

Digital Printing of Textiles, Obstacles & Overview

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Abstract

This report discusses the current state of, obstacles to and prospects for digital textile printing.

Methodology

The author interviewed technology and textile market developers, reviewed available literature, and tested digitally printed fabrics to collect the data for this report. I wish to specifically thank Dr. Ray Work, Sean O'Neil, and David Key of DuPont, Judson Early and Keri McQuire of TC^2, Chris Quain of Jetmark, and Patti Williams of IT Strategies for their reflections on ideas presented herein.

Overview

Direct digital printing of textiles has won market acceptance as a print proofing and design sampling method. Stork, Scitex Iris, and Encad have produced inkjet sample printing systems which are serving the textile market. Canon has developed a short-run production bubble-jet textile printing system. Seiren of Fukui, Japan has harnessed piezoelectric inkjet printing for short-run textile production. Others have used indirect or transfer digital printing. Apparel Technologies is creating electrostatic transfers for printing on synthetic fabrics, including polyester, micro-denier polyesters, polyamides (nylon) and elastomeric fabrics. It provides these in both sample and short-run production quantities. Service bureaus which cater to the textile design industry, such as RothTec Imaging and Showbrand Photo in New York City, are using inkjet systems, such as Stork's TCP-4000 series continuous inkjet and Encad's drop-on-demand thermal textile inkjet systems.

A number of digital printing technology developers are advancing printing devices for textile printing. In my NIP-13 paper , I reported on the successful, aspects of four digital textile printing systems, along with their not so successful ones. They included textile printing systems that Seiren, Canon, Toxot, and Stork developed. Since that report, Encad and Mimaki have introduced integrated digital textile printing systems. Calcomp and its partner Scitex Iris are reintroducing the CrystalJet for textile sampling and short-run production. A number of developers have targeted the 1999 International Textile Machinery Association (ITMA) show in Paris for the release of digital textile printing equipment. Reportedly as many as a dozen new textile printing systems will debut at ITMA.

Obstacles

Last year at NIP-13, I presented a paper which listed a number of "failure modes" for the development of digital printing systems. That analysis restated the obvious that digital textile systems failed because they were in some way inadequate. They were inadequately integrated, financed, not developed fast enough or did not print fast enough to satisfy market demands. They could have arrived too early or too late to meet changing market needs. They could not produce an adequate range of color to match customers' wishes. They failed to win adoption because they, their inks or media cost more than potential users could justify. I circuitously defined inadequacy as failure and failure as inadequacy.

This paper attempt to make amends by specifying both financial and technical obstacles which stand in the way of broader market adoption of digital textile printing technology. This examination of those obstacles also suggests ways around them.

Economic Factors

Who Benefits From Digital Textile Printing?

Dr. Ray Work asked this question of others and myself at an informal discussion on the state of digital textile printing. Those in attendance agreed that designers and retailers were the ones to benefit from digital textile printing. It could reduce their inventory risk, provide quick response and just-in-time delivery of risky fashion items, empower designers and retailers with digital design and specification tools to control the textile printing and product manufacturing process and its results. Chris Quain of Jetmark noted that manufacturers of equipment and supplies for digital printing textile also had something to gain. Current printers and jobbers do not, which may explain in part why current textile printers have been slow to adopt digital printing.

Conventional analog textile printers, such as rotary screen printing operations, which print about 65% of the world's textiles, have a large capital investment in equipment from which they expect a continuing return. Some of these companies also use digital proofing to sample a portion of their output. Vertically integrated plants for the home furnishings market reportedly digitally sample about 35% to 50% of their output before printing analog production runs. They use systems such as Storks TCP 4000 series of inkjet match-to-print proofing devices. Many years will pass, however, before production digital printing enters these plants, because their run lengths are relatively long and current digital printers are meeting some of their design sampling needs.

These printers and their equipment suppliers are first working to reduce turn around and set up time and expense. Almost 100 rotary screen printers have adopted solid inkjet printing to mask emulsion coated screens prior to exposure in order to reduce delays associated with engraved screen making methods.

Print runs have been decreasing in run length per colorway. Stork reports in its last survey of Developments In The Textile Printing Industry the following figures for average run length per colorway in meters:

Printing Method	1989	1992	1994
Rotary Screen	4520	4160	3520
Flat-bed Screen	2320	2030	1680
Roller Printing	6200	5410	4600

Stork's survey discovered that run length decreased in all world regions.

I interviewed three U.S. rotary screen printers in mid-1996 to discover if this trend was continuing. All reported continued decline. The average run length per colorway for these printers was about 2,400 yard. Frederick Noll, of Imaging Technology Consultants, reported an average run lengths of 2500 yard in his presentation at the 1st Digital Printing of Textiles Briefing in May 1997. Printers are currently reporting further decreases in average run lengths. Recent reports indicate that run lengths have decreased to under 2,000 yards in North America and just over 1,000 meters in Europe. The Stork survey underscores the task for its industry, "Because of these short run lengths, printers will have to pay more attention to efficiency. The flexible deployment of people and machines is getting ever more important."[1]

These demands particularly stress non-vertically integrated operations. These jobbers are increasingly being asked for shorter print runs, while their print technology is most cost efficient for much longer runs. The low cost and acceptable quality of textile printing from developing economies is driving the developed world's jobber textile printers out of business. Those that remain are targeting high value added niches, such as printing elastomeric, micro-denier fabrics, and fashion fabrics. Short-run digital printing could assist these printers in satisfying market demand, but these businesses are unlikely to reinvest in new technology when under financial strain, on one hand seeing printers in developing countries garnering the long-run commodity business and on the other hand, short run printing either moving closer to the design studio or into an agile apparel manufacturing facility.

The chain for the production of apparel in the U.S. has many links and resultant inefficiencies which add time and money. Retailers and designers are trying to shorten this chain, consolidating links, reducing cost and improving turn-around. This process is redefining where textile printing takes place. Digital textile printing enables it to occur very close to, if not at, the point of purchase. It places control of the process in the hands of the designer and with easy to use programs the final customer can be the designer.

In my NIP-13 paper, I compared four models. Only the Seiren and Stork models are actively printing textiles in significant quantities or at multiple locations. Encad's textile printer has now entered this group with an increasing installed base. They contrast with the Canon and Toxot models in capital cost. The Stork and Encad device target textile design sampling. Neither answers all customer demands, but they both have addressed customer needs sufficiently to win adoption. Who benefits from these devices? Designers, retailers, the equipment and supply manufacturers benefit.

Seiren continues to stand alone as the world's largest producer of fabric for non-floor covering markets. It uses many piezoelectric inkjet printing machine rather than relying on a few larger print devices. This permits greater flexibility in responding to market needs. Seiren continues to enjoy high demand for its digital printing, despite Japan's economic recession.

Customers who want personalized or customized printing also benefit from digital printing. Indirect transfer digital printing currently provides solutions for many of these needs. Personalizing and customizing items with digital transfer printing now generates over $6 billion in sales in 1997 and is growing at about 28% per year based on sales of transfer papers.

Weather direct or indirect, customers, designers and retailers are gaining control of the textile printing process. It is moving closer to them through textile printing service bureaus located at the design centers of New York, Los Angeles, Paris, and Milan. Textile designers are buying digital printers for design sampling. Mall kiosks are offering customers to design their own digital printer heat transfers. Sites on the internet are offering customer similar choices. Retailers benefit in eliminating much of their inventory risk, while customers benefit with increased choice and selection.

These trends suggest that smaller less expensive printing devices will win adoption faster than large industrial based printers. Those who will benefit from digital textile printing are those who will buy it. As the industry economic model for textile printing continues to move long run production commodity printing to printers in developing countries, digital printing will satisfy quick response high value added needs closer to the customer.

Development Time For Digital Printing Systems

Idanit surprised many developing its 162Ad printer in a mere two to three years. Digital printing equipment development usually takes much longer and profitability from such development longer still, if ever. The development of technology requires time and entrepreneurial commitment, belief and investment. Canon and Hewlett-Packard demonstrated this commitment for the long-haul during the late 1970s and 1980s when they developed thermal inkjet printing. Their persistence eventually paid off with profitable sales in the 1990s. Dr. Ray Work termed this necessary ingredient as "passion". He suggest that any new print technology requires at least ten years to bear fruit. The speed of the Idanit development was in part due to its use of proven Dataproducts piezoelectric print head technology. Integrating other elements, particularly ink and software, demand time to perfect the marriage and eliminate bugs.

The need for time in technology also requires money to sustain efforts and finance inevitable errors. Smaller companies will often generate useful inventions and concepts. Larger companies are usually better suited to develop these and defend their patents. Invention requires sufficient finance to carry them to realization and profitability.

Technical Limitations

Process Color Limits For Textile Printing

Four color process color can matches about 60 to 65% of the available textile color gamut. Stork and Zeneca claim that their eight color match-to-print system can replicate about 90% of available textile dyes. In short process color can not replicate spot color textile printing exactly. One needs spot color to match spot color for sampling. Spot Colors can cover the full range of color. They reproduce color without the muddying which can accompany process color.

Spot Color & Automating Color Kitchens

Spot color based digital printing will require extensive color database software, automated color analysis, and computer controlled ink dispensing and mixing. Inkjet printing inks are high technology mixtures which require precise controls, especially when mixed with other colors. Such a system would have to accommodate twelve to sixteen primaries, as well as special colors like fluorescents and metallic colors. It would have to be able to mix and dispense both pigments and dyes. The difficulty of forcing metallic particles through inkjet orifices will likely impede their use for some time with inkjet printing. Conventional color kitchen systems lack the controls which an inkjet ink system would require. The complexity of creating such a system is a strong force for retaining process color approaches for digital printing.

Ink Deposition & Textile Printing

How much ink is enough? Conventional analog printing methods, such as screenprinting, deposit an excess of colorant to achieve color saturation. They can deposit sufficient binder to achieve acceptable pigment adhesion to fiber. Inkjets, on the other hand, deposit thin layers of ink which are vulnerable to abrasion and fading. These devices operate at significantly lower viscosity levels which limit the amount and type of polymers which can effect the bonding of pigment to textile fibers.

The movement toward higher resolution and finer droplet sizes which preoccupies developers of inkjet for paper printing diverges from the need of textile printing for lager ink volumes to achieve desired color saturation and dye penetration of textile fiber.

Fabric Pre-Treatment

Stork and Encad have had the textiles which their printers process pretreated so as to compensate for their inkjets' limitations. These coatings add considerable value and cost to these fabrics. The market will tolerate these costs for sample printing since digital printing has a significant cost advantage over analog sample printing. The market, however, will not accept these costs for production printing. Almost all printed fabrics carry some pretreatment. Interviews with textile printers and buyers suggests that they will not purchase these fabrics for production printing if the cost of pretreated fabric for production digital printing exceeds the costs of pretreated fabrics for analog printing by more than 10 percent.

Waiting For Chemistry

Inkjet textile printing is waiting for chemistry. Zeneca, Ciba, BASF, DuPont and others are working to create inkjet printable colorant which will meet market demands. System developers must integrate ink chemistry with printhead technology and the drying-curing element which are part of a printer's material handling system.

Dyes and Pigments

People naturally resist change and will change as little as they must. Fashion designers and the public for which they work have grown to want the range and intensity of color, the wash fastness and fade resistance which conventional textile printing methods provide. Inks for ink-jet digital textile printing require high levels of refinement to operate without printhead failure, a means for pigmented ink to remain in suspension and not coagulate, and provide the coverage, color density, and fastness characteristics of textile screen printing. They must accomplish this without requiring fabrics with costly coatings.

Dyes require a level of refinement but do not require binder to adhere them to print textiles as pigments do. One can use dye-based inks at the very low viscosity levels (under 6 cps) which continuous, thermal, and Epson piezoelectric inkjets require to operate. Pigmented inks can also operate at low viscosity but sacrifice binder and typically require assistance from a substrate coating to adhere to it. More robust piezoelectric inkjet printheads can squirt ink viscosity in the range of 8 to 25 cps. This enables pigmented and dye-based inks to incorporate polymers which improve adhesion to textiles, wash and crock fastness, and permit the incorporation radiation curable polymers .

Since designers, retailers and agile apparel manufacturers are potential new digital printers of textiles, they will require minimal to no post-processing of textile prints. Radiation curing and compact steam fixing of both dye-based and pigment textile inks will bring textile printing from large plants into quick response fashion manufacturers, garment district service bureaus, and design studios.. New UV eximer curing from Fusion Systems, for instance, could provide a means for reducing the use of photo-initiators in UV curable inks and assuring complete cure.

Purging Color From Print Heads

If one is using spot color with inkjet print heads, one will have to purge this system as frequently as one changes color. Some printhead designs are better suited to effect these changes than others. The design of Sharp piezoelectric printheads, for instance, permits rapid purging. Also purging will result in some waste ink. Continuous inkjet systems are somewhat more amenable to purging than drop-on-demand printers

Focusing On Print Technology

Manufacturers have concentrated on liquid inkjet technology for wide format direct textile printing. Other digital technologies are used to print textiles. Color laser copiers and printers can produce effective transfer prints for a range of fabrics and fibers. Ricoh's recent introduction of a 36 inch wide output monochrome laser printer, with organic dielectric coating on its fuser roller, presages laser multi-color printers. Laser electrophotography can use UV resistant pigmented resin toners which could perform on fabric wall covering, wall paper and possibly directly on vinyl. Thermal transfer, solid inkjet and electrostatic printers also produce transfers for textile printing. Inkjet, however, offers the most promise for printing textiles.

Thermal inkjet is proving useful for textile sample printing as the Encad textile printer and HP wide format printers are demonstrating. These, however, require printing on high cost coated fabrics.

The focus for short run production printers has shifted to continuous and piezoelectric print technology. Stork TCP 4000 employs high resolution Hertz continuous inkjet printheads for creating design samples using dye-based inks. The textile world awaits Stork's latest version of continuous inkjet to appear at ITMA 1999 in Paris. This device promises to print eight dye-based colors at 20 meters per hour throughput. Epson printheads have proven useful for printing coated fabrics, and sublimation transfers but suffer similar limited usefulness as thermal transfer applications since they can not process inks with viscosity above 5cps. These high resolution heads and those from Hewlett-Packard may find application for print lines and contour edges as part of a hybrid system with other piezoelectric heads. The small droplet size of these printheads (As fine as 10 picoliters) insure their limited usefulness for textile printing which requires higher colorant deposit levels to achieve coverage and color saturation on the range of fabrics. More robust piezoelectric inkjet technology from Spectra, Xaar-Brother, Trident, Dataproducts, Topaz, and Inkjet Technologies are moving into the spotlight.

Textile printing requires printheads which can tolerate water and fire reliably. Textile printing economics requires that the heads be low cost and capable of being mass manufactured with a high level of consistency and repeatability. The nozzles must be reliable generating the desired droplet sizes consistently. In order to obtain resolutions in the target range from 200 to 360 dpi, and acceptable production speeds, printer manufacturers will have to arrange printheads in arrays. The larger the number of printheads the higher the potential resolution and print speed. Printhead cost will have a most important role to play in determining which heads manufacturers choose.

Nozzles Clogging, Cleaning, & Monitoring

One of the major failure modes for inkjet printing is nozzle clogging. Equipment developers have been employing a battery of methods to maintain nozzle openings, monitoring their performance and compensating for there failures. Nozzle plate wiping, printhead fire through, capping, and some form of computer monitoring are becoming standard for and increasing number of inkjet printers. Textile printing heads will require monitoring and cleaning due to possible lint build-up.

Cutting, Finishing & Sewing

TC^2, Gerber, & Lextra are actively developing cutting, finishing and sewing systems to complete the work of digital textile printing. One scenario uses inkjet printhead to apply a chemical cutting agent on textiles. TC^2 has developed and patented a number of digital cutting and printing strategies which further the goal of agile textile manufacture.

CCD arrays, laser and photo locators are helping to manage print registration for printing, cutting and processing of dimensionally unstable fabrics.

Novel Digital Printing Technologies

Amid the emphasis on inkjet, particularly piezoelectric inkjet, one should not loose sight of new digital technologies on the horizon which will in time replace inkjet printing. This will include both higher speed printing mechanisms and even some nozzle-less print technology. Funding will make some of them possible in decades to come.

Conclusions

The World Market for textiles is very price competitive. The collapse of Asian currencies insures that the trend toward the export of commodity textile printing from the developed world will continue. Designers, retailers and quick response manufacturers are most likely to acquire the control which digital printing offers them. This control enables retailers to shorten the textile and apparel production chain and increase their profitability. Printer producers will have to design their systems to fit the needs of these users in order to gain their business.

References

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