

High Color Performance in Industrial Application of Textile Ink Jet Printing

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Abstract

Since ink jet printing on textile is currently limited in sampling and small lot production with far slower speed ($2m^2$/min) than conventional textile printing (50 m^2/min) in average, screen printing will be applied for "large lot" production in the industry before the complete domination by the digital process. The colors presented with dots by digital ink-jet machines should be made equivalent to those with blocks by conventional textile printers. The color matching between the sampling and the industrial production can be achieved by mixing colors for ink elements to make the color difference (ΔE) < 1. The technology of mixing colors in this article involved the ink formulation which imparted the stability and compatibility of colorants, and the color management on customer demand. With the arising appeal for the cleaner production process, advanced pretreatment with no wash-off step on fabrics were investigated with the application of hydrophilic copolymers to present better ink-textile interactive performance (sharpness, color yield, etc.) and good durability. With the benefit of modified color system and effective fabric treatment will promise the quick response manufacturing linked to near-future innovation, e.g., body-scanning, CAD tailoring, and internet ordering workshop.

Introduction

Appealing to the digital age, the textile ink jet printing is striking progress from analogue to screenless and quick-response on a continuous basis. It emerges as creative technology, environmentally friendly and economical printing process in the advantages of no need for screens/ rollers, wider dimension of color gamut, instantaneous print capability with CAD system, photorealistic printing and scanned patterns / pictures with no design limitation.

In the current market, digital printing in textile is employed in sampling, short-run orders and customized production with the average speed of $2m^2$/min, far belower the traditional roller/screen printing of $50m^2$/min. The limited production would be expectedly improved with several multi-head machines printing simultaneously in the method of substrate-widthwise stationary or rotating drums.[1]

To be able to really dominate the screen/roller printing as the mass production method, the key technologies under the breakthrough involve the continuous printing with full fabric-width spanning of ink-jet heads, highly-frequent delivering of ink droplets in good quality, more than four elementary inks (CMYK) for wider color gamut achievement, special fabric pretreatment and simplified after-treatment. For complete application of digital printing in the textile and apparel industries, the integrated efforts are required from ink and dye manufacturers, developers of CAD software and finishing and printing specialists. Despite the update development of digital printing equipment and the market potential has been much exploited, we should get further understanding of present technical limitations by looking more closely at the formation of images from the tiny drops of colors and the capillary behavior of substrate surface, also by studying the printing quality agreement in terms of color yield, color fastness and pattern sharpness.

Objective

In the recent major textile fairs (ITMA and the European household textiles show Heimtextil, 1999), most of the presented printing units have been built up for the application of reactive, acid or disperse dyes. However, the majority of existing textile digital printers employs pigment-based inks with the easy after-treatment of dry heat, which consequently provides lower production costs. Moreover, inks formulated with pigments and disperse dyes impose most technical difficulties in the tendency of pigment particles to precipitate in the nozzle channels of print-heads. This article has foreseen the technology development and investigated in the clogging-free ink formulation and anti-migration fabric treatments. Most critical factor for color image is the dot-color presented digital printing, compared to the block-color presented conventional screen printing. The color quality between the two systems (i.e., color agreement between sampling production and industrial application, ie,. mass production) should be matched equally to meet customer's end demand. The dots in light color are observed apparently as defects which may impose influence on color management. If higher resolution is applied to produce much more tiny ink droplets for less dot-

like appearance, the running speed of the printer turns slower with relative more expensive cost as a result. The pre-mixing colors in inks was expected to impart higher color performance in this subject.

Ink Formulation

The ink-jet inks available nowadays for most substrates include reactive inks for cotton and acrylic, acid inks for silk, wool and polyamide, disperse inks for PET and pigment inks for all types of fiber. The water-insoluble inks (disperse dyes and pigments) are existing the most challenging technique in the association with the particle rheology. In largest printing market requirement, pigment base is superior to dye bases in color strength, lightfastness, bleeding and application suitability. To formulate the disperse/pigment inks in the form of emulsion (o/w), the basic requirements to be useful in textile ink-jet printing operation are generally met in the illustration of Table 1.

Table 1. The properties of disperse/pigment inks in the success of textile ink jet printing

	Standard range	Effect	Chemicals
Color	100%CMYK	Purified/Modified colorants for wide color gamut	High fastness of CI.Disperse/Pigment Blue,Red,Yellow, Black
Surface tension (dyne/cm)	40 ~ 60	<40, bleeding >60, slow wetting	Anionic/Nonionic / Amphiphile Surfactants
Viscosity (cps)	1 ~ 6	<1, droplet scattering >6, nozzle blockage	Viscosity adjusting agent
Particle Size (nm)	100 ~ 300	<100, particle aggregates >300, particle precipitation	Sulfonate-typed dispersing agent, Water-soluble resin
PH	7 ~ 8	Dyeing at neutral-caustic condition	Buffer solution
Precipitation (%)	0 ~ 5	>5, nozzle blockage	Water-soluble copolymer, auxiliary solvents

The colorants were selected to possess high color value, high purity, excellent water and light fastness, followed by dispersing/dissolving process and micro-emulsifying with the above auxiliaries and other additives (e.g., anfoamers, bactericide, or anti-oxidants, etc.) which should be compatible with the entire vehicle components without changing color shades. It would be the recipe of dynamically stable isotropic solution to provide long storage and ejection stability as well as good coloration.

Fabric Pretreatment

Once the ink droplet is ejected through the nozzle orifice onto the fabric surface, its low-viscosity liquid is liable to spread laterally by capillaries effects, i.e., wicking/ threading tendency, if the substrate is not pretreated with thickener/antimigration agents. Printing with dyes requires aftertreatment of steaming (100~180°C water vapor), washing, or reduction cleaning (for disperse dyes) to render well-fixed bright colors. It would be the textile industry's most preference to avoid the aftertreatment and even pretreatment, i.e., the application of pigment inks and sublimation printing. However, the pretreatment on fabrics before printed is still necessary to prevent the entry of ink liquid to the capillary spaces and increase the availability of surface area for the drops rapidly permeating into the fabric.[2] As a result, the low print-through and high color intensity are recognized as good print quality with good line definition and no color interference. The figure 1 and 2 presented the print quality differences between the untreated fabric and the well-pretreated fabric which were printed with the pigment-based ink.

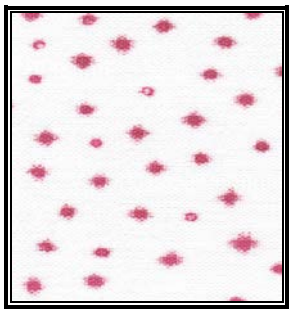

Figure 1. Ink droplets on untreated PET-fabric (low color intensity, bleeding/threading along the weft and warp yarns)

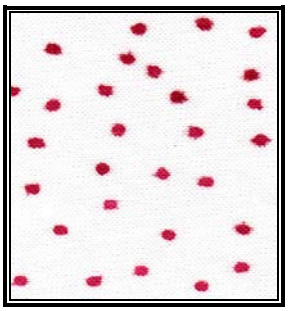

Figure 2. Ink droplets on pretreated PET-fabric (High color intensity, sharp dot definition)

The pretreatment agents were required to have good adhesion to the fibrous material to protect from loss of colorants and have to be flexible enough to avoid breaking off. The effect of various pretreatment on the color yield and water-fastness of the pigment printed fabric was displayed in Table 2, which indicated the incorporation of hydrophilic copolymer (siloxyl substituent) was better than guar gum thickener and acrylate antimigration agent with much higher color strength and better water-fastness.

Application in Industrial Production

The ultimate objective of the textile ink-jet printing is to be able to work as fast and reproducible as mass production in the textile printing industry. The method for the bulk production in the initial stage is possibly continuing to adopt the rotary screen and flat-screen printing. However, the strategies for improving the printing speed and reproducing an ink-jet print on a screen printing machine are remaining great challenges nowadays with very few wholesome development voiced. [3]

Table2. The effect of different fabric pretreatment on the relative color strength / water-fastness (printed on soured, 100%PET fabric)

	Cyan /wf.*	Magenta /wf.*	Yellow /wf.*	Black /wf.*
Blank	50 / 2-3	50 / 2-3	50 / 2-3	50 / 2-3
Guar Thickener	60 / 3	55 / 2-3	55 / 3	60 / 3
Acrylate antimigrator	75 / 4	70 / 3-4	65 / 4	70 / 3-4
Siloxyl copolymer	95 / 4-5	95 / 4-5	95 / 4-5	90 / 4-5

* Water-fastness scale according to AATCC 61-1986IIA standard

Major difficulty in the printing quality consistency between digital sampling (with CMYK) and screen printing production is faced by wider color gamut and light color shade, where color mixtures are observed apparently in dot-like by ink-jet while uniform block-like by screen. The fact brings about the concept of more than four elementary colors for inks (i.e., multicolor and multi-printhead), and leads the trends to integrate the color calibration from designer's computer image to the end-production printouts with the development of CAD color communication software (eg.CRT colorimeter and translation program between RGB and CIE co-ordinates).[4]

• Multicolor

The color gamut is usually presented in CIE x-y chromaticity diagram and CIE Lab color space diagram to display the shade range of substractive color mixing. The wider color gamut with additional primary colors (e.g., bright orange, violet, bright greenish yellow and etc.) are achieved, the more shade gamut is producible. That is the color of digital printing can be matched with considerable number of possible dye combination in the industrial application. Further more, the selection of these elementary colorants should consider their fastness and printing performance.

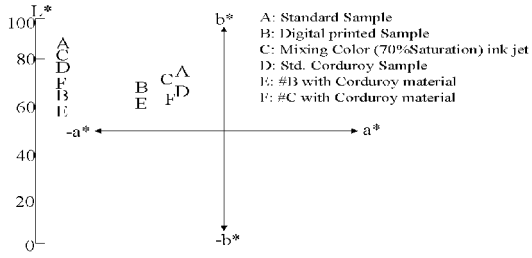

Figure 3. CIE Lab Diagram - Green Shade of mixing Color and fabric effects

• Mixing Colors

The coloration of digital printing is processed by standard colors (Pantone) or by the custom-made catalogue. For the color shade achieved by the process of CMYK, the bright shades at 100~300 dpi on the plain-weave fabric, especially light green (in Pantone: C=5~15, M=0, Y=60~85, K=0), light orange (C=0, M=10~25, Y=100, K=0) and yellowish red (C=5~10, M=100, Y=85, K=5) are observed in random-doting colors like dirty defects. And it did affect the color management results. As the figure 3 of light green shade illustrated, the standard printing sample (# A) was shifted to the plot of # B as darker green. By printing with the mixed light-green inks in equivalence to Pantone's concentration, the color shade could be changed with the percentage of the ejected dot amount. The results showed that 70% of the mixed color droplets (#C) got close to the standard color which suggested the mixing recipe of C=9, Y=55, M=0 and K=0 to achieve the same color strength and shade. Also, the corduroy fabric (# D, E, and F) presented lighter in shade than other three twist-weave fabrics because of less light scattered by the furry surface. The optimization of mixing other light colors is likewise to make the color difference (ΔE) less than 1 as required in the industrial application. This establishment of mixing color technology is possibly leading the way of printer development to the

compact design of color kitchen and color dispensing system, which can automatically optimize the color match between digital sampling and screen printing, as well as dispense various colored inks on demand for the preparation of mass production according to the applied fabrics.

Future Work

The ink jet printing in textile has been expected to make people do the business more effectively by improving creativity and reducing time-to-market with the global-wide digital communication of color and design. The resolution for the communication between the design/ coloration and the printer/production includes the setup of color gamut database of all available dyestuff categories, the cooperation with the process engineer, ink-jet hardware and calibration software which can also transfer the digital design directly to rotary screen printing without color difference. Similar to the pigments in the promised approach to ink jet system, dyes could be modified as good fixation on applied fabrics with satisfactory lightfastness and crock fastness without wash-off after-treatment.

References

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Biography

Shiau Yin Peggy Chang received her Diploma degree in Textile Chemistry from National Taipei Institute of Technology (Present National Taipei Technology University) at Taiwan in 1996 and MSc. Degree in Color Science from Heriot-Watt University at UK in 1997. Since 1998 she has worked in the Department of Dyeing and Finishing for textile chemicals at China Textile Institute in Taipei, Taiwan. Her work has primarily focused on the application of digital printing in textile, fabric treatments and polymer application. E-mail: cti728@www.textilenet. org.tw