments in ink formulation, jet design, pre/post processing requirement and higher throughput will provide the solution for extending digital printing technology beyond the mere preparation of proofing samples. Hopefully, the extension of digital printing into a full production mode will enable the developing textile printing market to thrive into the 21st century.

In this paper, descriptive defects in the digital printing of cotton fabrics are defined and quantified. Instrumentation needed to objectively measure these and other types of print quality defects are reviewed. Twelve pretreatments were carried out on cotton fabrics to find their effects on the final digital printing quality.

Textile Print Quality

In present day textile printing, the analog printing technologies based on rotary and flat screens are mainly used. Fabrics made of cotton and cotton blends are the major substrates printed upon. A typical screen printed fabric has different characteristics from a digitally printed fabric, such as spot color vs. process color and resolution (150 lines per inch vs. 300 dots per inch).[3]

The common defects in rotary screen printed fabrics are explained in the Table 1. Among these defects, the most common and significant ones are Out of Fit (or Register), Print Scrimp, Miss Color, Streak, Stick-In, and Mark-Off.[1] Many of these defects relate to mechanical imperfections in the printed-on fabric or in print machinery application mechanisms. Others relate to printing ink rheology. Objective print quality measurement refers to defining and quantifying image elements that determine the overall visual quality of printed textile fabrics regardless of the cause of the defect. The print quality parameters of interest are outlined in Figure 1. However, the measurement and quantification of these quality parameters should not eliminate a final subjective visual assessment of the printed surface.

Research presented in this paper addresses some preliminary attempts to establish the relationship between the pretreatment and the digital printing results in order to facilitate the use of digital machine vision and image analysis in the digital textile printing. Here a variety of textile fabric types were evaluated in an effort to determine the effect of fabric surface texture and wettability. The approach was similar to the techniques presently used for printing on paper, as in ink-jet, laser and xerography.

Table 1. Common Defects Found in Textile Analog Printing (Screen Printing)

Defects	Cause	Relative Rating*
Out of Fit	One or multiple screens are not in sync.	5
Print Scrimp	Printing over crease in the fabric	5
Miss Color	Running out of color in the screen	4
Streak / Snap	A foreign object caught behind the print blade	4
Stick In	Glob of lint on the screens causing missing color	4
Mark Off	Smudging off of a color onto another colored area	4
Color Drag	Wet print coming in contact with stationary objects	3
Pick Off	Lint buildup on the screens causing miss color	3
Piney	Poor color coverage	3
Mottled Color	Pigment roughness	2
Screen Marks	Lacquer coming off the screen	2
Water Stain	Fabric wetting before reactive or azoic dye is aged	2
Resist	Dyeing defect	1
Spewing	Excessive surface color building up on aging rolls	1
Rub Mark	Abrasion damage after color development	1

*Relative Rating: 5– High Occurrence, 1– Low Occurrence

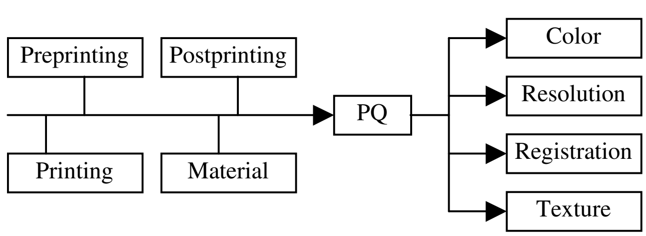

Figure 1. Print Quality Metrics

Pretreatment of Textile Fabrics for Digital Printing

Textile materials are porous, soft and pliable. In order to achieve well-registered, clear and sharp printing results using water-like printing inks without thickening agents in digital printing, the textile substrates need to be pretreated. In the case of cellulose reactive printing, certain amount of alkalis should be used in the pretreatment recipes. The bleeding on untreated fabric in digital printing is another issue that should be taken very seriously. In some cases, after-printing washing is not preferred, the pretreatment is then should be designed with that in mind.

The following chemicals can be used for the pretreatment of digital textile printing fabrics. High viscosity grade alginate is a good choice as a thickening agent. By using high viscosity grade, the amount used can be minimized, and the versatility of alginate makes it suitable for many different types of dyes including reactive dyes. Silicone compounds are used for two purposes. One is to compensate the hard hand caused by the thickening agents. The other is to control the surface hydrophilicity that is crucial to the final sharpness of the printed patterns on textiles. Urea is often used as a humectant for dye fixation. The other important compounds for the pretreatment of digital textile printing are quite special. That means these compounds are used only for digital textile printing not for the traditional textile printing. Silica can be one of them. The silica used should be in very fine state. The smaller the particle size, the better for holding the ink in the place where it is applied. This is because the smaller silica can have huge surface area which would effectively adsorb the dyes temporarily and release the dyes later on in the fixation.

Experimental

Materials

The cotton fabrics used in this study were obtained from Test Fabrics, Inc. A description of these fabrics is presented in Table 2. All are woven fabrics except #437 which is a cotton “T shirt” knit.

Fabric Absorbency Measurement

AATCC Test Method 79 was used to evaluate the cotton fabric absorbency.

Fabric Wicking Behavior Measurement

INDA IST 10.0-70 Method 10.3 was used to determine the fabric wicking properties.

Table 2. Description of Cotton Fabrics Studied

Style	Treatment	Thread Count	Yarn size	Weight (g/m^2)
423 twill	Mercerized	108x72	14/1x14/1 carded	258
428 sateen	Bleached	96x56	20/1x14/1 carded	235
437 knit	Bleached	38x44	30/1 combed	124
407 poplin	Mercerized	100x50	20/1x17/1 combed	189
400M print	Mercerized	80x76	40/1x32/1 carded	107
419 broad	Mercerized	132x72	40/1x40/1 combed	120

Pretreatment of Cotton Fabrics for Digital Printing

Two cotton fabrics, 400M print and 437 knit, were selected based on the absorbency and wicking behavior. The selected fabrics were treated with the recipes listed in Table 3. Prime Alginate T-400 is the alginate used available from Multi-Kem Co. Ultratex CSP is the silicone used available from Ciba Specialty Chemicals Co. MEK-ST is the silica used available from Nissan Chemical Industries.

Table 3. Pretreatment Recipes

Treatment	Alginate(g)	Silicone(g)	Silica(g)	Water(ml)
1	4.00	0	0	196
2	2.00	0	0	198
3	0	4.00	0	196
4	0	2.00	0	198
5	0	0	2.00	198
6	0	0	1.00	199
7	4.00	4.00	1.00	191
8	4.00	2.00	2.00	192
9	2.00	3.00	2.00	193
10	4.00	3.00	2.00	191
11	2.00	2.00	1.00	195
12	2.00	2.00	2.00	194

Digital Textile Printing

The digital textile printing was carried out with Epson Stylus Color 980 printer. A special Pattern was designed to facilitate the evaluation of basic printing parameters after printing. The pattern contains primary colors, red, blue, yellow, green and brown, and lines with different width from 0.5 point to 4.5 points. The Epson Photo Paper was used to print the same pattern for comparison. The pretreated fabrics were paper-backed for the digital textile printing.

After printing, the print qualities were analyzed using an optical microscope and a digital image analysis to quantify the print qualities in terms of color-related metrics (L*a*b*) and appearance-related metrics (line width).

Results and Discussion

Fabric Absorbency

As shown in Table 4, the absorbency characteristics of these fabrics are different. Notable is the observation that the Knit (437) and the Sateen (428) have a greater affinity for the 2-octanol than they do for water. This indicates that these fabrics have hydrophobic surfaces especially the knit fabric.

Fabric Wicking Behavior

The results are in Table 5. These data indicate that a slight wicking anisotropy can exist relative to the warp and weft direction in some fabric types. Here a P/F ratio of 1.00 denotes a uniform wicking behavior of the fabric in the warp and the weft directions. As shown, most of the woven cotton fabrics evaluated wicked fluid at a faster rate in the warp direction than in the weft. The W/O ratio (average value of warp and weft wicking rate) is an index as to the relative ability of the fabrics to wick hydrophobic versus hydrophilic fluids. With the exception of the Sateen (428) and to a much greater degree the knitted (437) fabric, most of the fabrics studied had hydrophilic character. This is indicative of the scouring, mercerizing and bleaching treatments given to these fabrics. It is suspected that the knit fabric has some lubricating finish on the yarns as a processing aid.

Table 4. Water and 2-octanol Absorbency

Fabric	Absorption Time (sec.)	
	Water	2-octanol
423 twill	2.6	2.1
428 sateen	20.4	1.8
437 knit	>1200	1.0
407 poplin	5.8	10.6
400M print	18.6	14.4
419 broad	11.3	16.6

Table 5. Water (W) and 2-octanol (O) Wicking Rate

Fabric	Fluid	Warp (P) cm	Weft (F) cm	P/F	W/O
423 twill	W	5.87±0.3	5.38±0.2	1.09	1.30
	O	4.70±0.1	3.97±0.1	1.18	
428 sateen	W	3.37±0.1	3.60±0.2	0.94	0.86
	O	4.07±0.1	4.03±0.2	1.01	
437 knit	W	0.20±0.0	0.05±0.0	4.0	0.03
	O	5.80±0.0	5.40±0.1	1.07	
407 poplin	W	5.58±0.1	4.97±0.1	1.12	1.32
	O	4.17±0.1	3.80±0.1	1.10	
400M print	W	4.73±0.2	3.80±0.2	1.24	1.05
	O	4.40±0.2	3.73±0.2	1.18	
419 broad	W	5.75±0.1	4.70±0.2	1.22	1.32
	O	4.32±0.1	3.70±0.1	1.17	

Effect of Pretreatments on the Line Widths

According to the previous experiments, fabric 437 knit and 400M print were selected for the pretreatment. The line width was measured with a micrometer and the values were the average of four measurements.

From figure 3, it can be seen that the 1% silicone pretreatment on the woven fabric gave an overall good line width, comparable to the effect achieved on photo paper.

Figure 4 shows almost the same effects on the knit fabric as in Figure 3. Here silicone-alone pretreatment is rendering best line definition. In some cases, the silicone pretreatment even gave better results than the photo paper.

Effect of Pretreatment on Lightness

It is observed in Figure 5 that the pretreated woven fabric with 2% alginate, 1.5% silicone and 1% silica shown good results in color retention for all 5 color shades used.

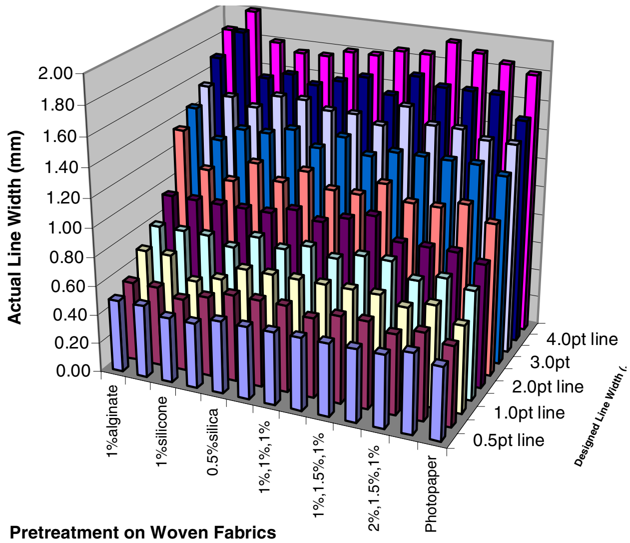

Figure 3. Effect of Pretreatments on the Line Width digitally printed on Woven Fabric

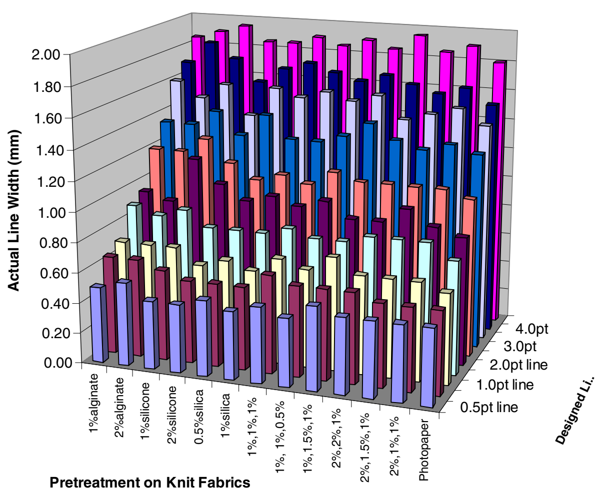

Figure 4. Effect of Pretreatments on the Line Width digitally printed on Knit Fabric

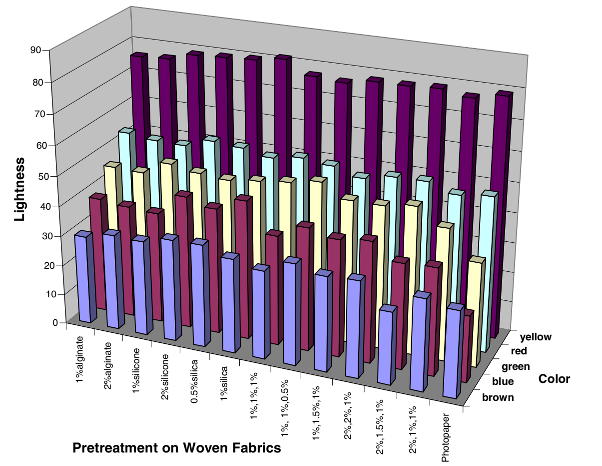

Figure 5. Effect of Pretreatment on Lightness of Colors on Woven Fabrics

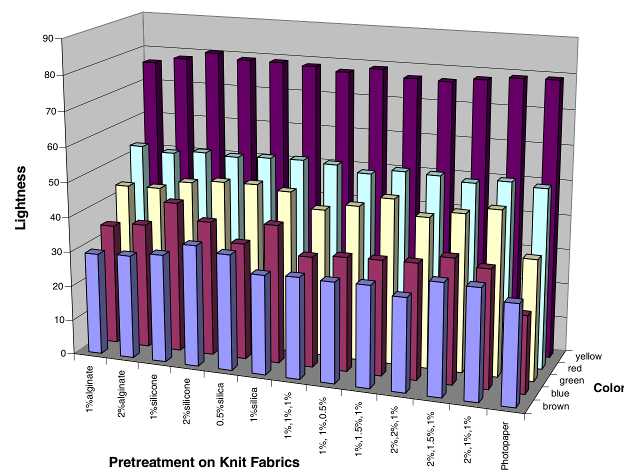

Figure 6. Effect of Pretreatment on Lightness of Colors on Knit Fabrics

On knit fabric, the combination of 2% alginate, 2% silicone and 1% silica gave the lowest lightness when compared to the photo paper.

From figure 5 and 6, it can be seen that the recipes containing 2% alginate, 1% silica and 1.5-2% silicone were good for all 5 color shades on both woven and knit fabrics. That means this combination would render a stronger color on the treated cotton fabrics.

Effect of Pretreatment on a* and b* Values

It can been seen from Figure 7 that all pretreated fabrics, woven and knit, were greener compared to the photo paper except for the green color itself which showed no big difference between the pretreated fabrics as well as between the pretreated fabrics and the photo paper.

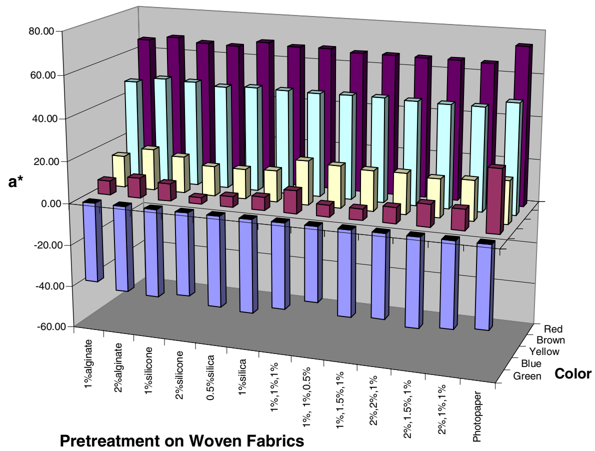

Figure 7. Effect of Pretreatment on a value of Colors on Woven Fabrics*

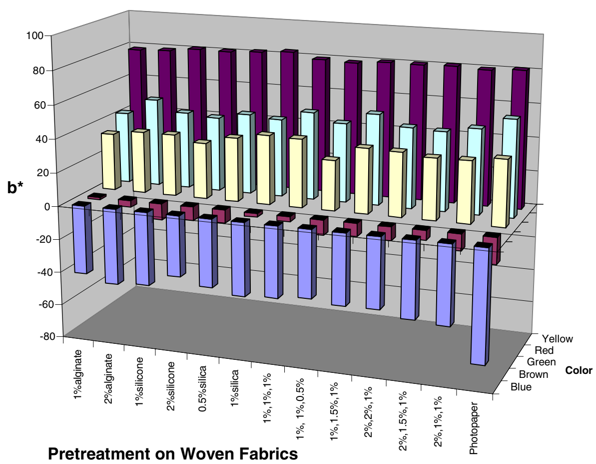

Figure 8. Effect of Pretreatment on b value of Colors on Woven Fabrics*

As far as the b* value is concerned, the pretreatments did not give too much influence on woven fabrics as shown in Figure 8, while the blue color appeared more blue on photo paper.

From figure 9, all pretreated knit fabric did not show too much a* value differences among them, which is similar to the results shown in Figure 7

From Figure 10, it can been seen that there is no significant difference between the b* values on pretreated knit fabrics, which is similar to the results shown in Figure 8.

Overall, Figures 7 to 10 show that the color gamut affected by the pretreatments. It can be seen that the a* values (figure 7 and 9) of fabrics, both woven and knit, were not changed much among different pretreatments, even though the photo paper seems a little redder. The b* values (figures 8 and 10) had the similar trends among pretreatments except that the photo paper had a little bluer tone.

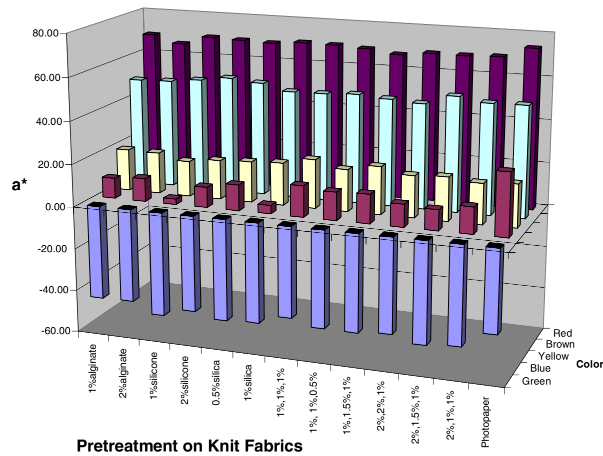

Figure 9. Effect of Pretreatment on a value of Colors on Knit Fabrics*

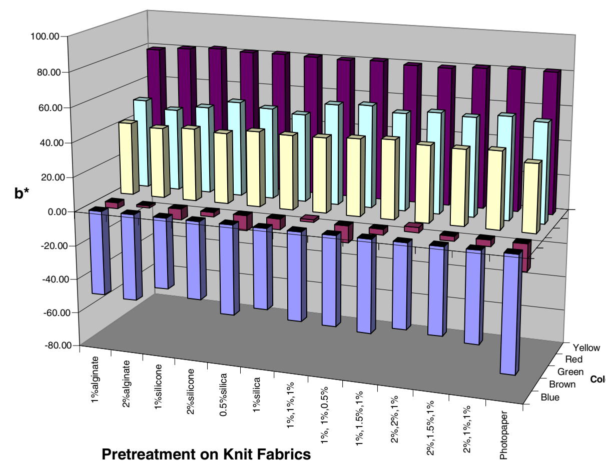

Figure 10. Effect of Pretreatment on b value of Colors on Knit Fabrics*

Having considered all effects, it would be reasonable to recommend the recipe with 2% alginate, 2% silicone and 1% silica for the pretreatment of cotton fabrics, woven and knit, for digital printing.

Conclusion

Several print quality characteristics were measured on a variety of cotton fabrics. Fabric absorbency, fabric wicking behavior were measured. The knit and sateen fabrics have most hydrophobic surfaces. Woven fabrics show very high anisotropic wicking behavior. A few combinations of alginate, silicone and silica were used as pretreatment for cotton fabrics. Overall this study showed that digital textile print quality is strongly influenced by the fabric pretreatments. The print quality was not significantly affected by fabric structure, and the hydrophilicity of the fabric surfaces. The pretreatment can give cotton fabrics required characteristics of digital printing substrates, i.e., the balanced hydrophilic/hydrophobic characteristics.

It was found that the print quality of digitally printed cotton fabrics with the optimum pretreatment was as good as that of the photo paper. This indicates that quality digital printing onto textile fabrics is achievable. Once the effective solution for post treatment is available, digital textile printing can be used not only for preparing samples but also for production quality printed textile fabrics.

References

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Biography

Yong K. Kim, a Professor of Textile Sciences at University of Massachusetts Dartmouth, joined the faculty in 1981 after he earned a Ph.D. in fiber and polymer science from NC State. He holds a BS and M.S. in textile engineering from Seoul National University (Korea) in 1974. Yong's research interests include textile process design and manufacturing systems, mechanics of fibrous structures and composite materials.