Ink Jet Technology for Textile Printing

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Abstract

Ink-jet printing has been used for several years in the textile industry as a quick output for decision making based on printed samples of an original design. The preliminary work and cost of sampling are thus greatly reduced, and print design capabilities enhanced. Hopefully the development of production applications using ink jet technologies will shorten the time to print, and fulfill the strong industry need for quick response and fewer intermediate stocks. Different projects are under development in Japan and in Europe. Yet they do not seem to really answer the demands for short-run printing in terms of speed, costs and ink range. This paper describes how solutions based on the continuous, multilevel deflected, ink-jet technology could address these issues. The main technical challenges including drop generation with large width print heads, performance and availability of inks for different fibers, image processing and color rendition techniques are examined.

Introduction

Textile printing is a market area of huge proportions: 23,000 square kilometers of material are printed world-wide, each year. Since the introduction of the rotary screen process by Stork in the 60's,[1] the main printing technologies have made little progress. It is still necessary to make a printing mask (engraving a roller or a screen) for each color of a design. This step is costly and time consuming, and is identified as a major bottleneck in the Quick Response Manufacturing scheme. Digital printing technologies will inevitably replace older printing technologies. This has already occurred in the paper printing arena, where printing companies are beginning to use electrophotographic or ink-jet systems for short run production. Examining ink-jet printing for paper substrates does not provide all the clues to how textile ink-jet printing might be implemented. The differences in substrates, color gamuts, industrial processes, imply different solutions. For textiles, research and development on ink-jet printing has been on-going for many years. Current applications include carpet printing, textile proofing, and short-run printing.

Carpet Printing

The earliest developments in ink-jet printing of textile products were for carpets.[2] In this application, print resolution is very low (10 to 20 dpi). Print speed is not as demanding as for fabrics, thus few printing heads mounted on traversing systems can be considered as sufficient. It is usual to use pre-mixed colors.

Proofing

Ink-jet proofers are now common in the industry. A textile printing company will either purchase artwork, receive an order with a specific artwork, or ask its own in-house artists to create the artwork. Once the artwork exists, technical decisions have to be taken such as how many colors, which colors, what repeat length should be used, etc... As only 60 out every 100 designs become production designs, and only half of them will break even due to the costs of preparing print production on fabric (screens engraving, strike-off), some means is needed for color proofing all along the process in order to repeatedly check the pattern and the design. Proofing makes possible the approval of the customer before beginning the costly preparations.

High resolution samples may be obtained from proofers using the binary continuous jet technology and dot size modulation offered by companies such as:

- IRIS Graphics, for printing on paper or on a specific precoated cotton. Color management uses four primary colors (Cyan, Magenta, Yellow and blacK referred to as CMYK) without ink recirculation.
- STORK for sampling directly on fabrics using specific reactive dyes developed by ZENECA. It allows the printing on pre-treated cotton, rayon, silk, wool and linen. A conventional post-treatment (dry, steam and wash) is necessary. It uses 8 colors (CMYK, Golden Yellow, Orange, Red and Blue), and ink recirculation.

However, prints made by such proofers have print characteristics which differ notably from the final industrial screen printed product. Such proofs can therefore not be used as production approvals which require strike-off prints with representative inks and fibers. Their present use is generally limited to generating colorways. Large format ink-jet printers (like the HP DesignJet 750, the Encad Novajet,... all based on thermal ink-jet heads), currently used for printing posters, should also be able to serve this colorways application, with a good print quality (they offer print resolutions from 300 to 720 dpi, print format up to A0/E size, and CMYK color management) and lower prices than these currently dedicated proofers.

Short Run Printing

The other projects are focused on large width continuously printing system. Precursory projects include the ICI "Polychromatic" project in the early 1970's; the BURLINGTON dye applicator and printing prototype;[3] and the CSIRO "Stream Jet Deflection" technology in the 1980's.[4] The beginning of the 1990's have brought some new announcements from Canon, Seiren and Stork.

The Canon "Wonder-Print" system[5] is able to print 63 inches wide, with two rows of 8 printheads that contain 1360 nozzles each. The print resolution is 360 dpi. The printer's speed is 3 feet per minute. The system uses reactive dyes/acid dyes/dispersed dyes water-based inks, for respectively cotton and silk/nylon/and polyester. The system uses 8 colors (CMYK +4 specials colors—including light cyan and light magenta in some cases).

SEIREN, the largest fabric printing company in Japan, has its own ink-jet production system. Unconfirmed reports from Japanese sources[6, 7] have mentioned its capabilities of printing on cotton, silk, polyester, and polyamide, using reactive and disperse dyes. It is said to use Drop On Demand heads with a 180 dpi print resolution. SEIREN has already begun to supply the market with digitally printed fabric.

STORK is presently working with ZENECA, FELIX SCHOELLER PAPIER (Germany), and K.B.C., on a research program funded by the European Community. The program objectives are described as follows:[8]

- "improving the productivity from 10 square feet per hour to 200 square feet per hour;
- meeting ISO standard... with lightfastness rated at 3-4 and washfastness at 4;
- reducing the number of different colors to about one half of those currently employed".

The "FashionJet" machine, the first result of this program, was presented at ITMA 95 as a demonstration machine. It uses four colors (CMYK), multijet traversing print heads, with each head (one per color) having 10 jets, spaced 39 mils apart. The printed width is 4.6 feet and the present speed 15 feet/hour.

Limitations of Existing Systems for Textile Short-run Production Printing

None of the above described systems offer a real solution for production, as presently textiles are printed in widths ranging from 45 inches to 126 inches (most commonly between 45 and 75 inches), at a print speed in the range of 33 to 200 feet/minute. In order to compete with the present screen printing technologies for short-run printing, ink jet must offer at least:

- print speed in the range of 33 to 66 feet/minute;
- equivalent print quality to that obtained with screen printing;
- capability to run both pigment and dye based inks,
- reliability equivalent to that of the present screen printing machines,
- equivalent user costs.

Due to these demands, Drop on Demand (DOD) systems appear not well suited for this type of industrial applications:

- they are limited in speed by their low drop ejection frequency, and by the frequent need for maintenance operations (like wiping the nozzle face or discharging a small amount of ink outside the textile printing area) at each scan;
- thermal printheads have difficulties in handling pigmented inks on one hand. On the other hand their dye based inks which use extremely purified dyes are rather expensive.
- by nature, thermal printheads have a finite lifetime (order of magnitude: 1 billion drops per channel) and need to be replaced regularly. As an example, printheads with a lifetime of 1 billion drops per channel, functioning at 5 kHz can only withstand printing for about 56 hours before failure. This seems to be quite short from an industrial point of view.

On the contrary, the Continuous Ink Jet (CIJ) Multilevel Deflected technology (heavily used for industrial marking and coding purposes) has some advantages to address these issues.

Main Features of TOXOT's Multihead Printing Technology

CIJ Technology

In this technology, ink is forced at high pressure through a small nozzle (from 10 to 100 microns in diameter). The emerging stream of ink breaks into small droplets. In the non stimulated case, the cylindrical is allowed to spontaneously form droplets at a non uniform rate due to noise and amplification by the surface tension of the liquid. Usually, the drop formation is forced by stimulating the ink in the reservoir at a high frequency (typically 100 kHz), with a piezoceramic transducer. This causes the jet to break up in a regular and controlled manner. After creation, the drops need to be selectively controlled so that images can be formed. Electrical charging and deflection of the drops is the most frequently used technique. A variable electric charge is imparted to the drops by placing a charge electrode at the point of jet break up. The charged drops are then deflected when they subsequently pass through an electric field which is created by applying a high voltage between a pair of electrode plates.

There are two methods of printing. In the first one, the charged drops are used for printing. The distance at which such drops are deflected is proportional to their charge. The uncharged drops are collected in a gutter. This is referred to as the multilevel deflected technology. It is, for instance, possible to control up to 30 different dot positions per nozzle. In the second method, the uncharged drops are used for printing, while the charged ones are collected by the gutter. This is referred to as the binary method. Only one dot position is possible per nozzle. This, of course, increases by more than an order of magnitude the number of nozzles needed to print a given width. This may not be the ideal solution both for reasons of cost and reliability. As for the multilevel method, the ink collected in the gutter can be recirculated.

Technical Challenges

Ink Formulation. In designing ink-jet printing devices, one of the difficult tasks to consider is the formulation of the ink. Ink-jet ink formulation requires compromises between print quality, nozzle maintenance and dry time. Continuous Ink-Jet offers the potential of a wider range of inks. Clogging problems, due to evaporation and crusting at the nozzle are less frequent due to the continuous running of the jet.

Today more than 50% of the traditional worldwide textile printing is done using pigmented systems. As the size of particles in the ink is of particular importance to avoid problems with nozzle clogging and sedimentation, ink-jet has more difficulty to deal with pigmented inks. New means to characterize and to tailor the formulation of textile water-based pigmented ink-jet inks either thermally or Ultra-Violet curable[9] have been recently developed. Printing on cotton, polyester-cotton and polyester is now possible with good washing and rubbing fastness as shown in Figure 1. Reactive and disperse dye based inks are also under development.

in all tests, best result rate is 5	Thermally curable inks	UV curable inks	State of the art for pigment screen printing
Cotton (Washing at 95ºC)			
Change in color	4	3-4	3
Staining	4-5	3-4	3
Polyester (Washing at 60ºC)			
Change in color	4-5	1	3
Staining	4-5	1	3
Poly-Cotton (Washing at 60ºC)			
Change in color	4-5	3-4	3
Staining	4-5	3-4	3

Figure 1. TOXOT Textile Ink Color Fastness to Washing (ISO 105-C06)

Print Quality. This is too often viewed as a consequence solely of print resolution. Many other parameters have a significant impact on the print quality:[10]

- the print addressability (distance between printable dots);
- the print accuracy (reproducibility of respective dot positions);
- the printing process: single or multiple pass, interleaved printing;
- the color separation process;
- the halftoning process (gray level management);
- and the ink/substrate behavior (feathering, bleeding, color mixing,... etc.), implying a profound mastering of both the pre and post-treatments.

The multilevel deflected continuous ink-jet technology offers advantages to master the first three points. It is, for instance, possible to use the same print head at different addressabilities using different drop trajectory configurations. Dot positioning can be adjusted using the charging process, thus offering an easy way of correcting possible nozzle plate defects.

Color Rendition. Until recently, ink-jet printing used mainly a trichromatic approach with four primary colors: Cyan, Magenta, Yellow and Black. These inks are provided to the printing heads and mixed (color dots superimposed or laid down next to each other) on the printed material. Compared to conventional textile printing which uses a separate screen for each of the colors required, the resulting color gamut appears to be insufficient for textile printing. A solution is to use between 6 and 8 primary colors.[5] This can be handled quite easily using a larger number of print bars.

The ability to produce both light and dark shades is also very important. Whatever the halftoning method used, a single density per color often leads to a poor image quality linked to a grainy appearance of the image for the light tones. Using dual ink densities per color provides improved results.[5, 11]

Another approach is the use of premixed "spot" colors. Having only solid color to print minimizes the complexity of halftoning algorithm, taking full benefit of the dot resolution (120 dpi) of our first implementation.

This also simplifies the necessary color correction at the printing stage caused by small differences in the substrate absorbency between batches of fabric which may be of different origins. In this situation, fast change of ink with minimum material waste is essential. An ink management system able to change color in a 75 inches wide print bar in less than 2 minutes,[12] minimizing ink waste, was therefore developed.

Drop Generation and Charging with Large Width Printheads: In order to reach the required speed, the use of large width printheads appears mandatory. A multijet array printer, similar in general principle to the one developed by ICI in the 1970's, was developed. In contrast to ICI's the print-head is based on small print modules which can be put side by side to form a single print bar.[13] A major difficulty is the control of the jet breakup into drops devoid of satellites at well defined distances from the nozzle plate. The latter restriction is particularly stringent due to the induced acoustic crosstalk when operated in multijet devices.[14] Special care has also been paid to the fabrication of the electrode system comprising several layers of ceramic appropriately metallized using thin layer technologies. This allows to obtain charge, detection and deflection electrodes for 8 jets all in one single block.[15]

In its first implementation, each module prints 1.34 inches in width, using 8 jets. Print resolution is 120 dpi and continuous printing speed is 65 feet per minute. This is an order of magnitude higher than the Canon " Wonder-Print " system,[5] and more than two orders of magnitude that of the "FashionJet" machine developed by STORK et al.[8] A first machine (19.7 inches wide, 6 colors) has been in use for printing floor coverings since the beginning of 1994.

The critical steps in our development were achieved with success by leveraging on the progress made in data processing components and especially in their integration. For instance, each module has its own intelligent circuit board which is able to control in real time the behavior (break-up, charging, synchronization, and recycling) of close to 700,000 drops per second.

Conclusions

Proofing on textile using ink-jet is now available with immediate positive impact in the textile industry. By delaying the costly engraving operations, it already expands textile printing marketing opportunities. Full width continuous printing of fabric represents the actual industrial challenge.

Present systems based on thermal ink-jet seem to us to have limitations in terms of printing speed, range of ink and printing costs. Systems based on the Continuous, multilevel deflected, ink-jet technology, with modular multijet printheads provide a better suited solution since they offer:

- larger printing widths (up to 158 inches), able to print at the requested speed;
- possibility to use the same technology both for sampling and production;
- dye and pigment based inks;
- permanent printheads;
- high reliability through complete electronic control of each jet.
- a medium range resolution, sufficient for most applications and which can evolve towards 200 dpi without major technical difficulties.

The technical barriers to production-speed digital imaging on textiles are falling. Even if it is difficult to predict how quickly the better suited ink-jet technologies will enter the textile printing business, changes are at hand. However it is likely that the success of any industrial ink-jet project will also depend on the capabilities of a group of players all along the textile chain and their ability to work together in partnership: from fabric to printing through chemicals, up to apparel, distribution and retail.

Acknowledgments

The authors wish to thank Dr. Arthur Soucemarianadin for useful comments and discussions.

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