Speculations on Digital Textile Printing with PZT Printheads

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Introduction

The next great frontier for digital printing may be textiles. Of course, textiles were actually one of the first applications of digital printing. Recall that Milliken has been jetting designs onto carpets since 1975 using an air-valve deflection continuous ink jet with a production speed of 20 meters/ minute at 20 dpi. Today Seiren is digitally printing 10 million yards of fabric per year. And Canon has hardware for sale. Yet most digital printing has been reserved for coupon or sample printing and not production printing. This paper presents some basic requirements for production printing and discusses application of several types of ink jets. The potential and current usefulness of piezo-based printheads will be presented.

System Requirements for Digital Textile Printing

The many possible approaches to production textile printing might be divided into three scenarios as presented in Table I.

Table I
Textile Printing Scenarios

	Speed	Colors	Image Quality
Entry Level	17 yd^2/hr (20 m^2/hr)	8 inks	Process colors visible
Sampling	80 yd^2/hr (100 m^2/hr)	8 plus spot colors	Process colors visible. Rapid ink changeover required
Limited Production	80 yd^2/hr (100 m^2/hr)	12 to 16 inks. Wide range of spot colors	No visible process colors. Rapid ink changeover

The over all economy of the system must be practical. This implies high system reliability and printheads capable of jetting large volumes of ink at high line speeds. Inks must be engineered for specific applications with spot colors available via quick and efficient ink changeover. There will need to be inks tailored for particular fabrics and fabric blends. These inks need to be cost competitive considering ink costs as part of system costs. Print width should be 65 inches (165 cm) or more. Resolution should be at least 200 dpi for spot colors and greater than 400 dpi for process colors to be "invisible." There are at least a couple of major ink challenges: first, if truly agile manufacturing is to be achieved, the production system should minimize or eliminate wet post processing presently required; and second, for competitive costs to be achieved, jetted inks must improve significantly in efficiency of utilization.

Attributes of Ink Jet Printheads in Textile Printing Systems

Over the years, virtually every variety of ink jet has been used in imaging on textiles. Each type of ink jet offers some advantages and each has significant issues to be resolved before production level systems will be practical. For example in the mid-90's, Toxot, a division of Image, supported Embleme by supplying multi-level continuous ink jet printheads and water-soluble UV inks for T-shirt printing. The Embleme textile printer yields 40 to 60 T-shirts/hour. Toxot has also been constructing printheads for a six color, 2 meter wide digital printing system for vinyl floor covering. If this system were reconfigured for textile printing with 180 dpi multi-level continuous jets, the production rate would be about 12 meters/minute. Toxot and several other manufacturers of continuous ink jet printheads and inks have demonstrated applicability and dependability particularly for industrial applications. Among the problems yet to be solved are complexity and system cost.

Of all the types of ink jet printheads, thermal or bubble jets are undoubtedly the most successful. Besides their ubiquity in office and wide-format markets, they have been used to produce fabric proofs and limited production runs. The application of thermal ink jets to digital textile printing benefits from the economy of scale and design simplicity.

The best known thermal jet product is the Canon "Bubble-Jet Textile Printing System." Here a total of 21,760 jets print 8 process colors, 360 dpi, in a 65 inch wide format at print speed of 1060 ft^2/hr, about 1 meter/minute potential through put. This device has not yet achieved commercial acceptance for several reasons. Among these are the printhead failure rate (life is typically 12 to 16 hours of operation), image quality, and system cost. Also fabrics must be pre-coated to prvent bleeding and then post-treated by washing to fix color and then dried.

A major failure mode for bubble or thermal jets is kogation where reactive ingredients or impurities in the ink cook onto the heat resistor. These deposits build up over time causing jet failure. The heat resistor also suffers from normal wear due to the implosion of several thousand bubbles per second. Life of a printhead is typically 0.5 to 1 liter or 5 to 30 ml/jet.

There is considerable potential for improving bubble jet life. Changes in ink chemistry may reduce the propensity for kogation. There is the possibility of leveraging from continuing improvements in heat resistor manufacturing processes for office applications. Major improvements in printhead life are needed for production textile printing.

Piezo-Driven Drop-on-Demand Ink Jets

Some of the most exciting developments are with piezo-driven ink jet systems because this type of printhead is readily integrated into practical, cost effective systems and because there is the potential for simple designs with long printhead life. The term "piezo-driven" encompasses several fundamentally different printhead designs but none of these designs suffers from the inherent bubble jet failure modes; none exhibit kogation or thermal resistor breakdown. At least conceptually, it is possible to desing PZT-driven printheads with no wear out mechanism.

Seiren has assembled a system which integrates computer aided design, computer aided manufacturing functions and approximately 250 Sharp pievezoelectric ink jet printers. These printers image at 180 dpi across the width of the fabric and up to 360 dpi along the length. There iare considerable pre- and post-processing costs and the print speed is slow, but Seiren has succeeded by focusing on high value added applications where the high cost of digitally printed fabric is off-set by low energy usage, minimal pollution and reduced personnel costs.

One interesting, relatively new design is that of Xaar whose printheads print with solvent based inks. It is possible that Xaar-type printheads can jet water based inks if interior passages are properly passivated to protect PZT electrodes.

Epson multi-layer piezo printheads were originally designed for the office market with aqueous inks. These "permanent" printheads are proving highly reliable in office printers and may be very useful in textile printing at 360 to 720 dpi resolutions. At 14 kHz the Epson printheads are approaching useful throughputs. Roland has built a system combining an Epson printer with a fabric cutter for the non-textile sign market, but this 360 dpi system has potential for in-line fabric cutting and printing. One of the limitations to the Epson printheads is that ink viscosity must be relatively low, less than 5 cps. Also the Roland system apparently uses inks requiring pre- and post-treatment.

If only four scanning piezo heads are used, one for each color, then production speeds are going be suitable for printing samples. Arrays of printheads will improve through put but may introduce image quality problems; also the reliability of large arrays of piezo ink jets is unproved. Scanning several printheads can improve speed but requires precise printhead alignment. One possibility for a fairly fast textile printer might be based on the Idanit 162Ad printer which is currently being used in 4-color process printing of a variety of 1.5 x 2.5 meters sheet media. The printer uses about 5000 jets (Dataproducts PZT printheads) and has a throughput of 270 yd^2/hr (3.75 m^2/min), high enough for production. Today Idanit uses butyl acetate solvent inks which may not be suitable for many textile applications. In addition, the printer concept needs to be extended to continuous roll printing.

Spectra designs and manufactures printheads utilizing the shear mode of a large slab of piezo material. Printhead materials have been selected to be very chemically tolerant, important for reliable operation with a range of textile inks. One class of printheads is currently used in product marking and has demonstrated reliabilty of several hundred kilos of jetted ink. This is equivalent to more than 3 liters of ink/jet. A set of 256 jet printheads, one for each color, could be scanned at 300 dpi (10 kHz operating frequency) to give a production speed of about 20 m^2/hr for 72 inch wide fabric. The printhead is designed for easy color change over so that process colors and spot color printing are enabled. These printheads are designed to print with relatively high viscosity inks which may offer advantages in ink formulation for textiles. We at Spectra think that the printheads just described may be appropriate for entry level textile printing systems and that they may be extended to short run production systems.

Possibilities for Non-Traditional Textile Inks

Traditionally textile inks have been formulated for specific fabric types and used either dyes or pigments as colorants. Dye-based formulations require pre- and post-treatment of the fabric plus conventional curing. Depending on the type of dye, fixing may require washing fabric; frequently only 70% of the dye remains on the fabric. Effluants from post-treatment require careful handling to minimize environmental impact. Pigment-based formulations often are heat set and don't require washing after printing, but the resulting hand may be relatively hard and the image may not meet durability requirements such as dry cleaning and abrasion resistance.

Textile inks for jet-based systems require modification and these changes have to be made without compromising the final quality of the printed textile. Filtration requirements are stringent to prevent orifice blockage. This constrains colorants to dyes or carefully filtered pigment suspensions. Dyes must be carefully selected to minimize precipitation and undesired impurities. Also one can see from Table II that the range of fluid viscosity is rather limited for jetting.

Table II
Ink Viscosity Ranges for Ink Jet Inks

Aqueous Ink Jet	1-3 cps at 20 °C
Continuous Ink Jet	1-5 cps at 20 °C
PZT Driven Ink Jet	5-30 cps at operating temperature

Combine the requirement for relatively low viscosity with the imperative for high level filtration and high color strength and one can see that reformulation is more than just diluting existing textile inks. One needs special strategies for formulating spot colors with reactive dyes particularly in low viscosity solutions. Pigmented jet inks should be pre-mixable and fixation could take place at time of printing just as in traditional textile printing.

Successful jet textile inks must be reliable in the printing system. This will be easier to achieve with piezo-driven printheads than with bubble or continuous jets. Textile jet inks will need to offer increased colorant intensity relative to office jet inks because the absorbency of fabric is approximately 5 times that of paper. Ink jet printing systems should offer inks which reduce or eliminate the requirement for pre-treating fabric. The inks should also eliminate post-printing washing not only to enable point-of-use printing but also because post processing raises environmental issues. These attributes may be obtained by developing jet ink formulations which are very different from traditional inks. These inks might be based on fast reactions with specially activated fabric or slow spreading inks set with heat. Other possibilities are jetting two component inks or inks which are “dried” by UV light.

Conclusion

Digital printing of textiles will become increasingly common, moving from sample printing to production printing as systems are developed which capitalize on recent improvements not only in electronics and software but also printheads and inks.