# Image Quality of Inkjet Printing on Polyester Woven Fabrics

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## Abstract
*This paper is concerned with image quality of lines inkjet printed on polyester woven fabric. Lines (ideal width of 0.1 mm) running in the warp and weft directions were inkjet printed onto different fabrics, and print quality (line width, edge blurriness, edge raggedness) was assessed. The effects of printing direction, weave structure, and finishing on line image quality are discussed.*

## Introduction
Inkjet printing offers potential in augmenting traditional printing techniques to reduce inventory size, for example in garment label printing. In traditional label printing, an engraving plate and label inventory for each garment size is needed even though the labels are identical except for the size of garment. Combining inkjet printing with traditional printing offers a new approach. The labels with all information on them except size may be printed using traditional printing, and garment size can be added with inkjet printing as needed. Thus the number of engraving plates and inventory may be significantly reduced. An understanding of the effects of fabric structure (weave and knit pattern, fiber and yarn linear densities and diameters) and ink/substrate interactions (including wetting, spreading, and wicking) with the fabric substrates is needed to facilitate the use of inkjet printing of labels.[1]

Tse *et al.*[2] reported factors affecting print quality in inkjet printed cotton fabrics, and discussed tools for quantifying print quality of printed cotton fabric. The fabrics were pretreated (mercerized or bleached), but not finished. A commercial desktop inkjet printer was used to print on the cotton fabrics, and print quality (PQ) analysis was performed using an automated print quality analysis system to quantify quality attributes including line width, image noise, optical density, tone reproduction and CIELab color. Their results suggested that the most significant parameters are fabric structure, yarn size and hydrophilic/hydrophobic nature of the fabric.

Fan *et al.*[3,4] investigated the effect of pretreatments on inkjet printing quality of woven and knit cotton fabrics. In their investigation, pretreatment refers to finishing the fabrics with twelve different water mixtures of alginate, silicone, and silica. The main focus of the research was to find the effect of the pretreatments on final inkjet printing quality with photographic quality paper as control. Their results showed that print quality is influenced by fabric pretreatment, the most noticeable being the appearance related quality, i.e., line width. In contrast to results of Tse *et al.*[2] for unfinished fabric, they found that print quality was not significantly affected by fabric structure and hydrophilicity of the untreated fabric surfaces.

The objective of the research discussed in this paper is to develop a better understanding of the effects of several parameters on inkjet print quality of printed labels on polyester fabric. The effects of printing direction, weave structure and finishing on line image quality will be discussed.

## Experimental
### *Materials and Equipments*
Polyester fabrics were chosen because garment labels are typically made of polyester fibers.[5] Eleven different types of polyester fabrics were obtained from Testfabrics, Inc.[6] The different fabrics were selected to study effects of yarn and fiber size, yarn structure (spun and filament), fabric surface roughness, and woven fabric structures. Some of the fabrics were produced from 100% filament polyester yarns, and others were made from spun polyester fibers. Description of the polyester fabrics discussed in this paper can be found in Table I.

A VisionJet system with an Utrajet II inkjet head made by Trident International was used to print on the fabrics. Printing tests were conducting using VersaPrint™ black ink made by Trident International.[7] The compositions of VersaPrint™ black ink are 60 – 80% of polyalkylene glycol, 15 – 40% of polyalkylene glycol alkyl ether, and solvent black 29 as a colorant. The surface tension and viscosity of the ink was 24 mN/m and 70 cP, respectively, at room temperature.

Polyester fabrics were coated using 24.5% acrylic emulsion (Hyunjin No. 6-pp). The fabrics were dipped into the coating bath and squeezed with 2 kg/cm$^2$ of pressure and dried at 80°C for 5 minutes. Pickup ratio of acrylic emulsion coating on various polyester fabrics are shown in Table I.

### *Printing and Analysis*
An Optica system with Utrajet II inkjet head made by Trident International was used to print on the fabrics. Fabrics were cut into rectangles with dimensions of 5.08 mm × 7.58 mm (filling × warp or warp × filling), taped on index cards of 7.58 mm × 12.66 mm, and then placed on the print table. The system is designed so that the frequency of firing ink is controlled by the moving speed of the plate on the print table, allowing consistent images to be jetted. The distance between the inkjet head and the substrate was adjusted to 3 mm which produces lines with ideal width of 0.10 mm on polyester film.

**Table 1: Description of Polyester Fabrics**

| Style #[a] | | Commercial name [a] | Yarn size[b,c] (μm) | Fiber size[b] (μm) | Pick-up ratio[d] (%) |
|---|---|---|---|---|---|
| Filament Polyester | 700-3 | Poly Taffeta (plain) | 230 × 250 | 16 | 19.72 |
| | 700-4 | Poly Satin (satin) | 150 × 380 | 16 | 10.64 |
| | 700-5 | Poly Poplin (plain) | 380 × 390 | 17 | 21.85 |
| | 700-7 | Hercules (twill) | 255 × 290 | 16 | 13.33 |
| | 700-8 | Ply Duck (plain) | 380 × 570 | 26 | 12.26 |
| | 700-9 | Poly Pongee (plain) | 200 × 250 | 20 | 1.97 |

a. Information was provided by Testfabrics, Inc.
b. Data were measured using SEM.
c. Filling Yarn × Warp Yarn
d. Acrylic resin

For quantitative analysis, the printed fabrics were scanned using a HP Scanjet 8250 scanner which measures reflectance. HP Scanjet 8250 scanner's gamma correction, called 'midtone', was used to convert reflectance to gray scale. This gave a linear relationship between reflectance and 8-bit grayscale. Using standard reflectance tiles (Ceram Technology) the value of midtone of the scanner that produced a linear relationship between reflectance and grayscale was found to be 1.1.

The scanned images were analyzed using a MATLAB program based on standard (ISO/IEC DIS 13660). The output was print quality in terms of line width, edge blurriness, and edge raggedness. Line width is width of the line measured normal to the line between both edge thresholds. Edge blurriness is the haziness or indistinctness of outline. Edge raggedness is the geometric distortion of a straight-lined edge from its ideal position. The value of Raggedness is the standard deviation of the residuals calculated perpendicular to the fitted line.

## Results and Discussion

The effects of printing direction, weave structure and finishing on line image quality will be discussed in this section.

Line image quality usually varies with print direction because fabric structure is not symmetrical. An unfinished satin fabric will be used to illustrate the effect of print direction on line image quality because the effect can be very large with satin weaves due to the long floats on the surface of the fabric. The effect of printing direction can be reduced by applying finish to the fabric. This will be discussed later in this section.

Line image quality for printing unfinished 5-harness filling-faced satin polyester fabric (#700-4) depends greatly on the printing direction as can be seen in Table II. The reason for the difference can be explained using Figure 1, which illustrates the effect of print direction and fabric structure on line image quality. It also illustrates how wicking in the yarn running transverse to the printing direction affects line image quality.

Figure 1 (a) shows a schematic of printing in the warp direction along a warp yarn. For a 5-harness filling-faced satin polyester, notice that four out of five of the filling yarns interlaced with the warp yarns run over the warp yarns. When the ink drops fall on these filling yarns, the ink wicks in the filling yarn direction, which is transverse to the printing direction. Since these filling yarns float over up to four warp yarns, the wicking distance is large, causing line image quality to be poor. The wicking of the ink in the filling direction can be seen in Figure 1 (c) which is a scanned image of fabric printed in the warp direction. When ink falls on the warp yarn, notice that wicking in the filling direction is much smaller.

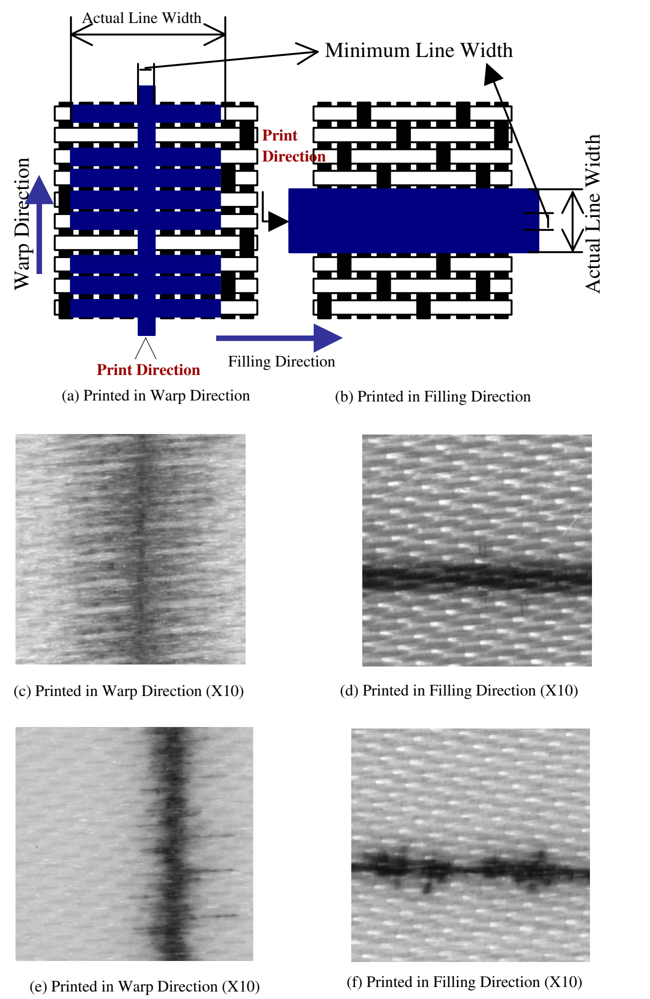


*Figure 1. 5-harness filling-faced satin polyester fabric. Schematic of structure printed in: a) warp and b) filling directions; scanned images of unfinished satin fabric in: c) warp and d) filling directions; and scanned images of acrylic resin finished satin fabric in: e) warp and f) filling directions. Fabric printed with VersaPrint ink.*

Figure 1 (b) shows a schematic of printing in the filling direction along a filling yarn, and Figure 1 (d) shows a scanned image of fabric printed in the filling direction. Since four out of five of the filling yarns interlaced with the warp yarns run over the warp yarn, most of the ink falls on the filling yarn. Ink falling on the filling yarn, tends to wick in the filling direction which is the line direction. When the ink drops hit the warp yarns which interlace over the filling yarn, wicking along the warp direction occurs. However, these warp yarns interlace under the filling yarn on both sides the filling yarn along which the line is printed. This tends to reduce wicking in the warp direction. Due to these two factors, wicking in the warp direction which is perpendicular to the print direction is much less than for printing in the warp direction. Consequently, line image quality is much better for printing in the filling direction for this particular fabric. This illustrates how fabric structure can play an important role in line image quality for unfinished fabrics.

Since plain and twill weaves have more yarn interlacings, line image quality for these weaves is expected to be better than those for the satin weaves, which is the case as can be seen in Table II. However, explaining the differences in the line image quality parameters is more difficult because the other parameters such as yarn size, fiber size, picks per cm, and ends per cm may be important. Systematically varying these parameters to show their effects is difficult due to limited availability of fabrics.

**Table 2: Line Image Quality for Selected Fabrics and Conditions**

| Fabric | | Print Direction | Line Width (mm) | Blurriness (mm) | Raggedness (mm) |
|---|---|---|---|---|---|
| 700-3 Plain Weave | Unfinished | Filling | 0.32 | 0.39 | 0.23 |
| | | Warp | 0.43 | 0.51 | 0.22 |
| | Acrylic Resin | Filling | 0.23 | 0.27 | 0.048 |
| | | Warp | 0.24 | 0.33 | 0.11 |
| 700-4 Satin Weave | Unfinished | Filling | 0.57 | 0.45 | 0.062 |
| | | Warp | 1.42 | 0.98 | 0.43 |
| | Acrylic Resin | Filling | 0.36 | 0.40 | 0.26 |
| | | Warp | 0.37 | 0.35 | 0.079 |
| 700-5 Plain Weave | Unfinished | Filling | 0.28 | 0.38 | 0.20 |
| | | Warp | 0.35 | 0.54 | 0.19 |
| | Acrylic Resin | Filling | 0.23 | 0.49 | 0.12 |
| | | Warp | 0.20 | 0.33 | 0.13 |
| 700-7 Twill Weave | Unfinished | Filling | 0.30 | 0.55 | 0.35 |
| | | Warp | 0.43 | 0.59 | 0.36 |
| | Acrylic Resin | Filling | 0.28 | 0.34 | 0.07 |
| | | Warp | 0.28 | 0.39 | 0.30 |
| Control[a] | | | 0.17 | 0.094 | 0.012 |

a. HP premium inkjet paper

Due to differences in fabric structure, printing direction also has an effect for plain and twill weaves as can be seen in Table II. The effect of fabric structure will be illustrated by comparing image line quality for two plain weaves, #700-3 and #700-5. Scanned images of lines printed on these two fabrics are shown in Figure 2. Figure 3(a) and 3(e) shows lines printing in the warp direction along a warp yarn for fabrics #700-3 and #700-5, respectively. Notice the differences in the wicking patterns for the two fabrics. For fabric #700-3, when the ink drops fall on the filling yarns, the ink wicks in the filling yarn direction. Even though interlacing occurs with the adjacent warp yarn, the interlacing does not keep the ink from wicking under the adjacent warp yarn and can be seen through it. The ink wicks far enough that it can be seen two warp yarns over (the filling is on the surface) in some cases. When the ink drops fall on the filling yarns in fabric #700-5, the results are different. The interlacing appears to limit the transverse wicking. The ink wicks in the direction of the filling yarn, and the line is broader than when ink falls on the warp yarn. However, if any ink has wicked under the adjacent warp yarn, it difficult to see, and no ink appears to have wicked further. When lines printed in the filling direction on these two fabrics were compared, similar results were observed.

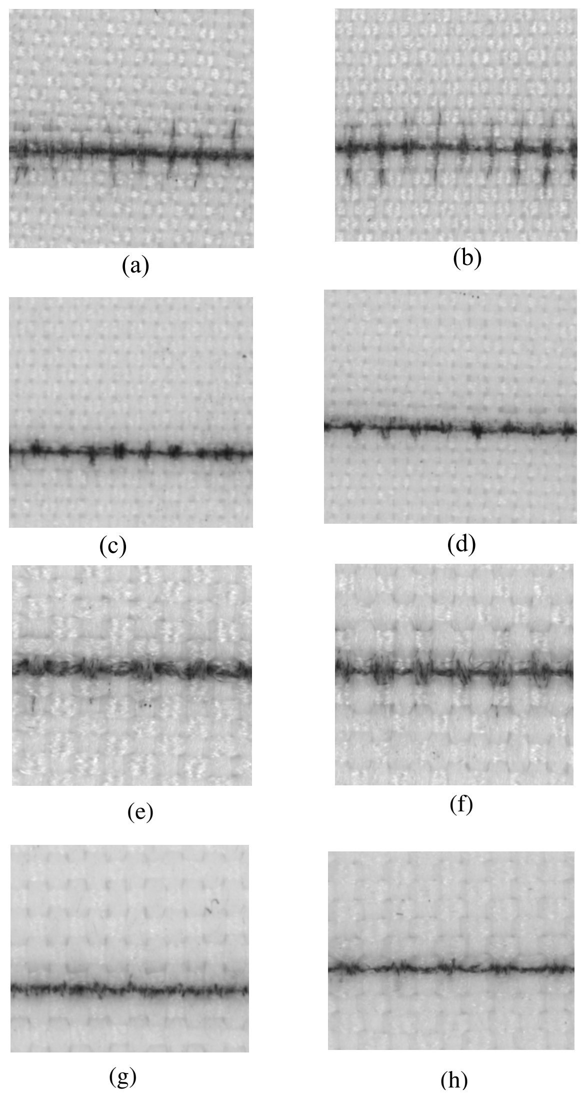


*Figure 2. Scanned images of unfinished plain fabric (#700-3)printed in: a) warp and b) filling directions; and scanned images of acrylic resin finished satin fabric printed in: c) warp and d) filling directions. Scanned images of unfinished plain fabric (#700-5) printed in: e) warp and f) filling directions; and scanned images of acrylic resin finished satin fabric printed in: g) warp and h) filling directions. Fabric printed with VersaPrint ink.*

The line image quality parameters for unfinished fabric clearly illustrate why fabric finishing is very important for printing lines on polyester fabric. Finish can reduce the effects of the fabric structure discussed above. Comparison of the line image quality parameters in Table II for fabrics finished with acrylic resin with unfinished fabrics clearly shows that finish can improve image quality. Comparison of the scanned lines for the three unfinished and finished fabrics, see Figures 1 and 2, shows that finishing with acrylic resin reduces, but does not eliminate, transverse wicking.

## Conclusions

The effects of printing direction, weave structure and finishing on image quality of lines inkjet printed on polyester woven fabric were investigated. Image quality for lines printed in the filling and warp directions are usually different due to asymmetric fabric structure. When ink drops hit yarns running transversely to the printing direction, wicking in the transverse direction may occur and reduce image quality. Due to the filling yarns floating over the warp yarns, line image quality parameters for 5-harness filling-faced satin polyester fabric are inferior to those for the plain and twill weaves used in this study. Applying finish to polyester fabrics can reduce the effects of the fabric structure and improve line image quality; however, finishing with acrylic resin reduces, but does not eliminate, transverse wicking.


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## References


1. Rossman, M., Paxar Corporation, Private Communications, October 2003
2. Tse, M., J. Briggs, Y. Kim, and A. Lewis, "Measuring Pint Quality of Digitally Printed Textiles," IS&T's NIP14 International Conference on Digital Printing Technologies, 250-256 (1998).
3. Fan, Q., Y. Kim, M. Perruzzi, and A. Lewis, "Effects of Pretreatments on Print Qualities of Digital Textile Printing," IS&T's NIP18 International Conference on Digital Printing Technologies, 236-241 (2002).
4. Fan, Q., Y. Kim, M. Perruzzi, and A. Lewis, "Fabric Pretreatment and Digital Textile Print Quality," Journal of Imaging Science and Technology, 47 (5) 400-407 (2003).
5. Test Fabrics, Inc. "Technical Catalog," 27-28 (2003).
6. Trident International, "Ultrajet™ Imaging Subsystem with Large Ink Supply-User's Manual," 10.1-10.25 (1997).


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