Inkjet printing—A revolutionary ecofriendly technique for textile printing

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Some of the aspects of inkjet or digital printing, such as comparison between conventional and digital printing, digital printing systems, suitable inks based on dyes and pigments, colour management software, application and future scope of digital printing, are briefly discussed in view of the demand-activated manufacturing architect to satisfy the changing fashion trends and new market requirements.

Keywords: Inkjet printing, Rotary screen printing, Textile printing

1 Introduction

In ITMA 1999, an array of different technologies for digital printing on fabric was presented. Though the idea had been around for nearly 15 years, it was not until now that equipment adequate enough for production on textiles was shown. However, the different competing technologies that were displayed showed a lack of clear-cut direction and served only to confuse buyers, most of whom were unexposed and uneducated about the capabilities of these technologies. Educated buyers were wary of purchasing a technology that might be obsolete by the end of the year. However, as we moved through the year 2000 into 2001, the development of bigger, faster and better print engines capable of increasing print speeds is being reported. The commercial availability of this technology will redefine the way the traditional textile producers run their business. The importance of understanding the process and building experience with the current technology cannot be underestimated.

This paper briefly discusses some of the aspects of digital or inkjet printing, such as comparison between conventional and digital printing, digital printing systems, suitable inks bases on dyes and pigments, colour management software, application and future scope of digital printing.

2 Trends Influencing the Emergence of Digital Printing

Worldover, 11-13% of the textiles produced are printed. This amounts to nearly 27 billion running meters of textile material. Dynamics of global trade has been pushing the print production towards the developing countries. As a result, Far East has the major share of 50% with the USA having only 11% and the EU, 15%. A major reason for this shift is the long, polluting and capital intensive nature of conventional textile printing. Digital printing has the potential to reverse this trend.

Changing fashion trends and new market requirements are also pushing the drive for digital printing. The most influencing factors are:

- Personalization and quick response: rapid fashion change necessitates quicker transposition from design to production and shorter print runs as a consequence.
- Design piracy: original designs are copied very fast and repeat orders are rare. Speed in transposition and quick potential profit realization are important.
- Printing on new and unusual surfaces: printed made-up products, engineered prints, and technical textiles are demanded by customers.
- Environmental constraints: environment-friendly wear properties and production processes.
- Pressure on costs: short fabric lengths mean shorter inventories and saving in storage space.

3 Conventional vs Digital Printing

If one considers conventional textile printing, it is immediately obvious that the variable with the greatest effect is fabric length. For long lengths, analog printing technology like rotary printing is fast (30m/min on an average), continuous and economical. The colour gamut is wide and no special pretreatment of fabric is required before printing.
For short runs, however, the process is uneconomical owing to high downtime, high wastage of fabric and inks, high engraving cost, high labour cost and cost of time spent on colour-matching, paste making, sampling, design, registration, etc. Operations like screen engraving, print washing, and screen washing add significantly to the pollution load. Design sampling or proofing is particularly a very lengthy and expensive process (Fig. 1).

Digital printing, therefore, offers distinct advantages for short runs, sampling and proofing. There are no screens; consequently, all costs pertaining to screen engraving, paste making, strike-offs, downtime and wastage are eliminated. There are no registration problems and unlimited choice in terms of repeat size is available. Any number of colourways can be printed. Inventory and pollution control costs are minimal as all the dye goes onto the fabric, no thickener or paste is used and, water and energy consumptions are low. The technology is amply suitable for just-in-time deliveries and mass customization.

The technology is, however, still limited by low production speed, low availability of fast and low-viscosity dyes, and small size of colour cartridges. Fabric must be specially prepared to be able to run on these printers in open width condition and absorb dyes quickly. Many pigments, like pearl, metallic and white, are not yet available for printing through these printers yet. Material handling is also limited. Stretch knits and performance fabrics are not printable as yet. Durable solutions for post printing operations like print fixation and finishing are yet to emerge.

4 Digital Printing Systems ¹⁻³,⁴⁻⁶

A digital printing system for application on textiles is an integration of four components, namely the inkjet head, ink chemistry, media and the colour management software. For each component, various technologies and suppliers exist. Based on the choice of level of technology available today, two major types of system, namely the Drop-on-Demand (DOD) and the Continuous Ink Jet (CIJ), have emerged (Fig. 2). The most important features of the inkjet printer are the printing head and the nozzles. In case

![Fig. 1—Conventional vs digital printing](image-url)
of both these technologies, numerous nozzles are used for each colour. These nozzles are 10-100 μ in diameter, providing a resolution of up to 720 dpi (dots per inch). Between one thousand and one million ink droplets are processed per second.

Many digital printing solutions have been made possible through integration of the experience of different companies, specializing in their respective fields. One such group is Ciba Speciality Chemicals, Sophis and Mimaki. Another is Ciba Speciality Chemicals and Digital Printing Systems (Aprion). A third group having dye heads Zimmer (Austria) and Jemco (Israel) and ink head DyStar is developing a new printer which is claimed to be able to achieve production speeds of 200 m/h. This printer named "Cromotex" is being designed for fabric widths of 2 m and printing eight pre-mixed colours with a resolution of 100 and 125 dpi.

4.1 Inkjet Heads

In DOD system, the drops are generated and ejected when required. Drops can be generated either by a bubble (thermal) jet or a piezo crystal. These print heads are relatively simple and cheap; however, their life and applications are limited. Only very small droplets are generated. Consequently, a very large number of nozzles are required to get acceptable results. Thermal jets are inexpensive, use water-based inks and produce a very fine droplet size. Piezo crystals can use any type of dye or pigment and are more suitable for high volume printing.

Continuous inkjet, on the other hand, generates droplets continuously, but only the required droplets are directed towards the target spot of the fabric by electric charge and deflection. Unneeded droplets are redirected to a gutter. CIJ printers are further classified into two types: binary and multi-deflection. The binary systems are expensive and not adapted to process colours. Multi-deflection systems are cheaper, allow for larger drop size and multiple dye types. They are, therefore, well suited for textile printing at high speed.

4.2 Ink Chemistry and Media

Inks for digital printing require special control on parameters like viscosity, conductivity, surface tension, chemical stability, physical stability, pH and foam-free properties. Without the colour chemistry base and in-formulation technology, the particle size distribution required for such inks is not possible. A further requirement is ideal combination of ink and substrate.

BASF and Ciba Speciality Chemicals (Table 1) are the two major manufactures of reactive inks for cotton and cotton blends, emulsion inks for PET, acid inks for silk, polyamide and wool, and pigments for all types of fibres.
Another choice for the manufacturers of inkjet products is to use dye- or pigment-based inks. According to most industry experts, this choice should depend on the desired application. Dye-based inkjet inks use a liquid colourant, that is usually water-based, to turn the media in specific colour. Because of their makeup, dye-based inks are not waterproof and tend to be affected by UV light. This results in the colour changing over time. For optimum performance, this type of ink also requires a proper media, selected according to the application. If the media is too dense, the ink can’t penetrate and beads on the surface. If the media is too absorbent, the dot gain is too high.

Pigmented inks use a solid colourant to achieve colour. The line quality and accuracy of plots produced by pigment-based inks are usually superior to that of dye-based inks. With this process, the solid particles adhere to the surface of the substrate. Once the water in the solution has evaporated, the particles will not go back into the solution, and are, therefore, waterproof. In addition, the pigmented inks are much more UV-resistant than dye-based inks, and hence it takes much longer for noticeable fading to occur. Another advantage of this ink is that the choice of media is much less important.

Given these facts, it would seem that the future of the inkjet industry lies solely with pigmented inks. This, however, is not the case as inkjet manufacturers foresee continuing production of both pigmented and dye-based inks. One reason for this outlook is that presently dyes are much more suited to everyday applications, run cleaner, provide better yield, offer better particle size and are easier to filter.

Inks are used by the printer in two ways—process colours and spot colours. Process colours are generated on the fabric by mixing and exactly placing multiple single drops. When printing on paper, just four basic colours (cyan, magenta, yellow and black) are used, while for printing on textiles, usually 4-12 colours are used. Eye blends the individual colours to create the required colour shade. Theoretically, an unlimited number of shades are available. Spot colours, on the other hand, are premixed dyes (as used for screen printing) giving exact shade reproduction, increased coverage and thereby higher productivity.

4.3 Colour Management Software

Digital printing software controls design, colour calibration, colouration, colour resolution, inkjet printer control.

The design, scanned or produced with creative software, is translated into a high-resolution image file. Interactive functions, such as the repeating of the pattern, retouching or processing of half tones, cleaning-up and defining of the contours, are the basic requirements. Ordinary design software packages, already widely used, such as Photoshop, Painter, Freehand, etc. offer good value. A design created in this way is already based on digital data and can, therefore, be further processed without loss in quality and in the shortest possible time.

The simulation of print samples by inkjet printer should replace the sample table. The use of multiple colours, which is synonymous with textile printing, can be achieved now-a-days with the printers that use up to 16 different colours. This enables colourations made up with colour mixtures and spot colours. Calibration of the inkjet printer is indispensable and the only way to achieve a true translation from computer screen to print result.

Those companies, which have already experimented with digital proofing, have experienced the
potential cost savings possible with this method. By an estimate, approx. 6% can be saved in screen production, and as much as 20% in sampling by digital proofing. The labour cost of conventional sampling is also higher than that of the production of printing screens.

4.4 Process Engineering
The knowledge of the processing chain is the printers’ most valuable know-how. Pre- and post-treatments of the printed fabric enable fashionable effects and add value to the textiles. The cooperation among printer producers, chemical industry (inks) and finishing companies (pre-and post-treatment) results in complete package.

If pre- and post-treatments are carried out by third parties, a problem of logistics arises. In view of this, the textile machine producers have come up with a new solution for those companies that do not have sufficient facilities for pre-and post-treatments of the fabric. Printing systems with integrated pre-and post-treatments are now made available, for instance by Arioli (Italy).

5 Applications of Digital Jet Printing
Sampling or proofing is the most obvious use for digital jet printing as its conventional cost in the textile industry is extremely high and producers are under constant time pressure.

In Western Europe, the production of printing screens costs about US$ 400 per colour. Proofing, from the conception to printing on fabric, takes a minimum of 4-6 weeks. If 20 designs/collections with an average of 8 colours are taken as an example for calculation, the production of printing screens alone would cost more than US$ 60,000. To produce such a number of collections, 10 - 12 weeks of development time is needed. Inkjet printing can thus offer a cheaper and much quicker sampling route.

In knitting, the digital production is already standard from the draft design to the knitting machine and all the way to the making-up process. For this purpose, Shima Seiki (Japan) offers Systems Apparel Design, ATD. This system includes modules for planning (draft design, printing, weaving and knitting) and making-up (sample production, graduation, marking, cutting and knitting). The company now also offers a module for printing as well as a printer SIP 120. The system is complemented by a module for "presale sales promotion".

As presented at ITMA, the cooperation between Stork (Netherlands) and Lectra Systems (France) is moving in the same direction. According to the agreement, Lectra Systems will develop a complete range of digital printing systems combined with CAD and automated cutting systems. The Manage Textile Print system (MTP) by Stork will integrate the complete textile printing process. It will enable colour matching between design and all textile-printing systems offered by Stork, including all Stork rotary screen-printing machines.

Other areas of application include the printing of curtains, decorative and furniture fabrics, home textiles, roller blinds, table and bed linen, wall paper, carpets, woven ribbons and labels, banners and flags, ties and scarves, etc. The customers, who discovered this service as an inexpensive way to produce small high-quality collections, are from the entire home and domestic textile sector, interior designers and architects, decorators, tailors and textile, bed and furniture traders.

6 Multiprint Concept – A Case Study
The multiprint concept envisages a textile printing facility where many production machine units would be placed in one room analogous to looms in a weaving shed. With an investment of, for instance, US$ 6000/unit and printing speed of 6m/h (150 cm fabric width), such a textile printing room with 50 units and two shifts could produce more than 2000 m/day. Such a textile printing concept for high quality textile prints, with above capacity and investment, would actually be feasible with today's technology with the usual advantages and limitations.

The textile finishing (dyeing, printing, finishing and converting) company Seiren Co. Ltd., Japan, has successfully used inkjet technology in production for several years now. The Viscotec system is the first commercially successful digital inkjet printing system in Japan. Research and development started 10 years ago and consumed about 20 billion JPY. Since then, 200 staff have produced approx. 10 million m² annually at a value of 13 billion JPY. The application areas of the products are: car upholstery fabrics (40%), swim wears (18%), ladies outer garments (10%), leisure wears (10%), sports wear (12%), and miscellaneous (10%).

The miscellaneous include large-surface products such as flags, posters or billboard surfaces. Almost all the textile substrates (like cotton, PET, polyamide,
Table 2—An estimate of growth of hardware installations of digital printers

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</thead>
<tbody>
<tr>
<td>Sampling and proofing DOD, Thermal, Piezo</td>
<td>375</td>
<td>558</td>
<td>765</td>
<td>1045</td>
<td>1390</td>
<td>1962</td>
</tr>
<tr>
<td>Personalization DOD, Piezo</td>
<td>150</td>
<td>728</td>
<td>1500</td>
<td>2000</td>
<td>2502</td>
<td>3862</td>
</tr>
<tr>
<td>Customization DOD, Piezo</td>
<td>220</td>
<td>396</td>
<td>588</td>
<td>2328</td>
<td>3648</td>
<td>5700</td>
</tr>
<tr>
<td>Agile manufacturing</td>
<td>-</td>
<td>-</td>
<td>5</td>
<td>12</td>
<td>50</td>
<td>75</td>
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<tr>
<td>Massive array DOD, Piezo (speculative)</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>8</td>
<td>35</td>
<td>55</td>
</tr>
<tr>
<td>Short run/ Rapid response</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>100</td>
<td>300</td>
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<tr>
<td>Massive array DOD, Piezo (speculative)</td>
<td>-</td>
<td>-</td>
<td>100</td>
<td>400</td>
<td>600</td>
<td>700</td>
</tr>
<tr>
<td>Production substitution (speculative)</td>
<td>-</td>
<td>100</td>
<td>400</td>
<td>600</td>
<td>700</td>
<td>800</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>745</td>
<td>1782</td>
<td>3258</td>
<td>5993</td>
<td>8325</td>
<td>12454</td>
</tr>
</tbody>
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elastane, etc.) as well as various weaves, brushed fabrics, artificial furs and knitted goods are used in printing.

The qualitative improvements are dramatic. In 1990, Seiren had a fault rate of 18%, but by 1998 it was a mere 1.4%. This reduction was achieved by reducing machine defects, such as clogging of nozzles or traditional printing with an average fault rate of 4-5%. The foremost advantage of the Viscotec system is the reduction of the throughput time from about 2 months to less than 10 days.

This low-fault rate and the high efficiency, exceeding 90%, compensates for the relatively slow printing speed of the printers and justifies Seiren's claim as to the profitability of this production method. Seiren also developed all the inks and chemicals.

Considering that for years the suppliers from the Far East, especially from Japan, have operated with minimum quantities of several thousand meters per colour, Seiren's new minimum quantity of 300 m² is quite revolutionary. There are 16,070 colours available. Besides the known advantages of inkjet technology, Seiren further claims that this technology requires no stock, which reduces printing costs a great deal. Within a period of three years, the stock-keeping costs reduced from 27% to 5%. So far, the largest area printed has been 50×40 metres.

7 The Future for Digital Jet Printing

It is hard to say what proportion of the market uses or will use digital technology in comparison to conventional printing techniques. Table 2 shows how hardware installations of digital printers will grow in future, keeping in mind the various market segments. An estimated 1000-1500 digital printers are in use world-wide mainly in US and EU.

Irrespective of how promising digital printing may appear, it is unlikely to replace analog printing methods like rotary printing, which will remain the preferred route for large batches. Digital printing will, however, gain significance in printing small batches. The current digital printing cost is between US$ 5-10 (ink plus substrate) per square meter. It is profitable for quantities under 500 linear meters for one design. Small print shops and custom garment manufacturers, serving local demands, will make use of this technology. The non-polluting, environment-friendly nature of technology will make the adoption easier. Production of small batches, presently being executed in low-cost countries (with high response time), will also shift to local markets in the developed countries. An estimated 10% of the total print market will be taken over by digital jet printing in next 10 years.

References
7 Ciba Speciality Chemicals, private communication.