An Exploration of Digital Technology over a Number of Manipulated Textile Surfaces

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Abstract

Ink jet printing for textiles has brought many benefits to the textile print industry. It has an ability to print on demand, using thousands of colours, and at reduced costs compared with rotary screen-printing for small scale production, ink jet technology has already established itself as a reliable method of printing for the textile industry.

This research investigates a new approach to ink jet technology. Numerous new surfaces are fed through a textile ink jet printer in the generation of bespoke printed textiles. This is an experimental approach to textile ink jet printing, recording practical solutions, and uncovering innovative processes for a new direction for digital technology for textiles.

Various surfaces have been enhanced using screen print techniques and embroidery, or manipulated by hand and digitally printed in the production of an array of unique digital resist techniques. This research combines the use of textile hand craftsmanship with digital technology, crossing the boundaries and discovering ways of combining these disciplines.

This research will highlights some of the possibilities with applying a hand crafted approach to ink jet technology for textiles, it demonstrate the control of colour, resist effects and the sensitivity of design which can be achieve using these new processes.

In addition to this, the research will demonstrate the added value of this crafted approach to digital design, as well discussing the potential for reproducing these complex textile craft techniques and digital resist effects using CAD and ink jet technology.

Acknowledgements

This research was made possible by the collective support and contribution of the following people.

Firstly, I would like to express my gratitude to my supervisors, Dr. R Annable, Dr. J Pearson and Penny Macbeth. Their support and guidance inspired me throughout.

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My final thanks go to family, friends and work colleagues for their continuous support, encouragement, patience and sacrifice.

Contents

Final word count 39,809

Illustrations

The printed fabric results will be stored at the University of Huddersfield

Tables

The fabrics shown in the following figures were formally displayed as part of the examination for this work:

Figure 2.8
Figure 2.10
Figure 3.2
Figure 3.3
Figure 3.4
Figure 3.5
Figure 4.1
Figure 4.2
Figure 4.4
Figure 4.5
Figure 4.6
Figure 4.7/4.8
Figure 4.9
Figure 4.10
Figure 4.13
Figure 4.14
Figure 4.15
Figure 4.16
Figure 4.17
Figure 4.18
Figure 4.28
Figure 4.29
Figure 4.30
Figure 4.31
Figure 4.32
Figure 4.34 (as part of the garment figure 4.42/4.43)
Figure 4.36
Figure 4.38
Figure 4.39
Figure 4.40
Figure 4.41
Figure 4.42
Figure 4.43
Figure 4.46
Figure 4.48

An Exploration of Digital Technology over a Number of Manipulated Textile Surfaces

Aims of Research

Craftsmanship in design adds uniqueness and offers an alternative to the current drive for mass production and focus on low cost. With the benefits of detail, bespoke design and high quality output, craftsmanship meets a demand for customisation, and with the advancements in digital technology can be economically viable.

The printed textile industry must always develop the design and technology to continually enhance production and creativity, to target future trends, and to remain profitable. Although currently a small sector of the textile industry, digital technology challenges the future of the printed textile market because of its high quality, flexible printing, at reduced costs. This PhD research combines digital technology with craftsmanship in a unique way to examine the transition and the production opportunities for small-scale production and customisation.

The practical results exhibited for this research is supported by this written thesis. These results are illustrated with the use of photography throughout this thesis. All the practical results are catalogued in Section 4 of this thesis.

The aims of this research are listed below.

- To investigate the use of ink jet print technology for textile sampling. To study the potential of this technology in the generation of bespoke, hand crafted printed textiles and the way in which these can be reproduced. This thesis will discuss the exploration of craft with digital technology for printed textiles for fashion products and accessories.

- To demonstrate the creative potential of using textile ink jet technology. Custom treated fabrics, such as embroidered, printed and manipulated, will be generated using techniques such as pleating and layering. Various fabrics will be fed through an ink jet printer to investigate for the feasibility for printing.

- To determine embellishment techniques that can be applied with ink jet technology, to enhance the surface quality, the decoration and depth to design. To demonstrate how certain embellishments such as additional screen printing effects can be planned and designed as part of the initial CAD design. This will study the registration problems that may arise with certain fabrics, and discuss the feasibility of using embellished techniques with those fabrics. It will also find out whether certain techniques produce stronger results than others. This research will also review the combinations of screen print overlays and possible embellishment techniques. As a result of this research a catalogue of design process information will be collected for future use with textile products.

- To examine the simulation of craft techniques such as patchwork and embroidery, using ink jet technology for production. This research will evaluate the quality of design, the importance of post-treatment and colour management in the production of reproducible results.

- To research the use of resist techniques to generate printed design patterns and textures. By examining the use of resist agents that can be used with ink jet printing, and combining the use of CAD embroidery and lace to act as a resist to the printed design. Experiments will demonstrate the application and combination of layered fabrics that can cause resisting effects to occur.

- To identify the potential markets and to demonstrate the commercial viability of these techniques and processes.

- To exhibit the printed results, to highlight and demonstrate the potential for this technology for textile markets.

This PhD research will contribute knowledge to the textile design industry, using digital print technology. It will evaluate hand crafted design produced with digital technology, and demonstrate the added value of this approach to small scale production in the textile print industry, highlighting the commerciality in the development of these processes in the textile industry. With a greater understanding of the technology and by investigating the new opportunities of using digital manufacture by incorporating craft techniques, the potential for digital printing has been opened up.

All the printed fabric results to back up this thesis will be exhibited and stored at the University of Huddersfield. Some of the results have been photographed for this PhD thesis for the reader to examine.

The research for this thesis was carried out between the dates of 2001 – 2010.

Papers Presented:

The following three papers concerned with this PhD research have been presented and the proceedings published. These papers were an integral part of this research for PhD and the full papers can be viewed in the appendix of this thesis.

- 'The Use of Wide Format Ink Jet Printers for Textile Print Sampling', World Textile Conference, 2ndAutex Conference, Bruges, Belgium, 1-3 July 2002.
  Authors: Dr. R.Annable, Dr. J.Pearson, P.Macbeth and H.Ryall. Practical work completed and presented by H.Ryall.
- 'The Use of Embellishment Techniques with Ink Jet Printed Repeated Designs',
  INTEDEC 2003: International Textile Design and Engineering Conference, Edinburgh/Galashiels, UK, 22-24 September 2003.

Authors: Dr. R.Annable, Dr. J.Pearson, P.Macbeth and H.Ryall. Practical work completed and presented by H.Ryall.

- ‘The Commercial Realisation of Complex Textile Craft Techniques by CAD and Ink Jet Printing’, ARCHTEX, Krakow, Poland, September 2005.
- Authors: Dr. R.Annable, Dr. J.Pearson, P.Macbeth and H.Ryall. Practical work completed and presented by H.Ryall.

The following paper has also been published:

- ‘Craftily Using Ink Jet’ 2006, *Textiles Journal*, 33 (2), pp. 20-22.
- Authors: Dr. J.Pearson and H.Ryall. Practical work completed by H.Ryall.

SECTION 1

Literature Review

Ink Jet Printing – An Overview

Chapter 1– Literature Review

Ink Jet Printing - An Overview

1.1 Introduction

Ink jet printing originated from the world of paper record printing. Ink jet printing for textiles has been thoroughly investigated since the mid/late 1980s (Dawson, 2003, p.19). It is still being investigated for its place in the textile industry. It is recognised that the majority of research published in this area is undertaken by suppliers and is aimed at the commercial development of the technology and related consumables. This chapter gives an overview to the current uses and the future developments of ink jet printing.

1.2 Ink Jet Print Technology

1.2.1Introduction

There are two systems of ink jet printing: Continuous and Drop on Demand, both of which have been investigated and used for textile ink jet printing solutions. These two systems relate to the print head technology. With continuous developments in the technology and the dye chemistries, the most commonly used application throughout the developing industry in 2009 is Drop on Demand (DOD), specifically Piezoelectric.

1.2.2 Continuous Ink Jet Printing (CIJ)

The continuous method uses a constant stream of ink, which is printed onto a rotating drum with substrate on it; the excess drops of ink pass through the fabric or get pumped into a reservoir and recycled. The binary ink jet method (figure 1.1) is not limited to the number of dyes available and is able to use a wide range of dye chemistries for a variety of substrates. This method uses the uncharged drops for printing and the charged drops are pumped back through to the reservoir. There is only one dot location printed per nozzle (Gregory, 2003, p.74).

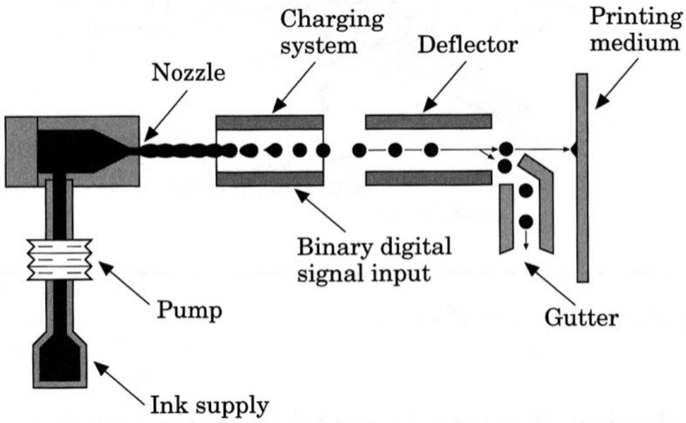


Figure1.1 (Fenton, Romano, 1998a) Binary Continuous

CIJ was the first textile printer to be sold for commercial use. The Stork TruColor printer was launched in 1991 at ITMA (the International Exhibition of Textile Machinery) (Gregory 2003, p.75). This was a leader in ink jet printing for small-scale production and prototyping of textiles. However, with the innovations in DOD technology it was later found that these printers were seen to be less flexible, generally more expensive than DOD ink jet printing and problems arose with the technology of recycling the ink.

1.2.3 Drop on Demand Ink Jet Printing (DOD)

Although continuous ink jet printing was seen to be a relatively reliable method of printing, the technology and dye chemistries for Drop on Demand printing have advanced further. So much so, that Drop on Demand in 2009 is the only mainstream textile digital printing systems available.

There are two types of Drop on Demand printing; Piezoelectric and Thermal. While some of the earliest solutions for ink jet printing for textiles used Thermal technology, the piezoelectric technology is the favoured approach for textile applications.

1.2.3.1 Thermal Ink Jet Printing

The dye inside the print head is heated up rapidly to 300-400°C per second, which creates a pressure and forms a bubble (Gregory, 2003, p.72). The build up of pressure pushes the bubble out of the nozzle. The bubble is ejected and bursts onto the substrate as the heating element starts to cool, causing a vacuum, which draws more ink from the reservoir to repeat the rotation (Figure 1.2) (Gregory, 2003, p.73).

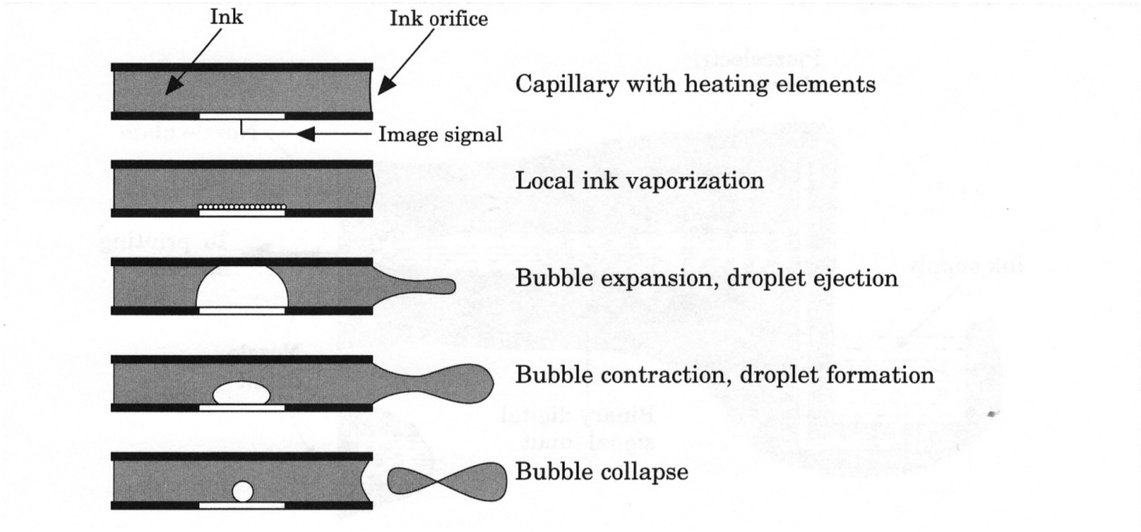


Figure 1.2 (Fenton, Romano, 1998b) Thermal/Bubble Jet

Due to the heat required for this technology, there were limited developments with the dye chemistries, and therefore this technology was very restricted for use in textile printing. This technology is therefore in 2009 only used within the paper printing industry.

1.2.3.2 Piezoelectric Ink Jet Printing

Piezoelectric ink jet (figure 1.3) printing works by sending an electric current to a piezoelectric crystal at the back of the ink reservoir. The crystal then flexes to create a drop of ink, which is fired out of the nozzle and onto the medium (Gregory, 2003, p.73).

The advantages of the piezoelectric ink jet technique are that there is more freedom of ink drop size and shape, which can produce higher resolutions prints, and it is also quicker than the thermal method as the ink does not need to be cooled and reheated after each rotation. This printing method is the favoured approach by the textile industry as it can cope with higher viscosities and therefore a wider variety of inks and dyes are available for piezoelectric printing (Mighall, 2009a).

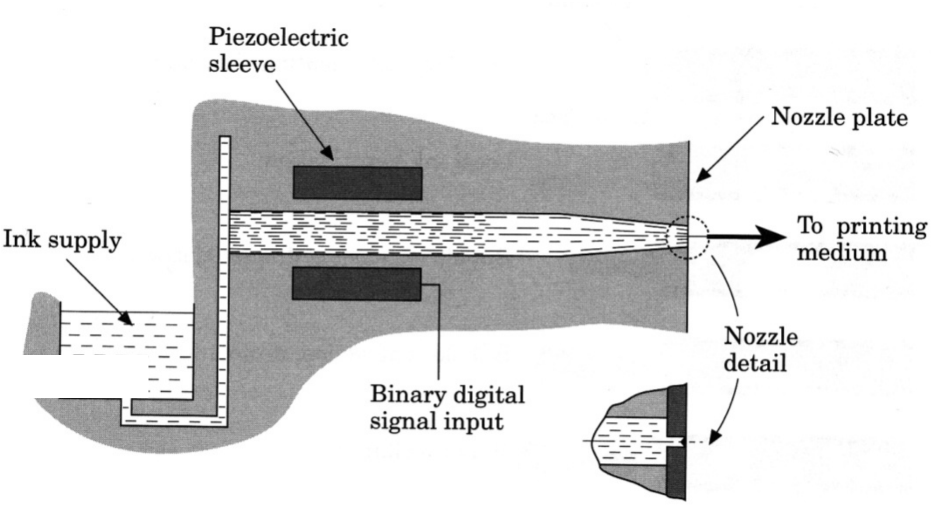
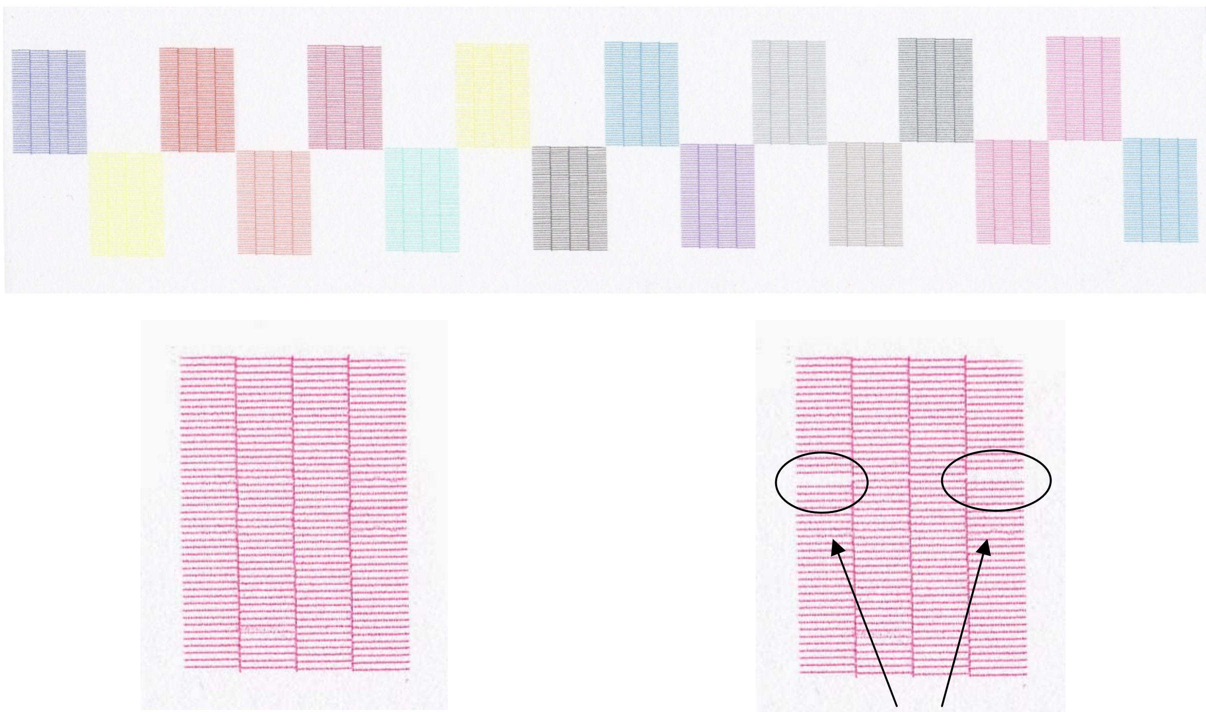


Figure 1.3 (Fenton, Romano, 1998c) Piezoelectric/Drop on Demand

While ink jet printers such as Mimaki's TX2/TX3/JV5 and Robustelli's Mona Lisa use Epson print heads, and the Reggiani's DReAM uses HP-Scitex print heads, all use piezoelectric technology. Automatic nozzle checking in new print head technology indicates misfiring nozzles while printing, triggering a head clean, therefore saving time and cost in reprinting (Mighall, 2009b).Alternatively a test print can be done prior to printing to assure the print heads are fully align and are printing correctly. Figure 1.4 shows a standard test print for a Mimaki TX2-1600 ink jet printer, plus highlighting the affect of a print head with misfiring nozzles.



Perfect Print Head Test

Imperfect Print Head Test, highlighting Misfiring Nozzles

Figure1.4 (University of Huddersfield, 2009) Print Head Test (Mimaki TX2-1600)

1.3 Ink Jet Printing for Textiles

Developed by Milliken® in the early 1970s, the first and most widely used ink jet printer in the textile industry was used for carpet and upholstery printing (Cahill, 2006, p.1-15). Using continuous technology, with coarse drop sizes of a maximum resolution of about 20 dots per inch, these enabled large quantities of dye to be printed for heavyweight fabrics. Most commercially printed carpet designs in 2009 are produced using digital technology.

The textile industry is driven by time, having to meet the constant demands of the customer for new products and the resulting short lead times. The industry needs to be flexible to change, as the customer may want to make style alterations and have shorter print run productions. This is particularly true of customers in developed markets, where luxuries are largely a given and there is a desire for differentiation, textile ink jet print technology is ideal for this mass customisation. The customer for ink jet printing will vary from the high-street companies demanding the slightly larger production runs for ink jet printing, to the independent designer/maker/crafts person, to the ultimate bespoke designer for innovation/trend setting and catwalks. Ink jet printing for textiles is moving the scope of what is possible to manufacture, as it can produce photographic imagery and is flexible to changes. Ink jet printing for textiles is a drop on demand solution, giving total flexibility for designers and print runs. Printing can be stopped and started instantly, with the ability to make alterations on screen allowing the design to respond to customer needs.

In a interview with S.Jones the Colouration Manager from Dawsons®, he stated that when conventional methods of printing are used, the complete process from design to product can take up to 8-12 weeks in 2010 (Jones, 2010). Depending on the printed output required, ink jet printing can take as little as 24 hours (Figure 1.5).

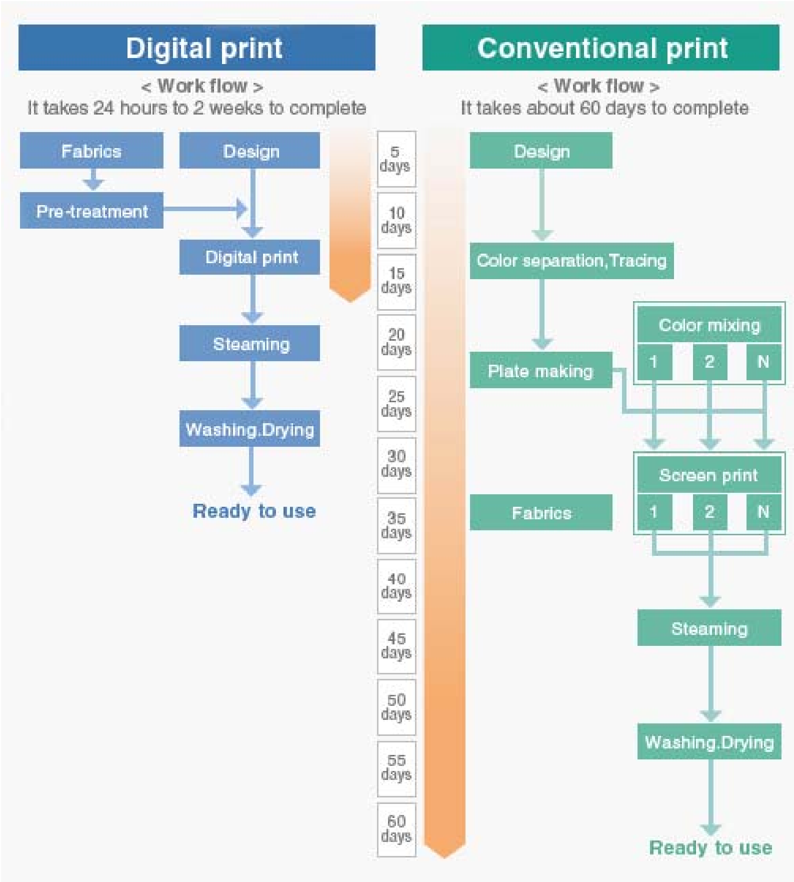


Figure1.5(www.mimaki.co.jp/english/tx/system/ 2009)

Work Flow Comparison for Conventional and Digital Printing

1.4 Current Usage of Textile Digital Printing

Digital printing for textiles is constantly increasing in volume in the UK textile industry in 2009/2010. This is happening in several ways; short run production, sampling before bulk production and education. A wide variety of ink jet printers are available on the market, each driven by customer base requirements, from the Mimaki TX2-1600 printing a maximum of 28.4 m^2/h, to the Reggiani DReAM printing 230 m^2/h.

Figure 1.6 demonstrates the worldwide increase usage for digital textile printing for low to high-volume printers. The chart shows the number of machines installed, peaking in 2007, with usage of digital textile printing continuing to grow in 2009 to 2010.

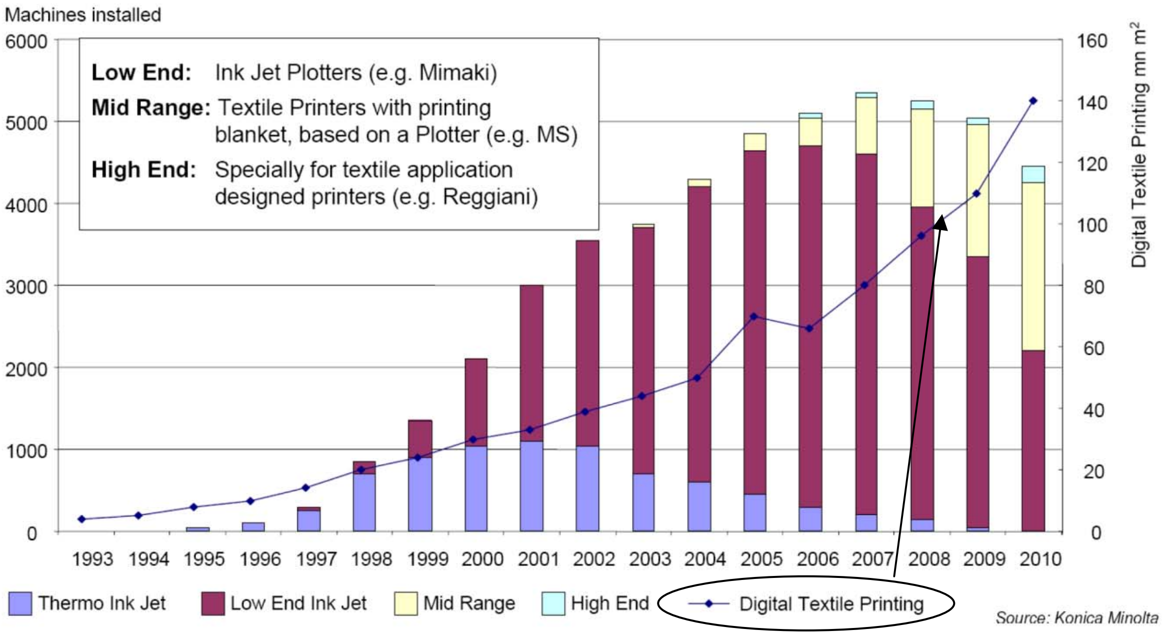


Figure 1.6 (Grimshaw, 2010) Market Developments in Low and High-Volume Digital

The author undertook a recent interview with M.Mighall, aPartnerfrom RA Smart (CAD & Machinery) ®which highlighted the current uses of digital textile printing in the UK. Many education institutions are running with digital printers for textiles and these are really beginning to push the scope of digital design for textiles. The majority of institutions in 2009run with printers such as the Mimaki TX2 (Figure 1.7) with reactive dyes because of their flexibility. Education requires this flexibility over speed of printing, as student projects are independently set, therefore require an individual approach to various methods of production.

Figure 1.7(2009) Mimaki TX2-1600

The main commercial areas for short run productions are evidenced with high-end fashion designers, sportswear and the advertising industry (soft signage for flags and banners). From the market research that the author undertook, fashion designers such as Jonathon Saunders, Matthew Williamson, Roberto Cavalli and Jean Paul Gautier, as well as high street stores Warehouse and Ted Baker show the use of digitally printed fabrics in their Spring/Summer 2009 collections. The high-end interiors markets are also beginning to see the real benefits of digital technology. The reasons for the move to digital print production are the removal of design constraints (colour limitations), the flexible changes for short run production, the ability to react quickly to seasonal changes and the high quality results.

This movement is captured within Figure 1.8, which demonstrates the potential for the use of this technology within the textile market. For example, the interiors market for upholstery and bed coverings shows a strong digital value proposition and strong growth potential; however, at present it has a longer production time. Although swimwear has a short production lead time, it offers smaller growth potential than upholstery and bed covering. However, swimwear still presents an ideal opportunity to use digital technology for production. T-shirt printing also offers good value for digital print, yet only a small market share and with a longer production time than swimwear, but still a key market area for ink jet printing. In contrast, Aerospace seating offers little commercial potential and a weak value proposition for using digital technology.

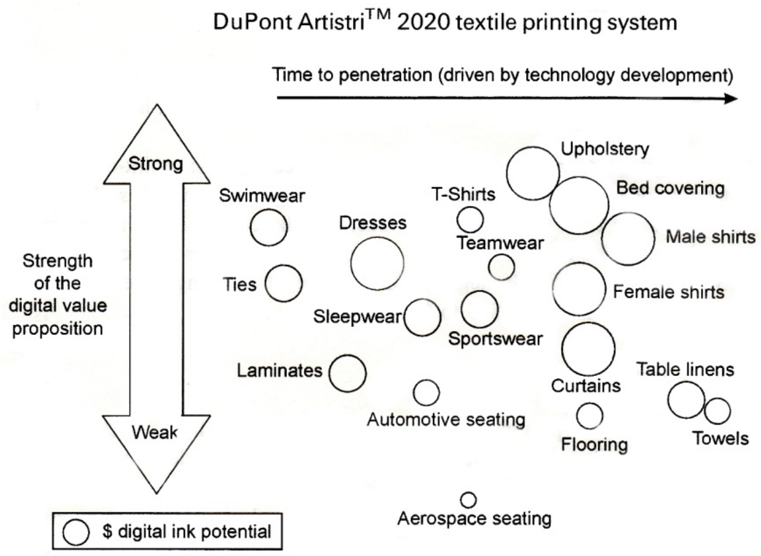


Figure1.8 (Raymond, 2006) Textile Printing Market Requirements from Digital Printing Technology

Although digital (ink jet) printers are being used as a method of sampling prior to bulk screen production (using squeegee), this is relatively limited. As differences remain between the two printing methods, a jet of ink and a squeegee, the digital sample will never be a true representation of the final screen-printed result. Nevertheless, the fact that digital can create an almost instant visual for the designers and buyers (and with it ability to print almost photographic quality), increases its desirability. As the desirability increases, so will the demand for digital printing, gaining a larger share of the printed textile market.

"Although digital methods still account for less than 1% of the global market for printed textiles, their share is likely to expand to as much as 10% by the early part of the next decade. Screen-printing still dominates the textile printing market with 80% of global output. However, this share is expected to fall as digital printing gains more of a foothold in the market. " (just-style.com, 2007)

Figure 1.9 demonstrates the setup and per unit costs for digital textile printing, based on a DuPont Artistri TM 2020 printer, and screen-printing in 2006. Fitting with the commercial focus on mass production and economies of scale, screen-printing is more cost effective than digital printing at volumes over 800 square metres. However, digital textile printing enjoys a significantly lower set up cost and achieves per unit cost of $5 within the first 100 square metres, compared to a screen-printing per unit cost $30 within the first 100 square metres. Time is money; therefore, the need for rapid decision making and reduced lead times is crucial, particularly in the economic downturn.

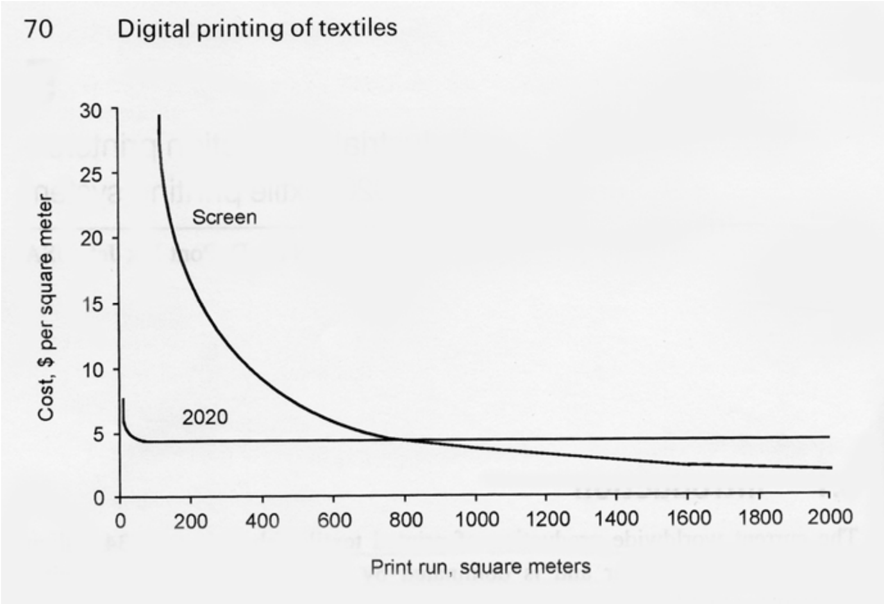


Figure1.9 (Raymond, 2006) The difference in cost between screen and digital printing setup process

Digital printing can cope with multiple colours in a single print run, while screen-printing requires a different screen for every individual colour, with a typical cost of £250 per screen in 2009 as stated by to R.A. Smarts®. Therefore, the unit costs associated with digital printing become more efficient as the number of colours in the design increases. As well as increasing the benefit of digital printing for short production runs, it also limits the commerciality of screen-printing for complex colour designs - or challenges the efficiency of screen-printing for longer production runs with complex colour designs (Mighall, 2009c).With digital printing no specific repeat sizes need to be used or even a repeatable design. This contrasts with screen-printing, where the design must be in repeat and to a specific size (the circumference of the rotary screen, or a division of).

The commerciality of digital printing can be further enhanced by increasing the speed. There are two methods for increasing the speed of a digital textile printer; add new print heads with increased number of nozzles or have more print heads running with the same colours (spot or process colour). There are printing speeds of up to 1700 linear m/h, with the print resolution of 300dpi (Isis by Osiris digital printer)in 2009; this is in comparison to a rotary screen printer, which can print up to approximately 1800 - 2400 linear m/h (Mighall, 2009d). Both these speeds apply to a typical width of fabric from 1.2 – 1.6m.To gain speeds this high, rows of fixed print heads run the full width (1.8 metres) of the printer for each colour used (Mighall, 2009e).

1.5Dyes for Digital Textile Printing

Four different dye and ink types are available for use in ink jet printing for textiles: reactive, acid, disperse and pigment. Each dye type is used for specific textile requirements, thus enabling a wide variety of fabrics to be used. Continuous research and developments improving the reliability, colour intensity, light fastness and the achievable colour space.Table1.1 demonstrates the properties that must be taken into consideration in the development of inks for digital textile printing.

Properties of ink for good quality Print	
Ink Properties	**Function properties**
Surface tension	**Colour: cyan, magenta, yellow, black**
Viscosity	**Colour strength: high**
Conductivity	**Solubility: 5-20%**
pH	**Fastness: light, water, smear**
Specific gravity	**Shade: same on different substrate**
	Toxicology: Ames –ve
	Thermal stability: Kogation

Table1.1 (Textile Asia, 2009) Dyes for Ink Jet Printing of Textiles

Table 1.2 reviews the availability and the properties of the dyes for digital textile printing. This table describes the suitability of the fabrics with the varying dyestuffs and highlights the pre/post-treatments required.

Dyestuff Available with Ink Jet Technology	Fabric Suitability	Pre-treatment Required	Post-Treatment Required
Reactive	Cotton, Viscose, Wool and Silk	Yes -for the chemical reaction to occur an alkali has to be applied as a pre-treatment	Steam and wash
Acid	Silk and Wool, and Polyamide fibres	Yes	Steam and wash
Disperse(indirect printing - Dye Sublimation)	Transfer paper /Polyester	No	Heat for transfer from paper to fabric
Disperse (direct printing)	Polyester (used for flags and banners to get higher penetration than dye sublimation)	Yes	Steam and wash
Pigment	Most fibres	No	Short heat or Ultra-violet curing post-treatment. A binder is required if not included in the ink chemistry.

Table 1.2(University of Huddersfield, 2009) Review of Dyes Available for Ink Jet Printing for Textiles

For the growth of textile ink jet printing in the commercial textile print market, many dye and print head technology developments are required. However, there is a strong environmental drive to increase the use, and improve the pigment inks and disperse dyes for textile ink jet printing.

Because no pre-treatment is required for digital printing to the fabric using pigment inks, and only a short heat or UV curing post-treatment is needed for the fixation of the inks, these make economical sense. Pigment inks are also much less fibre specific than most other dyes. To increase reliability, and to improve fixation and fastness, dye manufacturers such as BASF®, CIBA®, DuPont® and Clariant® are researching ways to continually improve the pigment inks for digital textile printing. This can be achieved by increasing the quantity of the binder added to the ink (just-style.com, 2007).

Strong environmental forces (less water used in post-treatment, less effluent to treat, less wastage from only printing on demand and predominantly using water based dyes/inks and the resulting cost savings), technological improvements, and increases in the range of fabrics available, have helped drive increased usage of disperse dyes as opposed to solvent based inks in the soft signage market.

Depending on production volumes, there are two methods for dispensing the ink. For higher volumes of print production, a third party inks system using refillable cartridges is typically used. For lower volumes, non-reusable cartridges can be employed. Regardless of the dispensing method used, it is vital to ensure that pressure within the ink system/cartridge remains constant to ensure even ink flow.

1.6Fabrics for Digital Textile Printing

It is essential that when using reactive, acid or direct disperse printing, to use treated fabric as explained in section 1.7.1. The fabric is treated prior to printing with the recipe shown in 1.7.1. After printing the fabric will need further treatment to fix the dyes and remove any excess chemicals. There are a wide variety of pre-prepared fabrics available for ink jet printing. However, to gain consistent print results there must be some consistency in the pre-treatment of the fabric.

1.6.1 Fabric Pre-treatment

Most fabrics are pre-treated, either by the manufacturer or by the user. The pre-treatment recipe for each dye and fabric is available from the dyestuff manufacturer. Below shows a standard recipe for the chemical padding added to Cotton fabrics in preparation for digital printing. The Ludigol® in this recipe is used for the protection against any reduction of the dyestuffs in printing (Thornton, 1994, p.120).

- Sodium Alginate Solution 250g
- Urea 100g
- Ludigol® (BASF AG) 25g
- Sodium Bicarbonate 25g
- Water to 1000g

(Hees, Freche, et al, 2003, p.51)

Fabric pre-treatments allow for maximum colour yield, clarity of image and quick drying time. Pre-treatment helps to control the size of the ink drops jetted onto the fabric, ensuring that minimum bleeding occurs. The chemical padding stiffens the fabric enabling it to run smoothly and evenly through the printer (particularly important with lightweight fabrics). The fabric pre-treatment works in conjunction with the fabric tension mechanism on the printer. The more simplistic form is demonstrated in Figure 1.10 the Mimaki TX2-1600.

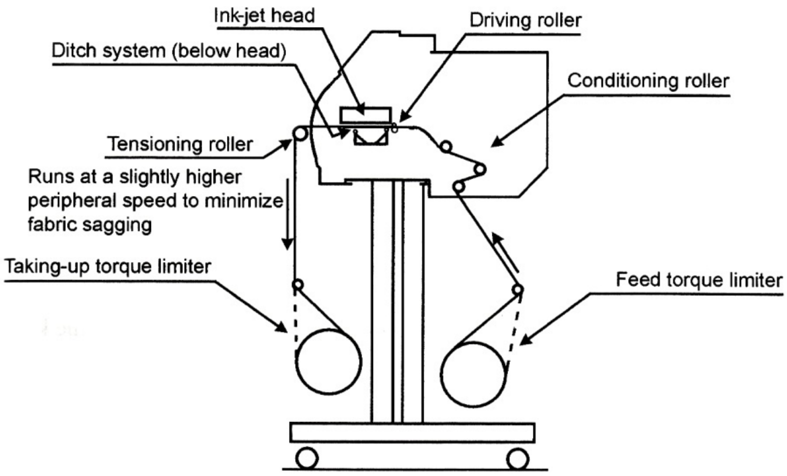


Figure1.10 (Kobayashi, 2006a) Mimaki TX2-1600 Textile Path

Newer versions and printers designed for higher volumes of printing, include a flat adhesive belt (with a drying and cleaning system), therefore fully restricting the movement of the fabric, and a heater to dry the fabric prior to rolling. This is vital when printing at faster speeds to ensure no dye transfer (Figure 1.11).

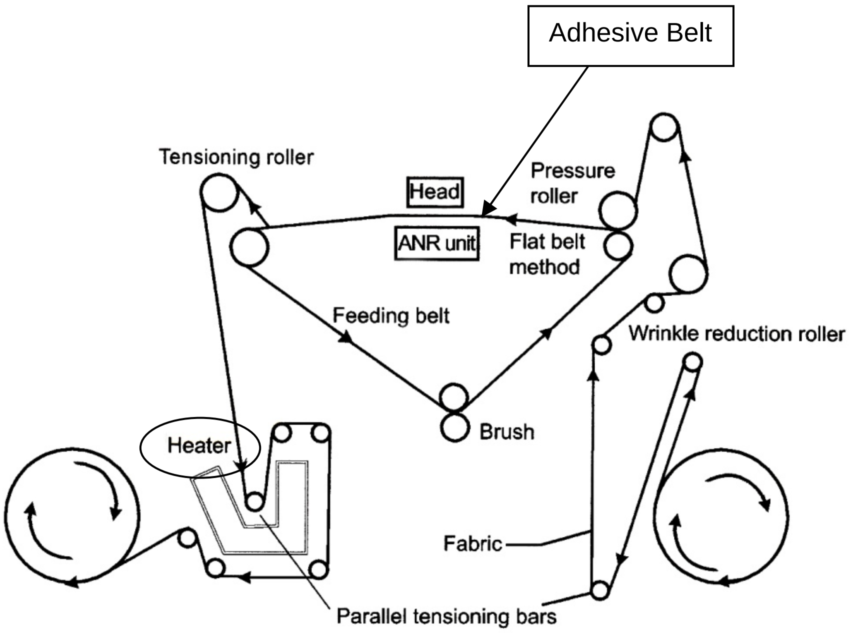


Figure1.11 (Kobayashi, 2006b) Mimaki TX3-1600 Textile Path

The compatibility of the dyes and fabrics can vary, depending on the printer used. In the author's opinion it is recommended to test each fabric prior to using; the lighter weight fabrics can react differently to the quantity of dye placed down. Within the printer's RIP (Raster Image Processor) software, it is possible to adjust the amount of dye placed down. The main problem that may arise is bleeding. On the majority of silk fabrics tested as part of this research the amount of dye was reduced from the standard 230% colour yield to 140%, subsequently affecting the colour outcome; the colours were paler and less intense.

1.6.2 Fabric Post-treatment

Colour and print quality consistency throughout the printing process is essential with all textile printing. So when using ink jet technology for sample printing, consistency is crucial for colour control and reproducibility for sampling and bulk production. Ink jet printing can save time and money in the design sampling stages, but to reap these benefits there must be consistently strong colour and print results.

Post-treatment is often a forgotten consideration for ink jet printing for textiles. A printer can be easily set up, but there must be the facilities for post-treating the printed fabrics.

1.6.2.1Steaming

Reactive, acid and disperse dyes require a post-treatment of steaming fixation and a washing process. In this research standard steam conditions have been investigated when using reactive dyes(see section 2.2, p.48).

1.6.2.2 The Washing Process

The washing of the fabrics occurs after steaming. It enables any excess dye, that had not fixed in the steaming process, and any auxiliary chemicals used in the pre-treatment of the fabric to be removed. Washing is a very important factor for reproducible image and colour results. If the washing process was done incorrectly, image clarity may be affected, and problems such as back staining or the fading of colours may occur. In this research, an industrial Wascator machine (Wascator FOM 71S, John Godrich, Shropshire) was used; this is used commercially to enable accurate control of the wash-off conditions to be obtained, therefore allowing more accuracy for colour reproducible results. This research followed the recommended wash instructions of two cold washes, two hot washes (at the specific temperatures shown in table1.3) and two cold water rinses.

FABRICS INFORMATION FOR INK JET PRINTING - REACTIVE DYES 09/10

FABRIC	WIDTH (cm)	PRINTING WIDTH OF FABRIC (cm)	STEAM TIME	WASH METHOD	TEMP OF HOT WASHES	TUMBLE DRY
COTTON SATIN	138	130	10 min	Wascator	Hot Wash 1: 80° C Hot Wash 2: 90° C	YES
COTTON POPLIN	147	135	10 min	Wascator	Hot Wash 1: 80° C Hot Wash 2: 90° C	YES
JUNIPER LINEN	150	140	10 min	Wascator	Hot Wash 1: 80° C Hot Wash 2: 90° C	YES
SILK/VISCOSE SATIN	137	125	10 min	Wascator	Hot Wash 1: 80° C Hot Wash 2: 90° C	YES
HAZELWOOD	150	140	10 min	Wascator	Hot Wash 1: 40° C Hot Wash 2: 50° C	YES
CHIFFON MOUSELINE	140	130	10 min	Wascator	Hot Wash 1: 40° C Hot Wash 2: 50° C	NO
SILK CREPE DE CHINE	140	130	10 min	Wascator	Hot Wash 1: 40° C Hot Wash 2: 50° C	NO
SILK GEORGETTE	140	130	10 min	Wascator	Hot Wash 1: 40° C Hot Wash 2: 50° C	NO
SILK TWILL	140	130	10 min	Wascator	Hot Wash 1: 40° C Hot Wash 2: 50° C	NO

Table1.3 (University of Huddersfield, 2010) Post-treatment Guidelines for Ink Jet Printing. Fabrics details are shown in Chapter 3

1.7Colour Management

1.7.1 Introduction to Colour Management

Colour management is a term for a system used to help administer and control colour communication from various input and output devices, this is vital to achieving reproducible results in all of the printing industries. For accurate or good represented results, colour management needs to be applied throughout the work process. There are many factors that can enhance colour reproducibility and many variables that can prevent the achievement of the colour results required. This research has investigated several methods of colour management and these have been clearly detailed in this chapter. However, for this PhD research (and in the author's opinion, the most reliable method), colour measurement is used only, to create colour standards and profiles for the printing output (detailed in section 1.7.2). This provides full control of the colours obtained using colour libraries once all post-treatment guidelines for ink jet printing are set in place (see section 1.7.7). Monitor calibration was not feasible for this research due to the wide variety of computers used, therefore adding too many variables.

1.7.2 Colour Measurement

The process of colour measurement aids the achievement of accurate colour results. Individual colours can be measured into a spectrophotometer, which once tested can be used to develop colour standards. These colour standards can be used for design and then be communicated between different systems and devices. Colour communication will only be successful when the colour required is available in each system's colour gamut (achievable colours). Colour profiles are generated to identify the achievable colours in one device. In this research a colour profile was used for the Mimaki TX2 generated by the supplier RA Smarts®.

1.7.3 Colour Communication

Colour management is used to communicate and translate to various input and output devices (a scanner); however, each device will hold a different colour space. A scanner, for example, can be dependant on the number of colours and, where appropriate, type of dye colours used. Colour profiles are colour maps that identify the maximum performance of a single device. ICC (International Color Consortium) profiles measure and translate colour from input to output devices. These profiles can then be fed into the relevant software, for example a monitor profile can be fed into PhotoShop® enabling a better visual representation. If a colour is unachievable, the profile will automatically change the colour to the nearest obtainable.

Colour management software provides the ability to generate colour profiles, and communicate between the different input and output devices. For example, Figure 1.12 demonstrates the different colour spaces for a typical RGB (Red/Blue/Green) CRT monitor and a typical CMYK (Cyan/Magenta/Yellow/Black) ink jet printer. Where the two spaces do not overlap, this highlights the unachievable colours through both devices.

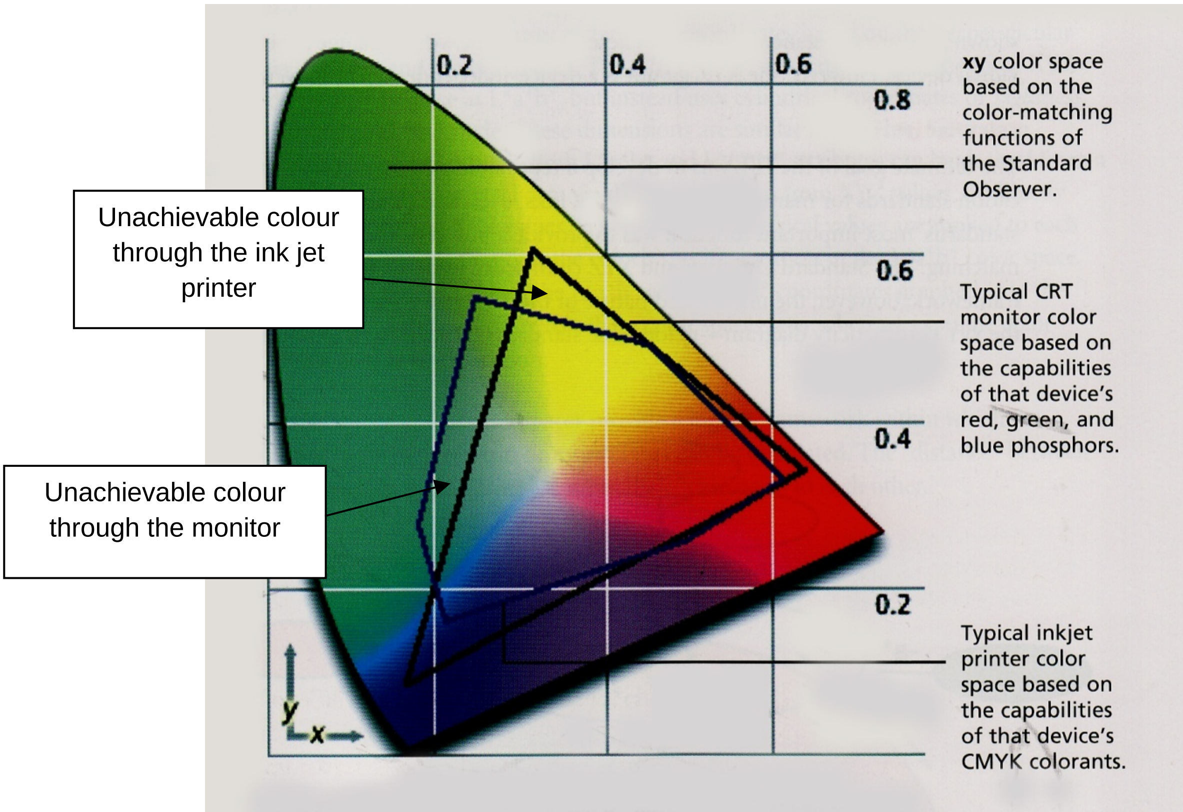


Figure1.12 (X-rite ®, 2004) The Limitations of Colour Spaces between a CRT Monitor and CMYK Ink Jet Printer

1.7.4 Monitor Calibration

Monitor calibration is essential in colour communication and is a controllable parameter for colour reproduction. By calibrating a monitor a better visual representation can be achieved. For the most accurate results possible, and to minimise the variables involved, the same monitor should be used throughout. There will be some consistency from using the same make or type of monitor, but this will still add variables into the equation.

There are many variables when achieving reproducible colour results with monitors. Whereas, cross monitor performance will depend on the voltage and temperature generation (the edge of the screen will have more space for the heat to disappear). This can have an effect on the colour from the side to the centre of the screen, particularly when dragging a colour from the default palette at the side onto a design in the centre. Likewise with all colour, the lighting conditions in the room will have a huge impact on how the colour is viewed. Also an LCD monitor can look very different when viewed from different angles (Mulla, 2009a).

In the development of a monitor profile, it is vital to define the optimum colour performance. Therefore the monitor must be warmed up before developing a profile, which must also include the setting of the white/black point. To ensure the most accurate results, monitor calibration must be done daily.

As noted previously, monitor calibration was not possible in this research due to the variety of computers used. The chosen method of colour management used in this research did not rely on the monitor for accurate colour performance; all colour matching was done directly to the colour library. The changes made on screen were largely ignored, therefore not affecting the colour results. However, monitor calibration, if only using one computer, would have allowed for both accurate screen and printed results, making the job of a designer easier.

1.7.5 Input Devices

Once again, there are many variables related to mapping from input devices. A known input source can be mapped (a scanner), however, for an unknown input source (digital camera) the colour management software will have to estimate the colour values. A scanner for example can be calibrated; it has controllable and reproducible lighting, but will have a degree of variability when scanning various surfaces. Providing the surface scanned is flat and no additional light source is added, the colour communication from the scanner to the colour management software will be reliable. However, this will greatly depend on the colour source and the surface of the scanned material. If a photograph is scanned, but the scanner is unable to achieve the colour, some unexpected results will arise. If a three-dimensional surface is scanned, allowing additional light to intrude, the scanner profile used will be unreliable.

Profiling digital cameras is virtually impossible. The lighting conditions, particularly for external photography, cannot be regulated. Therefore, a profile will never be truly reliable, as there are too many variables. When a photograph is brought into the software it will carry a default colour profile SRGB (Standard Red/Green/Blue), which allows the software to interpret the colour (Mulla, 2009b). This does not mean digital cameras cannot be used to record visual imagery. However, there must be an understanding that colour profiling with digital photography is very difficult, and therefore relies on other profiles to do much of the colour management.

1.7.6 Output Device

The output device (printer) can also be calibrated to identify the best possible representation of the printer's colour gamut. To achieve the profile, the software will send a series of predefined signals to the output device in the form of charts of block colours. These will then be printed and scanned into a spectrophotometer, then fed back into the colour management software to build the device's colour map/profile. This profile will then be used to obtain reproducible colour.

Again, there are variables affecting reproducible colour; the print medium, the dye used and the light source in which the colours are viewed. The print medium (paper/fabric) will define the whitest point of the print. Printing on a glossy rather than matt paper, or an optic white fabric rather than a natural coloured fabric, can have a huge affect on the colour outcome, which all needs to be taken into consideration. Individual profiles will need to be built for each medium. Printer's work with the basic CMYK (a four dimensional colour space) colour (plus any additional colours added), where as a scanner, camera and monitor work with RGB (a three dimensional colour space). This will instantly have an effect on the producible colour. In this research two colour profiles were developed for the Mimaki TX2, these profiles would differ for the dye type used (reactive/pigment). New profiles were generated each time a new dye colour was introduced. For each new profile, the charts would be re-printed and post-treated (to guidelines stated in this research, refer to section 2.2.1), then re-scanned.

Figure1.13shows the communication flow and emphasises the role of the CIE XYZ (Color Management Engine)in interpreting the information from the various RGB and CMYK devices, and in supplying this interpretation to the monitor and print devices. CIE XYZ or CIE Lab are universal colour languages, which are device independent (independent of RGB/CMYK colour spaces), but when using a profile these can be translated back into the appropriate colour space (Loser, Tobler, 2006, pp.180-198).

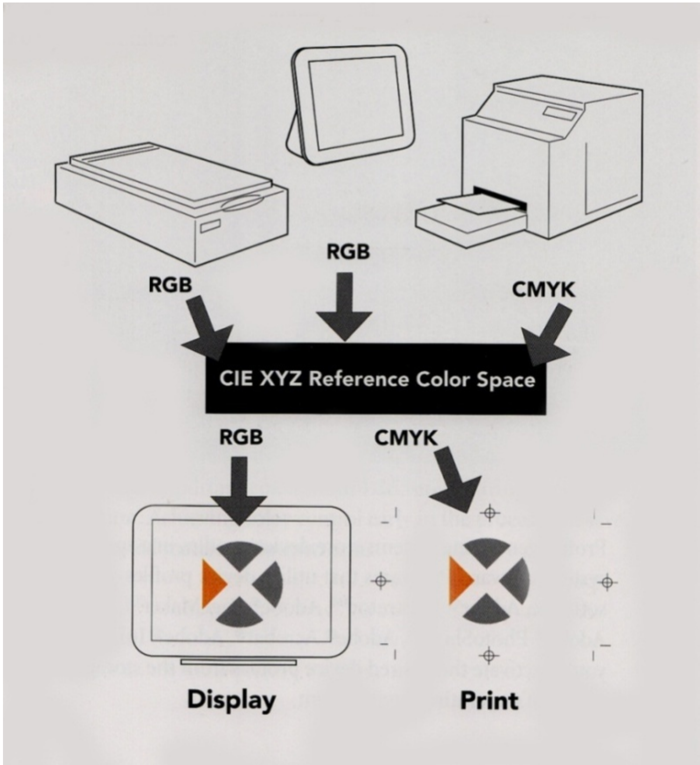


Figure1.13(X-rite ®, 2004)

The Translation using CIE XYZ from Varying RGB and CMYK Devices

1.7.7 The Use of Colour Management with Textile Ink Jet Technology

Ink jet printing was developed from wide-bodied paper printers designed for posters and banners. These have long established methods of obtaining full colour reproduction from the secondary colours of CMYK, known as process colours. Textiles have used a spot colour method whereby the actual colour in the form of dyes is used. There are some ink jet printers with the option for using the spot colour method for example the Isis by Osiris.

With the use of process colours there are some limitations to the printable colours or gamut, which are obtainable. Also the full potential of these colour spaces is not visible until after the post-treatment of the dyes.

The process used to produce a wide colour gamut from a selection of 8 colours is called dithering. In addition to the basic 4 colours of printing CMYK (Cyan, Magenta, Yellow and Black) dye technology has advanced and made additions to this selection possible. For example, colours such as orange, blue, light magenta and grey can be added to achieve the widest colour space possible. Figure 1.14 demonstrates the achievable colour space using all dye types with Mimaki® and Print Star® dyestuffs.

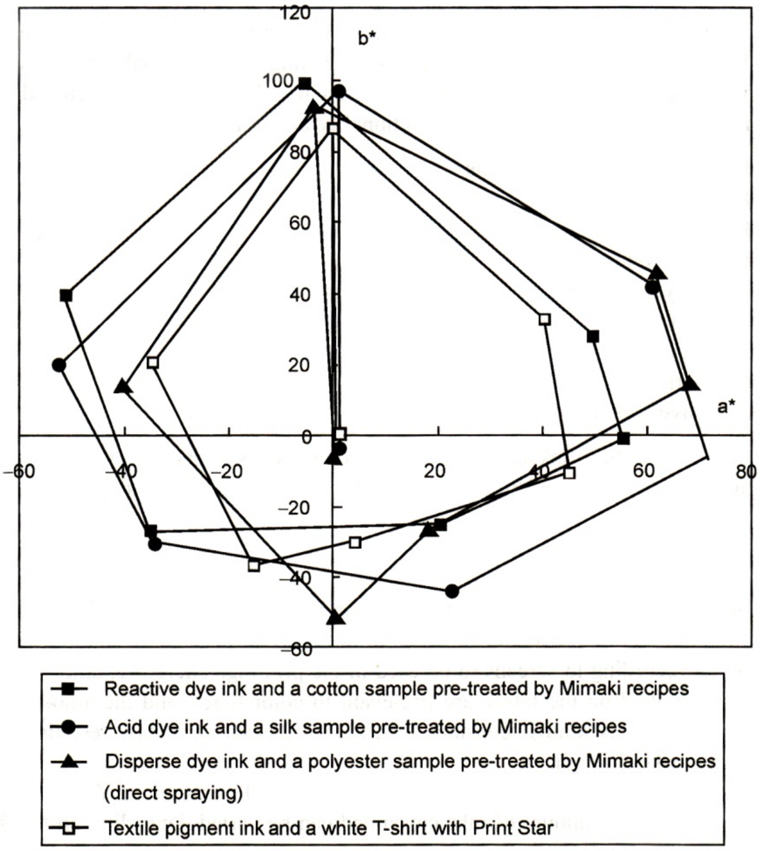


Figure1.14 (Kobayashi, 2006)Colour Gamuts of Fabric Printing Inks

When printing indirectly with disperse dyes (dye sublimation), it is popular to use only the four basic colours, as this offers a wider a colour space than to using the eight colour reactive dyes (Mighall, 2009f).

Textile specific software is available to manipulate images, which usually include flat and continuous tone designs, ability of colour separation, a powerful repeats functions and colour management.

On the other hand, RIP (Raster Image Processor) software for digital printing of textiles from a graphic package should be able to accept textile industry file formats from CAD design, screening separation programs and accepting common graphic file formats. However, as digital printing requires no colour separation, and as the commercial graphic packages become more flexible, there will be a move towards packages such as PhotoShop® and a reliance on the software RIP to do much of the textile and colour work.

The principles of colour communication between the input and output devices remain the same for textile printing; however, more variables apply. The monitor and input device calibration remains the same, but the main differences occur with the output device.

For the most accurate achievable results, colour measurement should be applied, returning to the principle of spot colours. Reproducible colours can be achieved by using the same dyes, by using standard (pre-tested) colour palettes and keeping all post-treatment guidelines the same. These standard colours (used for the proofing) can then be communicated to the dye house/fabric manufacturers for bulk production. However, some variables, such as the fabric, will remain. Each batch of fabric should be tested, as this can have a major impact on the colour outcome (Mulla, 2009c).

Colour libraries are a more simplistic and reliable method for colour reproducibility. Using textile software, a library of colours can be produced (using a chosen colour reference guide RGB, Lab, HSV) and printed onto a pre-treated fabric. This can then be post-treated using the standard guidelines. The colour library (Figure 1.15) is used as a standard in which the colour palettes can then be matched to. For the most accurate reproducible results, the colour matching should be done under controlled lighting conditions (light box), the same fabric should be used and the same pre/post-treatment guidelines should be strictly followed. The recommendation would be to have a library for each fabric.

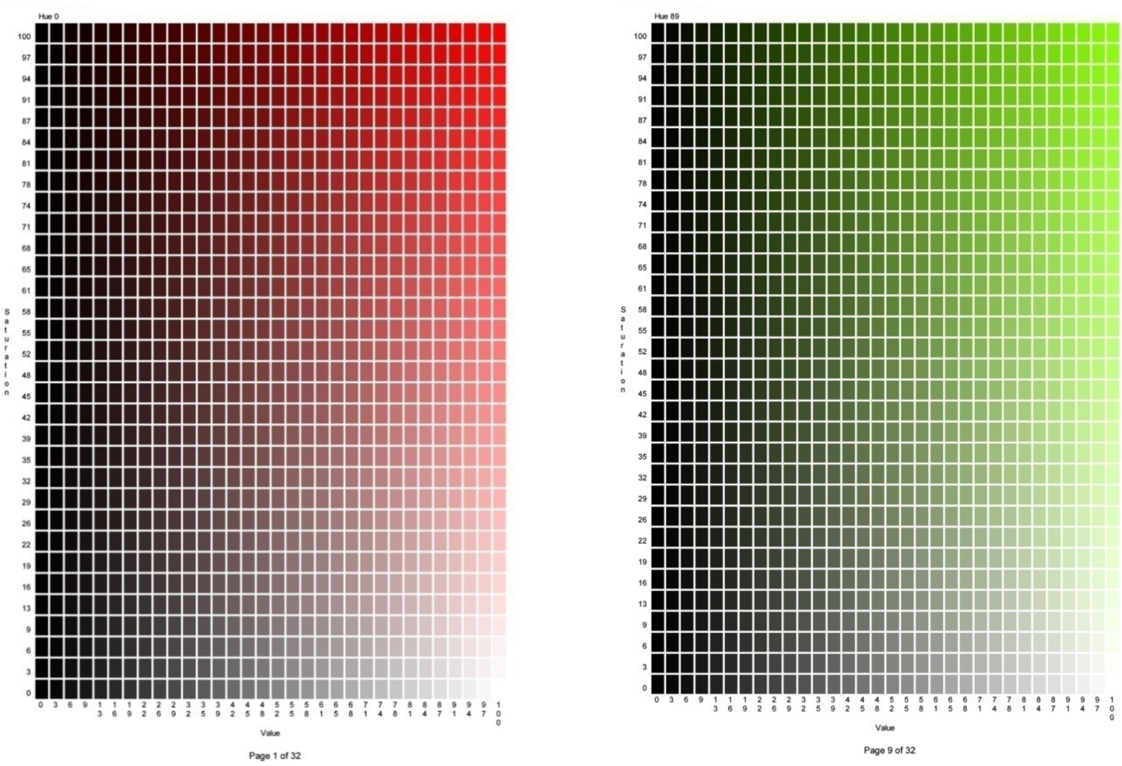


Figure1.15 (University of Huddersfield, 2009) Pages from a Colour Library Generated Through Lectra ® Kaledo Print Software

As discussed earlier, when using ink jet printing for the proofing, more differences will occur between the two printing methods. By implementing colour management software, the initial colour values can be communicated, saving time and money. When printing in full colour (no colour reduction) using ink jet printing onto textiles, there is no process to guarantee obtaining accurate colour. Colour profiles on screen and through the printer will aid in achieving the best possible result.

Although, there are too many variables to achieve consistent reproducible colour results, particularly with textiles, colour management software enables colour communication and therefore helps achieve a reasonable representation. This research has strictly followed all post-treatment guidelines set in the preliminary experiments (see section 2.2.1) and with the use of colour libraries (where appropriate) and printer profiles, reproducible colour has been achieved.

1.8New Boundaries and Developments for Ink Jet Printing for Textiles

There are many techniques that can be used with printed fabrics to enhance the design and the fabric's quality, which have been well researched within the traditional printed textiles area (refer to chapters 3/4). Many techniques can be used to develop the texture, colour and the nature of the fabric using overlays. These techniques can include the use of embroidery, lacquers, Expantex, foils, burnout effects such as devoré, discharge printing, resist methods of printing, and dyeing such as using wax and binding techniques, and all add additional cost to a printed fabric.

With the use of CAD and CAM within the textile industry, short run production is continually being developed and becoming more feasible. Ink jet printing offers a new approach to high end and a bespoke approach to the printed textile industry. It has enabled a reduction in costs and times required to expand this market area. Another great advantage of using ink jet printing for short run print lengths is the possibility of generating high quality, innovative, customised, bespoke fabrics at lower prices and at shorter production times. However, for this development in the textile market to occur, certain processes need to be adapted and certain problems overcome; the ink jet printer will need to be set up, the correct pre and post-treatments for the fabrics assigned, and the method of colour management to be used needs to be established.

The author envisages that ink jet printing for textiles will eventually replace traditional rotary screen-printing within the printing textile industry for bulk production as well as sampling. This will be more than a change in production method (not just the scale and the turn-around of production dramatically decreasing), but a change to the way we approach printed textile design.

This PhD investigates ink jet printing with a new lead in design, introducing opportunities for reviving the UK textile industry. This research demonstrates the strong design resources the UK textile industry has to offer, and encourages craftsmanship, customisation and innovation in design that can be produced economically. Bespoke textiles designs for fashion have been generated in this PhD, but this research will also discuss the potential of these techniques in entering alternative printed textile markets and the reproduction of these crafted designs to capture the high street demand.

Designers can afford to be more demanding in the number of colours used, choice of fabric, also the sensitivity and the complication to the print design. They can experiment with a highly creative, hand crafted look with near instantaneous results. Mass-customisation will support individuality and a large array of choice for the customer. Ink jet printing will also reduce costs for short production runs of high quality, bespoke designs. These changes in the market, influenced by the use ink jet printing for textiles, are only just being recognised.

This advancement would require more print manufacturers to be setup as digital printing plants. These could incorporate several ink jet printers running simultaneously to cater for the speed and quantity required, while allowing fabric and dye flexibility. 'Digital Print Asia (DPA)' is part of 'Yeh Group' (one of the largest textile and apparel companies in Thailand), which has grown from three ink jet printers at its inception in 2002, to twenty ink jet printers in 2008 (all based on the Mimaki TX2) (Tait, 2008, pp.22-24). This environment allows for a flexible production to printed textiles. All twenty printers could run with one design to allow for greater volumes of printing to be achieved, or each printer could run with a different dye and fabric combination. For someone starting a digital print bureau for fashion in the UK, could set up with a single Mimaki® TX2 1600 ink jet printer/small steamer and wash facilities, for this they would need an investment of approximately £40K in 2010. However, if they were looking to increase the number of printers, or run a faster printer, with a continuous steamer, this investment could raise to an excess of £150K in 2010 (Mighall, 2010).This flexible method of printing, suitable for mass customisation, is the ideal future for the UK textile print industry. There are investments being made for digital textile printing during the economic downturn, but these are mainly in the soft signage area using dye sublimation, as this is already recognised as the future for soft signage (the largest output for digital textile printing). It is vital that this and other research is undertaken to demonstrate the importance of investment for the UK textile industry.

When competing in terms of costs with low labour cost countries (such as China), the UK textile industry has struggled greatly in 2009. However, currently, the sectors of the UK industry that are thriving are those aimed at niche markets, with short runs, close to outlets. Companies with high flexibility, which can respond almost instantaneously to ever changing market/consumer demands, are also doing well. Ink jet printing is ideal for these sorts of companies, so should enable them to thrive even in an economic downturn. Of course, the weak pound helps exports; the high design and production quality of UK ink jet printing for textiles could find global markets. The use of ink jet printing could play to a major strength of the UK; the UK has a long standing reputation as a centre of excellence and innovation (www.uktradeinvest.gov.uk), enabling the UK to become a significant player in the global textile print market.

1.9 Discussions and Conclusion

Technological and dye developments are establishing ink jet printing as a sustainable production method in the industry. Therefore, to support these production changes, investigations must take place to ensure that the design process is developing at the same pace. This combined development will ensure that the true flexibility of ink jet printing is fully utilised, something that has become increasingly important in recent years for the UK textile industry.

1.9.1 The Transition between Digital and Craft

In section two of this thesis, the transition between digital and craft textiles will be examined to show the creative and commercial potential of ink jet technology. The principles of digital design for textiles and textile crafts are considered to be extremes. Textile crafts are unique pieces of artwork that can be highly detailed and very time consuming to produce, such patchwork, hand woven, embroidered or hand pleated. Digital design and manufacture for textiles sits very differently in the textile market to that of textile crafts. Digital design was generated for speed, ability to record, reproduce, and the production of high quality graphical effects, while crafts are known for its hand generation, unique approach and personal touch. Ink jet printing for textiles offers the opportunity to cross the boundaries of these two principles. This can be examined in two ways; by investigating the feasibility in reproducing textile craft techniques using digital technology (Chapter 2.0) and by adding a crafted approach to digital design, hand manipulating the materials prior to and after printing (chapter 3.0 and 4.0).

Digital printing for textiles is already clearly recognised for its benefits of speed and high quality printing for short run production; however, the true flexibility of the printer is only just being investigated. By utilising digital technology and employing craft techniques, the boundary of digital and craftsmanship can be crossed, creating new market opportunities. This PhD investigates and demonstrates the future possibilities of using ink jet printing in the generation of innovative, bespoke printed fabrics.

Section 2

Practical Experiments

Chapter 2

The Production of Complex Textile Craft Techniques using CAD and Ink Jet Technology

This chapter is based on the paper published in Textiles Journal Vol.33, 2006 titled "Craftily using Ink Jet' and the paper presented at ARCHTEX 2005 conference titled 'The Commercial Realisation of Complex Textile Craft Techniques by CAD and Ink Jet Printing'. The full papers can be viewed in the Appendix of this thesis. This chapter will demonstrate the benefit of using ink jet technology in the reproduction of textile craft techniques. It will evaluate the principal method of production, and describe the processes and techniques used for managing colour. For full details on all fabrics produced and exhibited as part of this practical PhD, please see section 4, p.137.

2.1 Introduction

The originality of a hand crafted piece of textiles will always appeal to the buyer (an example can be seen in Figure 2.1), but the associated time and cost will limit the commercial feasibility for average high street production (demonstrated in Figure 2.2).Crafted design is less commonly seen on the high street, because it is currently not economically feasible. The average high street customer, while having the attraction towards craftsmanship and individuality, is more focused on fast fashion as this has the lower price tag, and is therefore less willing to pay the higher price associated with an original crafted design, when it may only be kept in the wardrobe for one short season. While this research recognises those that will purchase fast fashion, this crafted approached to design also recognises a more discerning consumer (the type that shops at a boutique), that is concerned about sustainability and quality and will cater for them with this approach.

Crafted designs are currently sold in smaller boutiques, where the aim of these particular retailers is to encourage and promote individuality in design. The consumer will be one that is also interested and has the appreciation for the design, the personal touch and most importantly aesthetic qualities of the craftsmanship. This chapter will investigate methods in which craftsmanship in design could also approach the high street using ink jet printing focusing towards mass customisation, ultimately promoting more individuality in design for the customer and encouraging craftsmanship for the UK designers.

Figure 2.1 (Willoughby, 2008) Hand Crafted Garment using Hand Stitch, Appliqué and Print

Design Development and Sampling

↓

2 Weeks

↓

Production *(of one product)*

↓

1 week

↓

Completion *(of one product)*

Figure 2.2 (Ryall. H, 2009) Example of Time Taken for the Production of One Hand Crafted Product

To craft is a process involving particular skills in making something by hand (Oxford Dictionary, 2009) requiring attention to detail, technical skill and a creative mind in the generation of an original crafted artifact. Therefore to create a highly detailed textile craft, involving, for example, stitch, appliqué, print embellishments and hand-woven textiles, also requires patience and time. To reproduce a hand crafted piece of textiles, or even one that was generated as a small sample piece of 10 centimetres, on a far greater scale for mass production, would involve too much time to make the product commercially viable for the high street, therefore such pieces will continue to be individualised or will be produced as variations on a central theme.

Digital printing for textiles now presents the opportunity to give the visual appearance of a hand crafted fabric, while producing at faster speeds and at larger volumes but at affordable prices. By introducing this 'crafted look' to the high street, a new market opportunity arises for both fashion and interior textiles. This will also encourage the area of textile craft design to investigate and develop new techniques.

This section of the research aims to achieve an accurate representation of hand-developed craft techniques using CAD software and textile ink jet technology, to study the problems that may arise with this, and to produce economically viable, high quality printed fabric results. The processes investigated are documented to aid future production of simulated craft techniques onto printed fabrics, resulting in the discussion of the use of colour management, CAD software and potential end uses.

Limited previous research has been done in this area of textiles analysing the reproduction of aesthetic qualities associated with traditional hand surface design techniques of batik and discharge, investigating whether these could be achieved using graphics programs and digital printing technology. Some research was undertaken as part of studies for Master of Research, at North

Carolina State University in 2002 (Lawrence, 2002) Lawrence discusses how these techniques were successful in the creation of digital batik and discharge samples. It highlights ways to achieve the depth of colour through digital printing, to match the colour intensity of a dyed fabric, by two-sided printing. Two CAD programs were used, Photoshop® for the generation of the artwork, using techniques such as custom art brushes developed from the scanned in batik and discharge prints, and textile specialist software (Pointcarré) to limit the colour palette used. Colour management was also approached using colour matching for a collection of pre-tested colour standards. The limitations in this research by Lawrence were also highlighted, such as the ability to achieve pale colour tones was restricted (with only using 6colours of the same concentrate, and no pale colours), and the limited range of pre-treated fabrics available on the market. These issues having been recognized in 2009, they are being resolved and continually improved in the industry.

This chapter will investigate the simulation of hand crafted techniques using CAD and ink jet technology. It will discuss, in depth methods of colour management used to achieve photorealistic qualities onto fabric, with minimised limitations of achievable colour (within the printers colour gamut). These techniques are not limited to a small number of craft techniques, but are flexible to the designers/customers requirements. This research will also highlight the flexibility of these techniques for production, once the initial post-treatment guidelines are set up. All these techniques can also be catalogued for future uses. It is recognised by the author, that it is impossible to trial all crafted textile samples as each design will be unique, and the future uses of these techniques will greatly depend on the designer's creative vision.

2.2 Image Preparation for the Reproduction of Textile Craft Techniques using CAD and Ink Jet Technology

2.2.1 Preliminary Experiments – Colour Reproducibility

Steam conditions do appear to have a very strong effect on the ink jet printed colour outcome. Firstly experiments were undertaken to find the optimum steam time. This would then be used in all future trials. If steam conditions change or do not reach standard settings of temperature and humidity, varying results may occur. In this research so far four steamers have been used, three star steamers (taking loads of about 10m) and one sample steamer (taking roughly A3 sized fabric samples). The sample steamer is pressurised and uses direct steam.

The star steamers used different steaming methods; using direct and indirect steam. 'Direct steam' is where steam is pumped straight inside the steamer, whereas 'indirect steam' is when steam is pumped through a coiled pipe at the base of steamer, which lies in water. The star steamers all produce atmospheric steam conditions (not pressurised). Each method produced different results with colour strength. The steaming stage is critical for reproducibility of colour. Standard steam times can be achieved as a general for all fabrics, although this may vary for specifics.

	Temperature
Small Sample Steamer (Made by Werner Mathis from Robert Jackson-Wardle) (Direct Steam)	All Steaming was done at 102°C
Star Steamer 1 (Indirect Steam)	No temperature measurements were able to be taken
Star Steamer 2 (Direct Steam)	After 3 minutes - 100°C 5 minutes - 106°C 8 minutes - 107°C 10 minutes - 107°C 14 minutes - 107°C
Star Steamer 3 (Star steamer made bespoke by Sureprint of Mansfield) (The option of both Direct and Indirect Steam)	After 3 minutes - 103°C 5 minutes - 103°C 8 minutes - 104°C 10 minutes - 105°C 14 minutes - 105°C

Table 2.1 Steam Temperatures

The recommended steam time and temperature for reactive dyes from RA Smarts (CAD & Machinery)® is 9-10mins (in pressurised conditions, longer in atmospheric steam conditions) at 102°C,(Mighall, 2009g). This research started by looking at steam conditions under which reactive dyes, for ink jet printing, gave best colours and image results. All steam trials were printed on Cotton (non-optic) and once a wide gamut of colours was achievable, various other fabric trials were carried out. Tests were produced experimenting with steam times, to see what colour outcomes and differences came from steaming the fabrics at various times.

It is possible to measure the strength of colour using a colour spectrometer to get accurate data on colour outcome. Using ΔE, ΔL, ΔC, ΔH (Light, Chroma, and Hue angle) colour spaces provides an understanding of the varying colour changes that occur after different steaming times. Table 2.2 shows a comparison of 5 and 15 minutes steaming, with the standard 10 minutes steam time. There is a discernible difference visually in time of steaming.

Colour	Steam Time (Star Steamer 3 – Direct Steam)				
	5 Minutes		10 Minutes	15 Minutes	
	ΔE			**ΔE**	
Blue	**1.359**	Lighter, greener, less blue.	Standard	**1.147**	Darker, less green, bluer
Red	**2.607**	Lighter, less red, yellow.	Standard	**0.380**	Redder, less yellow
Green	**1.054**	Lighter, greener yellow.	Standard	**1.191**	Darker, less green, less yellow
Yellow	**0.895**	Darker, greener yellow.	Standard	**0.563**	Darker, less yellow.

Table 2.2 Comparisons of Steam Times and the Effect on the Colour Outcome

Table 2.2shows the colours are lighter with shorter steam times and darker with longer steam times. The yellow is the exception, as the colour is slightly darker with a shorter steam time than the standard. With the longer steam time it behaved in a similar way to the other colours. The largest difference at 5 minutes was the red, however in comparison it had the smallest difference after the standard 10 minutes.

2.2.1.1Results from Steam Trials

Shorter steam times produced weaker colours; steaming for 10 minutes produced the optimum colour results. This was consistent with all steamers. It allowed for strong, vibrant colours, consistent colour results and with little risk of ink bleeding. It is recommended that each steamer and fabric used is tested before use, using 10 minutes as a standard steaming time.

2.2.2 Experiments into the Appropriate Method of Colour Management for the Production of Complex Textile Craft Techniques

In this section methods of colour reduction and management were investigated, to ultimately achieve the best representation and most efficient method of working in the reproduction of hand crafted textile techniques using digital print technology.

2.2.2.1 Textile Craft Techniques

Selections of craft generated techniques were gathered from varying specialist textile craft practitioners of embroidery and weave as a basis for this research. These textile crafted samples were selected from members of staff and graduate's work from The University of Huddersfield. They were selected for the varying techniques, colours and structures used to give a broad basis for this research, see table 2.3.The textile samples of varying sizes (some as little as only 50x80mm) were scanned in at high resolution (400dpi). Scanning in at the higher resolution gives more flexibility for future resizing. All resizing should be considered before colour reduction for the highest quality of image to be achieved.

Figure	Craft Technique	Description
2.3	Embroidered sample	Amaya machine embroidered fabric with additional beaded hand embellishments (made with Calico).
2.5	Woven sample	Hand woven (on a computerized Arm Loom). Loosely woven bundles of ends are hand-manipulated to expose a double layered cloth, with contrasting colour balance.
2.7	Patchwork sample	Hand embroidered cathedral-window patchwork sample, made with Calico and leather.
2.9	Embroidered sample	Needle punched fabric with domestic machine and hand embroidery detailing, made with reclaimed fabrics.

Table 2.3 Detailed Description of Craft Techniques used in this Research

2.2.2.2Colour Reduction

To reduce the colour of a scanned image from its original true colour format (potentially millions of colours) is a difficult task, particularly when requiring an accurate representation of the original sample.

When producing digital representations of textile craft techniques, the image quality and colour standards must be accurate to the finished sample. High image quality can be obtained through scanning at an appropriate resolution, but colour must be examined in greater depth. When printing the true colour image with no colour alterations made, the printed outcome was unacceptable with harsh and unsubtle colours. This proved the importance of using a method of colour management, in doing so the reduction of colour is critical in this work. The colour reduced file must be perfect to that of the original. Figures 2.3/2.4 and 2.5/2.6 demonstrate that there should be no difference to the original scanned image in true colour to that of a reduced colour image of approximately 90 colours.

Precise colour reduction can be obtained in many ways. This can be done automatically using most general CAD software by specifying the number of colours required to remain in the design (those that are most frequently used). More accurately it can either be achieved by specifying the actual colours you require to remain in the design or by using 'palette builder' to select particular colours. For example, choosing a light and a dark tone, and then specifying the additional number of tones between the two colours, and finally allowing the software to automatically fill in these tones. This is then repeated to gather all colours tones required in the design, which can be done by using textile specialised software only.

It was still important to keep larger numbers of colours in each image to project a realistic version of the original crafted sample, to an almost photographic quality. Large numbers of colours in designs usually means a great deal of time spent colour matching all colours. This work has looked at ways in which to limit the number of colours that require matching and still achieving excellent colour results.

Figure 2.3 (Holroyd. M, 2005) Original scanned embroidered sample

Figure 2.4 (Holroyd. M, 2005) Reduced to 90 colours

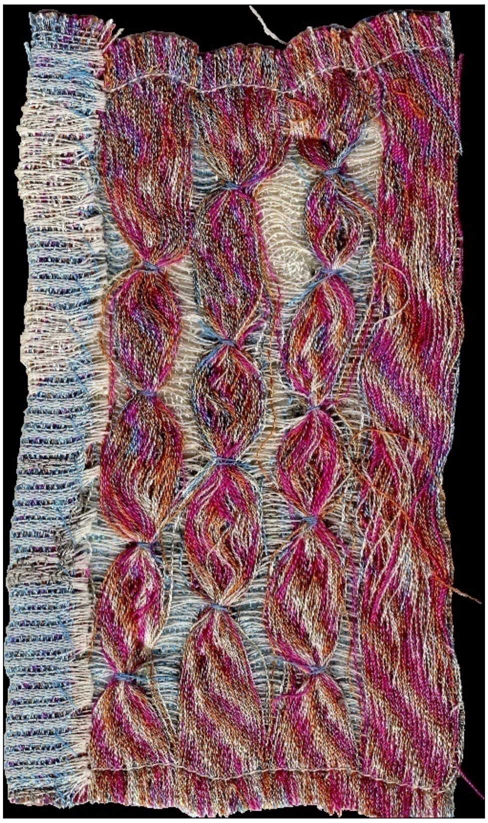


Figure 2.5 (Begum. S, 2005 Final Year Collection) Original scanned woven fabric sample

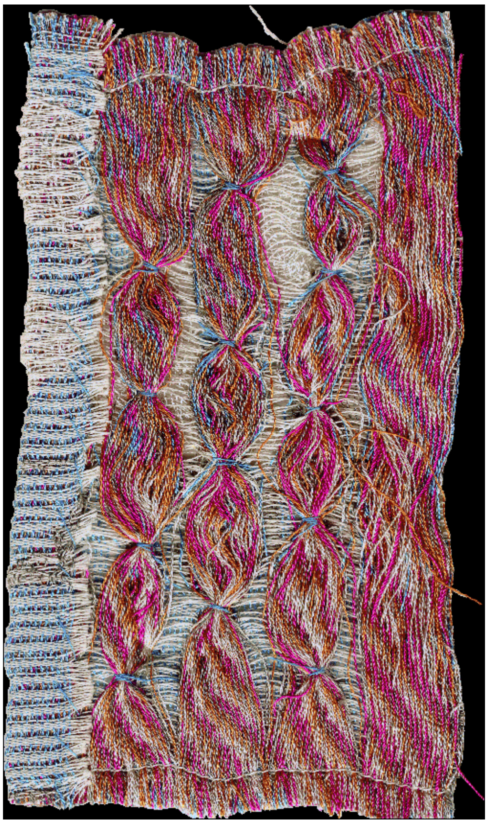


Figure 2.6 (Begum. S, 2005 Final Year Collection) Reduced to 95 colours

2.2.2.2.1Colour Reduction Method 1 –Most Common

This method works by selecting the number of colours that you require to remain in the design/image as described earlier. It is very quick to complete and sometimes achieves promising results, however from the author's experience this is rare. This is caused by the process only collecting the most frequently used colours in the design, and not capturing the accent colours and subtle tones that are needed to accurately represent that of the original image. In these experiments the images were reduced in colour to the maximum allowance in a reduced colour window (256). If at this stage the image was an accurate representation to the original, colour matching would be considered to ensure the required printed colour outcome. However, it was not feasible to colour match 256colours. Therefore, the colour palette was re-organised to show the colours ranging from the most to the least frequently used, which allowed for the most commonly used colours (over 1%) to be easily identified. However, it quickly became apparent that colour matching at the above 1% threshold would not achieve the desired standard, as many key colours would not be matched. Therefore logic would suggest lowering the threshold, ultimately increasing the number of colours required for matching, moving ever closer to the infeasible number of 256.

2.2.2.2.2 Colour Reduction Method 2 – Individual Colour Selection

This method was not used in this research due to it being very time consuming when selecting large quantities of colours.

2.2.2.2.3Colour Reduction Method 3 – Tones/Gradients

Using 'Palette Builder' (Lectra ®Kaledo Print) as described earlier (section 2.2.2.2); as 'tones/gradients', can be found in textile specialist software. This proved to be the most successful process for colour reduction. It requires only 2 colours to be selected at any one time (typically a light and dark tone of the same colour). The software then builds up the palette based on the optional number of tones selected between the 2 tones/colours chosen initially. This method is time efficient and flexible as only a small number of colours need to be selected, each with a wide range of tones, and groups of colours can be added and deleted as necessary. With careful selection, an accurate representation can be achieved easily.

Two experiments in colour matching were undertaken. They examined ways in which to achieve the best colour results possible and considered the time involved. In experiment one only the initial two tones/colours in each group were colour matched, which resulted in a smaller proportion of colours needing to be matched. For example, out of 125 colours only 50 colours were matched.

In the 2nd experiment the reduced palette was re-organised into a range of the most to least frequently used colours (an automatic function available with textile specialist software). This made it clearly visible for matching all colours used over 1%.

2.2.2.2.4 Printed Results

The strongest results achieved were those colour matched using colour reduction method 3 and in accordance to the method described in experiment 1. By matching the initial two tones/colours in each group, wider ranges of colours were matched.

For example, if the most frequently used colours in a textile craft sample are the pale cream and grey tones with the occasional red, yellow, and blue, matching all colours used over 1%, would not reach enough of the latter colours. This suggests that more colours would need to be matched, thus extending the amount of time required or leaving unexpected colour results after printing. This is demonstrated in Figure 2.7.

Achieving excellent colour outcome in this work is essential to enable an accurate representation of that of the original. Colour matching is essential for this to occur; however, some colours are still unachievable. In this research a Mimaki TX2 ink jet printer has been used. Eight reactive dye colours are used; cyan, magenta, yellow, black, grey, light magenta, blue and golden yellow. However, even with this number of dyes available some colours are still unobtainable. A possibility of improving the colour outcome would be to change the dye colours as necessary. Image quality is also essential to achieving strong printed results. The printer was set to print at a resolution of 720 dpi, this allowed for high quality prints to be produced.

2.3 Discussions and Conclusions

The printed results are visually very strong in this research as shown in Figures 2.8 and 2.10. They show an accurate representation of a variety of textile craft techniques. Once each sample is recorded in a digital format and the above work has been applied, the crafted samples become very flexible as to their future uses.

The production time of a 'crafted' sample is greatly reduced by as much as two weeks, rather than having to produce finished hand crafted product taking a week to complete, this digital method can work directly from an initial sample made. They can be custom made and commercially viable in small-scale production using ink jet technology. For example, some images lend themselves to be thrown into a repeat, which gives the customer the option of the amount of printed fabric they require. Using CAD software small areas can be simply extracted out of the original sample and dropped onto plain background or even accurately positioned onto another design. The colours are inter-changeable to customer needs and the scale of design can be altered on the computer screen (providing the quality of the image lends itself to this), or a complete change to the fabric used. Figures 2.8 and 2.10 demonstrate how a small hand crafted textile sample can be reproduced using ink jet technology for small-scale production.

In the next chapter, embellishment techniques such as screen print overlays will be investigated to show the methods when blending traditional and digital printing.

Figure 2.7 (McCarthy. N, 2005 Final Year Collection) Original scanned patchwork sample

Figure 2.8 (Ryall. H, 2005) Repeated patchwork sample and alternative colour-way - ink jet printed

Figure 2.9 (Breeze. H, 2005 Final Year Collection) Original scanned embroidered sample

Figure 2.10 (Ryall. H, 2005) Finished embroidered sample extracted onto plain background

Chapter 3

The Use of Embellishment Techniques with Ink Jet Printed Repeated Designs

This chapter is based on the paper presented at INTEDEC 2003: International Textile Design and Engineering Conference. The full paper can be viewed in the Appendix of this thesis. For full details on all fabrics produced and exhibited as part of this practical PhD, please see section 4, p.137.

3.1 Introduction

To embellish means to;

> "Make more attractive; decorate, add extra details to (a story or account) for interest".
> (http://www.askoxford.com/concise_oed/embellish?view=uk, 2009)

Ultimately this enhances the quality and look of the fabric, and adds value. The nature of the fabric can dramatically change with the addition of embellishment techniques. It is a dynamic way of simply enhancing the surface and creating bespoke qualities to a fabric, see Figure3.1.

The added time associated with the production of a printed fabric with a screen print overlay technique will increase the overall cost. But, when using ink jet technology the time and cost involved can be dramatically reduced, with the shortened production time and low set up cost. The finished quality will at least be similar to that of a screen printed fabric: it could be better (sharper; more life-like).The use of this technology for short run productions makes economical sense, and with its ability to produce a high quality output, the overall time and cost can be reduced without having an impact of the quality of the printed fabric.

The printed design will also have more scope; at no additional time or cost the design can have larger numbers of colours and have greater detail. The finished product can be much more exciting and innovative than a screen printed version, as it is easier (and far cheaper) to combine embellishment such as screen print overlay techniques using ink jet printing. The principle of drop on demand printing means that the customer can have full say in the quantities printed, therefore giving far greater flexibility in the generation of bespoke printed fabrics.

When applying additional decorative effects to printed fabrics in production, to save time and cost, the enhancement technique must to be considered at the beginning stages of the design. Using CAD, the design can be adjusted to correspond with the embellishment technique prior to printing. This chapter and area of research has been concentrating on setting up a strict process to be followed for the creation of embellished ink jet printed fabrics. Devoré, pigment and lacquer print embellishments were experimented with in this chapter only for the varying visual/tactile qualities they can bring to the fabric. They are also commonly used in textile practice due to their relative ease of application.

Figure 3.1 (Fernades. LC, 2009) Devoré embellishment onto a digitally printed fabric

3.2 Fabric and Equipment List used in Research

Equipment

Equipment Used in Research	Supplier	Details
Photoshop	Adobe	Creative Suite 3
CAD Embroidery Machine	Amaya	Design Shop Version 7 (7.00.046)
Domestic Embroidery Machine	Hobkirk Sewing Machines Limited	Bernina 1008
Wascator	John Godrich	Wascator FOM 71S
Kaledo	Lectra	Kaledo Print SoftwareV2R1
Mimaki Ink Jet Printer	RA Smarts	TX2-1600
Print Table	RA Smarts	Screen Print Tables
Sample Steamer	Robert Jackson-Wardle	Werner Mathis (Taking samples of A3 in size)
Star Steamer	Sureprint of Mansfield	Star steamer made bespoke for the University of Huddersfield (Direct/In-Direct Steam options)
Commercial Steam Iron/Press	A1 Sewing Machines	The presses have a boiler, a heated vacuum table and the actual irons F.LLI Casoli, Boiler Model: AG92 'Maciste' 5.5 Watts/Working pressure: 3-31/2 bar Table model: TLA51 Iron model: FV75 set at 70°C

Table 3.1, Equipment Used in Research

Materials

Fabric	Supplier	Composition	Type	Width	Weight	Pre-treated for ink jet
Chiffon Mouseline	RA Smarts	100% Silk	Ivory	140cm	6MM	Yes
Silk Habotai	RA Smarts	100% Silk	Ivory	140cm	10MM	Yes
Silk Medium Crepe De Chine	RA Smarts	100% Silk	Ivory	140cm	16MM	Yes
Silk Twill	RA Smarts	100% Silk	Ivory	140cm	18oz	Yes
Silk Viscose Satin	RA Smarts	82% Viscose 18% Silk	Ivory	140cm	120g/m	Yes
Silk Viscose Velvet	RA Smarts	82% Viscose 18% Silk	Ivory	140cm	250g/m	Yes
Cotton Poplin	RA Smarts	100% Cotton	Optic	147cm	135gsm	Yes/No
Cotton Satin	Whaleys Ltd	100% Cotton	Non-Optic	147 cm	235gsm	Yes
Cotton Satin	RA Smarts	100% Cotton	Optic	147cm	235gsm	Yes/No
Cotton Jersey	RA Smarts	90% Cotton 10% Elastane	Stretch	140cm	150g/m	Yes
Plain Cotton	Whaleys Ltd	100% Cotton	Optic	150cm	145g/m	Yes/No
Lace Fabrics	Bombay Stores	100% Polyester and Poly/Cotton Mix	-	1m	130gsm	No
Lace Fabrics	University of Huddersfield, Shima Seki®	1/167F30 Decitex Flat Bright Trilobal Polyester	-	30cm	-	No

Table 3.2, Materials Used in Research

Dyes/Inks/Pastes

Type	Manufacturer	Supplier	System	Colours
Reactive for Ink Jet Printing	Epson	RA Smarts®	Cartridges	Cyan Magenta Yellow Black Blue Orange Light Magenta Light Black
Pigment for Ink Jet Printing	BASF	RA Smarts®	Bulk Feed	Cyan Magenta Yellow Black Violet Orange Grey Violet
Reactive Print Paste	-	Kemtex Educational supplies	Urea, Sodium Bicarbonate, Manutex F700, Resist Salt (added and mixed at the Uinversity of Huddersfield)	Mixed colours using recipes from the DataColor Spectrometer
Pigment Print Paste Magnaprint Binder FF	Magna colours	Quality Colours	-	-
Pigment Laquer Paste Minerprint Matt Lacquer NT	Magna colours	Quality colours	-	-

Dyes/Inks/Pastes Continued

Type	Manufacturer	Supplier	System	Colours
Devoré Print Paste	-	Kemtex Educational supplies	Aluminium sulphate, Glycerine (Glycerol), Indalca (added and mixed at the Uinversity of Huddersfield)	-
Pigment Discharge Paste Discharge base AB	Magna colours	Quality colours kemtex		-
Bricoprint Pigment Colours	Serigraphics Ltd	Sellectasine	-	Mixed colours using recipes from the DataColor Spectrometer

Table 3.3, Materials Used in Research

Suppliers

Company	Details
A1 Sewing Machines	105 West End Drive, Horsforth, Leeds, West Yorkshire. LS18 5JR
Adobe	www.abobe.com
Amaya	Trademark House, Ramshill, Petersfield, Hampshire. GU31 4AT
Andrew Farrington Photography	www.andrewf.com
Bombay Stores	Bombay Buildings, Shearbridge Road. Bradford. BD7 1NX
Datacolor	6 St George’s Court, Dairyhouse Lane, Broadheath, Altrincham, Cheshire. WA14 5UA
Hobkirk Sewing Machines Limited	120-128 Darwen Street, Blackburn, Lancashire. BB2 2AJ
John Godrich, Shropshire	Pellow House, 109 Old Street, Ludlow, Shropshire. SY8 1NU
Kemtex Educational Supplies	www.kemtex.co.uk Chorley Business & Technology Centre, Euxton Lane, Chorley, Lancashire. PR7 6TE
Lectra	Albion Mills, Albion Road, Greengates, Bradford. BD10 9TQ
Magna Colours Ltd	www.magnacolours.com Upper Cliffe Road, Dodworth Business Park, Barnsley. S75 3SP
RA Smarts®	Clough Bank, Bollington, Macclesfield. SK10 5NZ
Robert Jackson-Wardle	The Courtyard, Bodenham, Hereford, Hereford and Worcester. HR1 3JX
Selectasine	www.selectasine.com Old Portsmouth Road, Peasmarsh, Guildford. GU3 1LZ
Sureprint	5e Botany Commercial Centre, Botany Avenue, Mansfield. NG18 5NF
Whaleys Ltd®	Harris Court, Great Horton, Bradford, West Yorkshire. BD7 4EQ
X-rite	The Acumen Centre, First Avenue Poynton. Cheshire. SK12 1FJ

Table 3.4, Suppliers of Equipment and Materials Used in Research

3.3CAD File Preparation

In this research the designs used are generated in repeat at a traditional design size used in industry of 64cm or a division of this. Although a specific repeat size is unnecessary for the use of ink jet printing, this allows the option of later generating the design using traditional printing methods. Also repeated designs gives more scope to the amount of printed fabric by increasing and decreasing the number of repeats using the CAD software or the Textile RIP.

Although reducing the number of colours per design is unnecessary for ink jet printing, working in reduced colour enables the colours to be matched prior to printing, thus cutting out any colour trials that would usually need to be done (as discussed in chapter 2). With the use of accurate colour reduction using the CAD software, excellent results can be achieved, still obtaining three dimensional and photographic qualities.

These designs were inspired by organic shapes and structures mixed with a kaleidoscopic inspired approach to image manipulation. The designs were taken from a mix of natural inspirations and three-dimensional structural drawing using fabric. The colours in this collection are more naturally inspired with a collection of green, silvers, aquamarine blues to add highlights, and with additional rich aubergine, red and purples. Again, these were all inspired by appropriate colour trends for fashion.

To be able to prepare all equipment and information ready for applying the additional decorative technique to the ink jet printed fabric, the overlay is calculated as part of the original CAD design. From either, a single colour separation or a design motif in the original design, an overlay can be extracted. This can later be used for developing a screen or can be fed into the relevant software. For instance a single colour separation can be used to generate a screen ready for a print overlay or transferred into an embroidery package ready for production. For this to occur certain requirements must be applied, such as the separation must be cleaned making sure there are no stray pixels and that the edges are smooth. Lines may also be required to be of a certain thickness for a print or embroidered area to be noticeable or feasibly produced.

3.4 Fabric Preparation and Development

The fabric shrinkage will need to be taken into consideration to enable accurate registration between the printed fabrics and the additional decorative overlay. This measurement will need to be taken after the printed fabric has been post-treated. A study has been done in this research to gain the shrinkage information on three fabrics at present: Plain White Cotton, Silk/Viscose Velvet, and Silk/Viscose Satin (refer to table 3.2, p.63). Previous tests had been done to gather information on whether the wash method and temperature had any effect on the amount of shrinkage to the fabric. There was no difference seen to the amount of shrinkage using the varying wash methods and temperatures. It is recommended by the author, that each new batch of fabric is tested for shrinkage and any changes are taken into consideration.

From the information gathered, the necessary size alterations to the CAD design and overlay were able to be made prior to printing (using Kaledo Print ® to resize the files), so that the result after the decorative overlays are applied is a 32 x 32 cm design (or to the original design size). This information will need to be gathered for any fabric used for printing and decorative embellishment.

When using a printed decorative embellishment overlay, the ink jet printed fabric will need to be pinned down on a backing cloth on the print table. This ensures that the fabric is kept taut and is square. Again this is essential for accurate registration. Techniques such as devoré, pigment ink, lacquer and more have been tested and have produced some very promising outcomes with good registration. Each embellishment technique was tested individually, with appropriate designs and fabrics. Each fabric used had to be tested for shrinkage and the appropriate allowance was given to the design prior to printing. When pinning the fabric onto the print table, allowances had to be made for each fabric to ensure accuracy with the decorative embellishment overlay. Certain fabrics (such as Silk/Viscose Satin and Velvet) caused more problems than others when keeping the fabric straight, particularly if the fabric had some stretch to it. Silk Viscose fabrics were used for their ability to work with the devoré technique. Carefully pressing the fabric helped to achieve accurate results. Once the decorative overlay was printed and dried, they were then post-treated. For the post-treatment of pigment and lacquer overlays, these are heat set for 5 min at 150°C. For the post-treatment for devoré on Silk/Viscose fabrics, these are baked for 2.5 min at 130°C, followed by a hot scour 70 - 80ºC with 1g Metapex wash detergent and cold rinse. Some of the best results were gained from the use of devoré on the Silk/Viscose Velvet and Satin fabrics see Figures 3.2 and 3.3.

The designs in this section were generated using a variety of resources of natural and man made subjects, following fashion trends in 2003.

After the devoré technique has been applied to these fabrics, very little colour can be seen left on the silk mesh as the ink is unable to penetrate all the pile when ink jet printed. To enable a colour to be applied to these areas, a reactive dye paste was used on the reverse of the fabric. The colour was originally matched to the CAD design and a recipe was developed using the Datacolor® recipe prediction system. The dye paste was pulled through a blank screen cutting out any registration problems that may occur again. An 11% increase in viscosity to the dye paste was required to ensure that the dye would not bleed and affect the other colours in the design. Examples of this can be seen in Figures 3.4and 3.5.

Figure3.2 (Ryall. H, 2003) Silk Viscose Satin with Devoré Embellishment

Figure3.3 (Ryall. H, 2003) Silk Viscose Velvet with Devoré Embellishment

Figure3.4 (Ryall.H, 2003) Silk Viscose Satin with Devoré and Reactive Print on Reverse of the Fabric

Figure 3.5 (Ryall.H, 2003) Silk Viscose Velvet with Devoré and Reactive Print on Reverse of the Fabric

3.5 Printed Results

The printed results are visually very strong on the actual fabrics, with good registration between the ink jet printed fabric and the decorative embellishment overlay. Once these processes from design through to finished product are complete, this printing process can be applied, adapted and enhanced to develop a collection of unique embellished fabrics. Effects such as the use of various fabrics and more than one overlay can be applied and there is a possibility of combining various decorative techniques.

3.6 Discussion and Conclusions

By applying these additional features to the ink jet printed designs, the printed textiles market has the opportunity to develop the area of customisation. The customer will be able to choose from a variety of designs, colour-ways, fabrics (that have all been pre-tested for their shrinkage), and decorative overlay techniques, in a referenced catalogue. Alternatively the customer may choose to develop their own design with selected decorative embellishments, to generate their desired outcome. The customer will have full flexibility in the amount printed, which currently, using screen-printing methods, is too expensive for short runs production. The outcome will be of high quality, bespoke fabrics, which will be commercially viable and highly desirable for consumers. This chapter has enabled the best method of practice to be set in place for the embellishments devoré, pigment, and lacquers. The core methods for producing a decorative overlay techniques to an ink jet printed fabric that has been calculated as part of the original design, are summarised as follows. An appropriate CAD design will be generated in reduced colour and colour matched to a colour library. A single colour separation will form the screen for the decorative overlay, that is cleaned from any stray pixels and delicate details are clearly defined. The design will then be digitally printed onto fabric, taking into consideration the size of the design to compensate for any shrinkage that will occur, to ensure the overlay will match the printed design with good registration. While the guidelines have been set up in this research, each new embellishment overlay and fabric will need to be individually tested to ensure strong results with good registration, to achieve the bespoke qualities required, however, the design as always will also play an important role.

All of these printed fabrics can be produced at reduced speeds and costs to that of traditional printing methods. However, cost will depend on the type and number of decorative embellishment overlays required. If the customer desires screen printed overlays, after ink jet printing, there will be a set up cost for each screen made. The time will be reduced as all overlays can be calculated as part of the original CAD design. Also test samples, prior to production, could also be achieve very quickly to that produced with traditional screen-printing methods. A method of colour management must be adhered to, to ensure the colour results are as expected.

The economical benefits of speed and cost reduction are gained with using ink jet printing as the method of short run production, but ink jet printing technology can also print highly detailed designs with larger numbers of colours, therefore giving additional design qualities that were previously unobtainable through screen-printing methods.

Small printing bureaus set up with textile specialised CAD software, print and embroidery equipment, and post-treatment facilities, would be to develop this area of customised print production. With the set up of the catalogue of decorative overlay techniques, pre-tested fabrics, the development of high quality, bespoke fabrics will commercially viable.

In the following chapter, these ideas and techniques will be taken a step further to investigate resist techniques that can be applied with textile ink jet print technology.

Chapter 4

An Exploration of Digital Technology over a Number of Manipulated Textile Surfaces - Resist Printing Techniques using Ink Jet Technology

4.1 Introduction

There is a constant stream of developments in ink jet printing for textiles, where the developments in the dyes are having a major impact on the speed, the amount of achievable colours and the reliability of the printing. New fabrics have been tested and are available, expanding the market for ink jet printing. The developments in the software generated for design and colour management are improving speed, ease of the production process and advanced design skills.

These are all enhancing the quality and quantity of ink jet technology being used in the textile industry and these are gradually replacing some traditional printing methods for short run productions. However, a new focus is needed to coincide with, and direct these and new developments, pushing the use of textile ink jet print technology as a highly creative design tool and not just a means of production. By utilising the high quality, true colour, and drop on demand flexible printing benefits, using a hand crafted approach, it is possible to produce exciting, reproducible and commercial printed outcomes.

Many new materials are able to be printed on using this technology and this is always being challenged, such as knitted fabrics, coarse weaves, and leather. This will be continually pushed with many exciting results. Once gaining an understanding of the printer's flexible options and limitations, the creative mind can begin experimenting with new and pre-manipulated materials. This area of research is examined in this chapter and has opened a new area for investigation.

This chapter investigates the transition between printed textile design with a hand crafted approach and with the use of digital technology. This research has examined the potential of pre-manipulating fabric in the generation of innovative resist printing techniques. This research has uncovered new printable materials, and the development of highly innovative approach to using ink jet print technology. The commerciality of this printing method will be discussed and analysed. For full details on all fabrics produced and exhibited as part of this practical PhD, please see section 4, p.137.

The designs and colour palettes used in this section were all based around a series of forecasted trends for the appropriate seasons.

4.2 The Development of Resist Techniques with Ink Jet Printing

4.2.1 Introduction to Resist Printing

Resist printing is a method whereby a barrier (physical, mechanical or chemical) (Wells, 1997a, p.125) is placed down prior to printing or dyeing, in order to block or counteract the dye, therefore leaving the background colour. As a standard, the resist medium will withstand the dye from colouring the fabric, but colour can be added to the resist paste or to the fabric prior to printing or dyeing.

Resist printing is the oldest method of patterning cloth, dating back to the fourth and fifth centuries of Coptic textiles (Storey, 1978). There are many commonly known resist techniques used with traditional printing; including physical (tied, compressed, stitched) (Wells, 1997b, p.125),mechanical (waxes thickeners, resins and pigments), and chemical (acid, alkali, salts and reducing agents) (Miles, 1994).

Many experiments have been conducted in this PhD research for developing resist techniques using reactive dyes and ink jet technology. These involve the use of chemical (print pastes)and physical resist methods (overlays and hand crafted techniques such as fabric manipulation). These are all described in detail in this chapter.

4.2.2 Resist Paste Experiments

Chemical resists are well researched with traditional printing methods, and with the use of reactive dyes. Examples include Storey's research into traditional printing techniques (1978),Goddard's MPhil research (1992) and Ripley's PhD research (2004).

An alkali needs to be present to aid the fixation of the reactive dyes to the fabric, and are therefore relatively easy to resist using acids. These chemical resist pastes can be coloured to further enhance the printed result.

At present, when using ink jet technology, it is not possible for these resist pastes to go through the print heads, and therefore they are printed manually using screen printing techniques. However, it is envisaged by the author, that research will eventually be done to investigate the feasibility of alternative print paste solutions such as acid resist, discharge and devoré, being printed using ink jet technology.

When using chemical resist agents with ink jet printed fabrics, it is vital to take the pre-treatment (refer to section 1.6.1) of the fabric (prepared for ink jet printing) into consideration. If no pre-treatment is added to the fabric for the use with reactive dyes, or the pre-treatment is damaged in anyway, there will be minimal or no fixation of the dyes. In these experiments the same reactive dyes for the ink jet printer were used as in chapter 2 and 3 and a Plain White Cotton (see tables3.2/3.3 for a list of materials and dyes used pp.63-64).

Preliminary experiments used a pigment print as a resist to the reactive dyes used with ink jet printing, but this had little effect. The results showed only as an over print effect, with no resisting occurring. Experiments in developing the resist paste were then carried out.

Rather than using a general pigment paste, discharge paste was used (this was a product pre mixed by Magna Colour Ltd®), as this can better cope with the use of acids. Since non-volatile organic acids, such as tartaric acid, citric acid and acid salts can act as resist agents (Ripley, 2004) tartaric acid was added to the paste in this case. The acid affects the alkali (sodium bicarbonate) used in the pre-treatment of the fabric for the reactive dyes, causing the printed reactive dyes not to fix to the fabric, leaving the resist print. Also, in one experiment a reactive resist agent was used, to the same 8% quantity as the acid. This did not make any difference to the resist print. Pigment inks were used to colour the resist paste, refer to the pigment discharge paste recipe below.

Pigment Discharge Recipe – Pre Mixed by Magna (Discharge Base AB)

1.6g	Emulsfier e.g. Luprintol
0.4g	Ammonia (0.88-35%)
15g	Binder
40g	White Spirit
43g	Thickening (e.g. Solvitose C% 10%)
100g	

Pigment Colour/Tartaric Acid

1%	Pigment Colour (minimum of 1% or 1g/100g Paste Strength)
8%	Tartaric Acid

The process started with the resist paste being printed onto the prepared fabric for ink jet printing. Once dry, the paste was heat fixed. The fabric was then fed through the ink jet printer and post-treated with a steam fixation and wash process as usual (refer to 2.2.1 for the steam and 1.6.2.2 for the wash process). Varying heat temperatures and times were experimented with for the fixation of the resist print paste. The original temperature tried was 150° for 5 minutes; this was according to the fixation of the pigment inks. Although there was excellent fixation of the resist paste, the heat process appeared to have an effect on the pre-treated fabric. This affected the colour outcome of the ink jet printed design, causing patchy faded areas and less vibrant colours in general.

Later trials were done at lower temperatures for longer times. This resulted in accurate colour outcome for the ink jet printed areas, but the resist paste colour was not fixed sufficiently. The most effective outcome came from baking the fabric at the higher temperature of 150° for only 2 minutes. This allowed the resist print paste to be fixed properly without damaging the pre-treatment to the fabric for the ink jet print. Example of this can be seen in Figure 4.1 and 4.2.

4.2.2.1 Printed Results

The printed results are visually very strong. The resist paste has blocked the reactive dyes completely, leaving a well-defined edge to the resist paste areas. This is a relatively simple process; however, this does require four stages of production; the printing of the resist paste, the heat fixation for the resist paste, the ink jet printing, and then the post-treatment. Ultimately having four stages in production will adversely affect the cost; however, the finished quality of the fabric will be high and will reflect the additional cost involved. To enable this for short run productions, large printing tables and post-treatment equipments must be available.

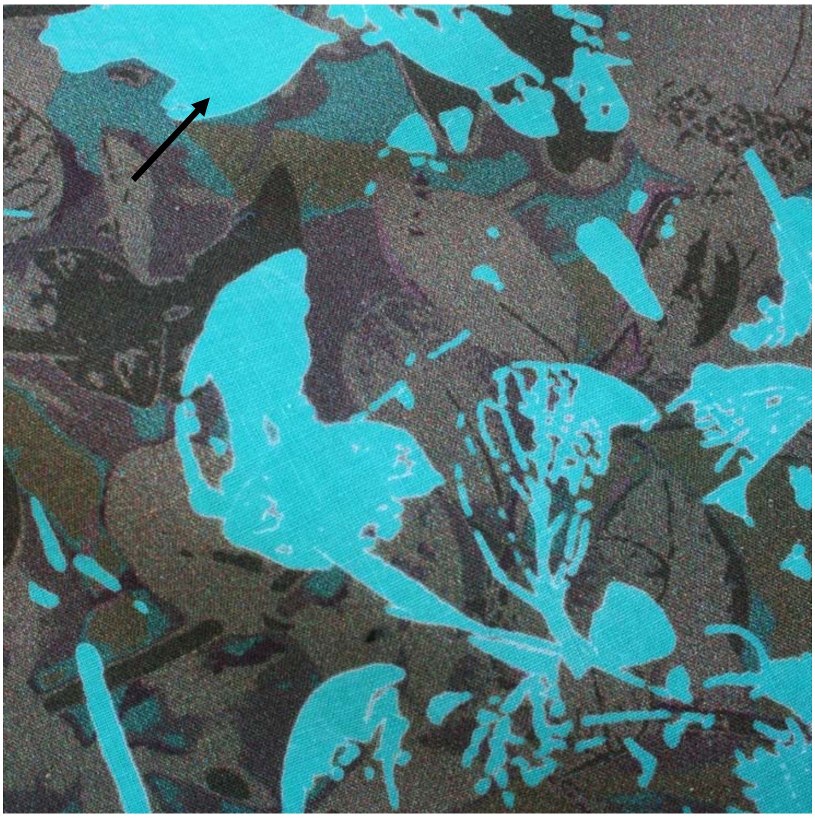


Figure4.1 (Ryall.H, 2003) Discharge Resist Paste used Prior Ink Jet Printing onto Plain Cotton

Figure 4.2 (Ryall.H, 2003) Discharge Resist Paste used Prior Ink Jet Printing onto Plain Cotton

4.2.3Introduction to Resist Print Experiments -Overlays and Pre-Embellished Fabrics

It is important to recognise that these resist experiments produced (sections 4.2.3 – 4.2.5) are all very much hand crafted fabrics. They involved great attention to detail, hand manipulated/stitched fabrics, and are therefore not in themselves commercially viable for the high street market. The designs used in this section are in 24bit (true colour) format; therefore the colours have not been matched. From a designer's opinion, the author wanted a wide range of soft gradient tones for these designs, which could not be achieved with reduced colour. It would also be impossible to match the colours of the ink jet print overlays, as they would mix with too many colours in a 24bit image. Future research in this area could experiment with these techniques using reduced colour and matched images. All 24bit colour designs used in this research were test printed (with post-treatment) to gain the desired colour outcome and therefore, a difficult process to complete commercially. Any colour alterations needing to be made were adjusted in Photoshop® to the image as a whole and re-printed.

These experiments are vital to demonstrate the creative nature and the crafted approach that can be applied to ink jet printing, to push future ambitions for this technology. In order to be this creative with ink jet, the designer/maker would require both creative and technical skill and confidence in using the technology. The techniques generated in these sections are only suitable for the craft market, involving a high price tag for the time involved. The outcome of these fabrics is for one-off catwalk fashion. They are trend setting/statement pieces that inspire future collections and are thought provoking in terms of process. However, in section 4.3the commerciality of these designs is discussed. In relating back to chapter 2, these fabrics are scanned, imagery is lifted and simulated designs (that are colour matched) can be generated, producing the visual aesthetic qualities generated with the hand crafted designs, which are commercially viable larger scale productions.

When considering resist techniques with ink jet technology, it is vital to consider the surface of the print medium. The material sent through the ink jet printer must have a relatively even surface and must not be too thick, to enable the print heads to run smoothly above the printable medium, and to gain an evenly printed result. The ink jet print heads are sensitive to blockages, these can be caused by loose fibres and if the print heads come into contact with the fabric, this will affect the ink flow and quality of the printed image. The print heads (using a Mimaki TX2) are height adjustable. The print heads would be adjusted according to the embellishment added. The height of the print heads will have an effect on the sharpness of the printed design; therefore it is vital to test the print head height. In this research, depending on the type of embellishment used, such as embroidery, the head height could be raised from a standard of 4-10mm for highly embellished surfaces.

Within this research, materials such as lace fabrics and processes such CAD embroidery and pleating are all used to create resist pattern effects. These techniques were used with both treated and untreated fabric for ink jet printing, dependent on the dye used. For all reactive dye printing the treated fabric was used, for pigment ink printing, untreated fabric was used (refer to table 1.2).Because of the creative and crafted nature of these experiments a variety of fabrics were used for the sampling to test the best and most appropriate fabric for the bespoke fashion outcome (refer to

Figures4.42/4.43). All final fabrics created for this research were made from a variety of three silks, Habotai, Twill and Chiffon (refer to table 3.2). Only Habotai was used in the final samples using pigment inks, as this was the most suitable for the chosen designs used, allowing for clarity for the fine printed detail (refer to Figure 4.17). Most final fabrics were developed using the reactive dyes, due to the intensity of colour that can be produce, which was most appropriate for this design collection (refer to Figure 4.10).

4.2.3.1 Lace Embellishment Resists

To obtain delicate resist patterns, lace fabrics can be applied prior to ink jet printing. The resist pattern formed will greatly depend on the lace fabric used, however, the design which is ink jet printed, will have a major impact on the strength, location and prominence of the resist marks made.

These designs for the digital lace resist collection were inspired by combining the colours and movement from the city night sky with small bursts of natural and floral influences. The colours used are bright pinks, reds and oranges, with highlights of yellows and contrast of dusky blues and black. These are lively, spontaneous designs that add vibrancy and energy. This collection is designed for the Haute Couture womenswear market. These designs are for fashion accessories and simple feminine garments, following the forecasted fashion trends at the time of the research.

To ensure the embellishment, such as lace, would lay flat against the base fabric, it wash and stitched down. Figure 4.3demonstrates the embellished fabric stitched to the base cloth, running through an ink jet printer. The print head height would be raised to 7-8 mm dependant on the texture of the lace fabric used. Figure 4.4 shows an ink jet printed fabric with a lace embellishment, removed from the printer, yet still attached to the base cloth. In these cases, the resist cannot add colour to the fabric, however, the fabric can be printed prior to adding the embellishment overlay.

Figure 4.3 (Ryall.H, 2009) Ink Jet Printing of a Knitted Fabric (Pigment Inks)

Figure 4.4 (Ryall.H, 2006) Ink Jet Printed Lace Embellishment (Pigment Inks)

The resist pattern can be controlled by two methods; by accurately placing down the lace embellishment by hand, and/or by using CAD and ink jet technology. In this research both methods were used. Where the overlay print covers the full design, the lace could be placed down by hand as and where required. An example of this can be seen in Figure 4.5. The lace was placed over the fabric, and then a plain black overlay was printed to cover the whole design, resulting in a continuous design. However, when the overlay prints were only required in small areas of the design, the CAD overlay image could be designed accurately to size and positioned using the ink jet printer. An example of this method can be seen in Figure 4.6. This design only required the lace resist in a single stripe. To blend the lace resist into the rest of the design, a black over print was design with gradient edges starting from transparent to black and from black to transparent (left to right). This allowed the lace resist feature to integrate within the design. The over print can be designed to the accurate size using the CAD software and the ink jet printer can be set up to accurately print where required. Where necessary a gradient (from colour to transparency) overlays were used, this allowed the lace resist to blend in and out of the design with no harsh edges.

Once dry from the printing, the lace embellishment can be removed to reveal the resist patterned created. There are two benefits of attaching a lace embellishment; the printed resist result, showing delicate resist marks, and the actual printed lace itself, capturing delicate colour and pattern, even on the very fine open lace, providing great possibilities for an alternative fabric for ink jet printing. Figure 4.7 and 4.8 demonstrates the delicate printed results that can be achieved through this method of a physical resist, and Figure 4.9 the printed knit fabric. These were printed with pigments, and have therefore all been post-treated with heat to fix the inks.

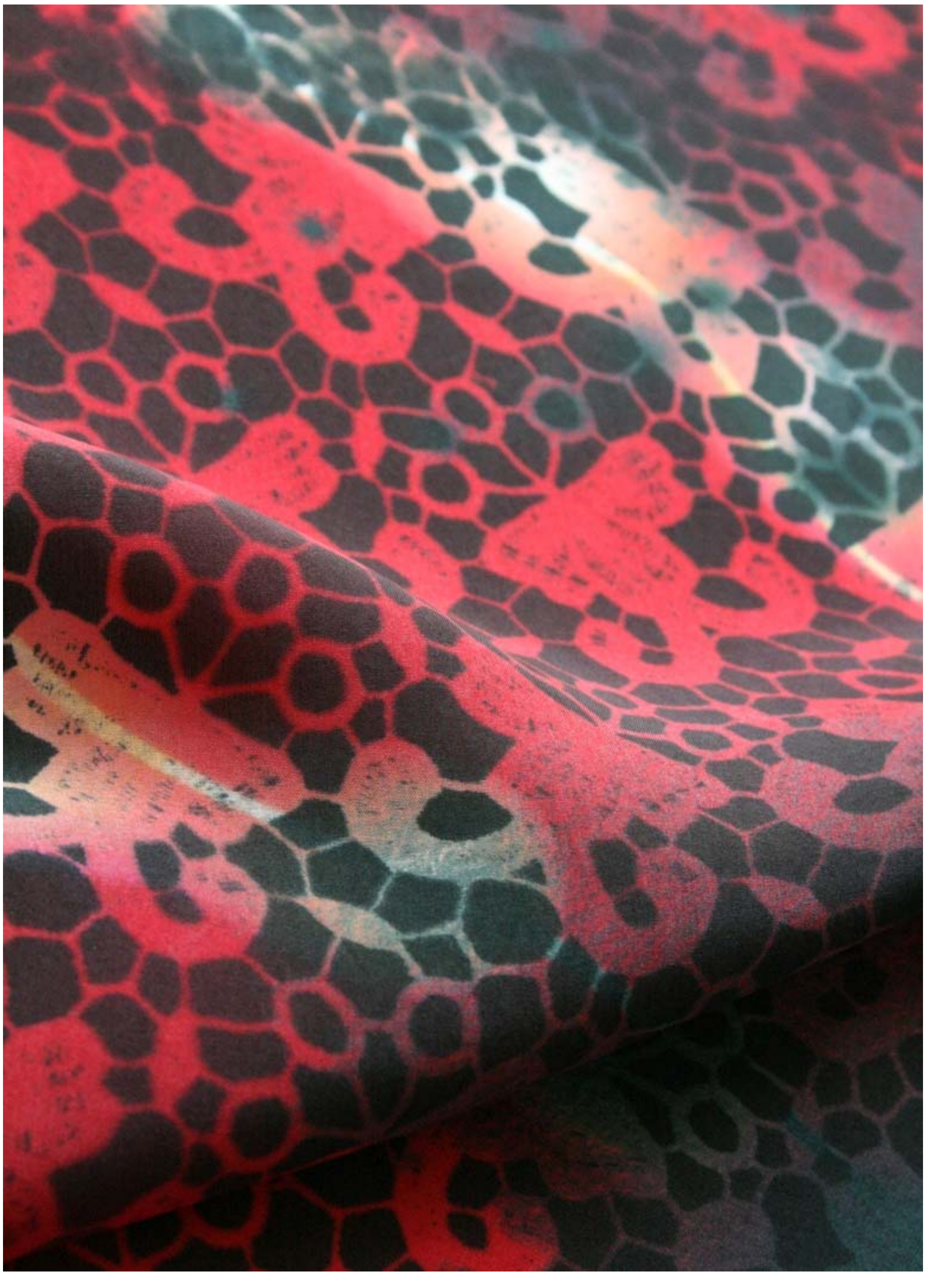


Figure 4.5 (Ryall.H, 2006) Ink Jet Printed Silk Habotai with Lace Resist (Reactive Dyes)

Figure 4.6 (Ryall.H, 2006) Ink Jet Printed Silk Habotai with Lace Resist (Reactive Dyes)

Figure 4.7 (Ryall.H, 2009) Ink Jet Printed Silk Habotai with Knit Resist (Pigment Inks)

Figure 4.8 (Ryall.H, 2009) Close Up Image of Figure 4.7

Figure 4.9 (Ryall.H, 2009) Ink Jet Printed Knit (Pigment Inks)

These resist techniques can be mixed and repeated to create the desired effect (prior to post-treating the fabric). Using the accuracy of the ink jet printer, the lace embellishment can be printed in the desired areas only, therefore allowing for more than one lace embellishment to be added. Figure 4.10 demonstrates the design qualities that can be achieved by printing three times; the initial under print and two further prints, each time adding one more lace embellishment overlay. However, considerations and print tests are required to ensure the colour outcome is as desired (with the mixing of the ink jet printed colours), after applying more than one print overlay. Due to the crafted nature of these techniques and because of the 24bit images used, it was impossible to colour match. The tests done to achieve the desired colour outcome were small pre-tests, of the same image and colour overlays to check the mix of dyes had the desired affects.

This is examining the impact in which a hand crafted approach to digital technology will have on the printed result. At present this method of production is being developed by hand and digital technology, therefore to reproduce the results exactly would be difficult to achieve. The investigation has proved to be highly successful with the generation of unique bespoke printed textile designs, which can be customised for individual clients. Investigation into the reproduction of such results is developed in section 4.3.

Figure 4.10 (Ryall.H, 2006) Ink Jet Printed Silk Habotai, with Two Lace Resists (Reactive Dyes)

4.2.3.2 CAD Embroidery Embellishment Resists

The designs generated using the embroidery resists and the initial pre-manipulation resists samples (discussed in section 4.2.4) are all inspired by 'restructured landscapes'. These blend and distort a variety of landscape images taken from different distances, with a mix of unexpected surface texture. These designs use a blend of cool blue/green tones, with accent turquoises for the under prints and deep blues and navy for the over prints - all inspired by the forecasted trends at the time of this research. Many of these use very subtle tonal images, allowing the embroidery and manipulation to generate the stronger pattern effects.

The use of embroidery can also create highly detailed printed resist effects, almost creating the illusion of the embroidery itself. The CAD embroidery work in this research was designed and developed using the Amaya ® embroidery machine (Figure 4.11/4.12) and 'Design Shop' software. These techniques can also apply to hand and domestic machine embroidery.

Following the same principles of adding a lace embellishment to create a resist effect with ink jet printing; the embroidery will need to remain relatively flat to pass through the ink jet printer. If the embroidery added makes the fabric uneven, the fabric would be ironed flat (with an additional layer of fabric to protect). In these experiments the print head height would vary from 6-8mm again dependant on the texture of the embroidery. These fabrics would not be able to be produced commercially for the high street due to some unexpected results that can occur (such as the fabric lifting and gathering in small areas); each fabric generated would need to be checked in detail to ensure it would feasibly pass through the printer. These unexpected outcomes can result in some exciting printed results that were not originally planned, and can therefore add to the character of the finished fabric.

The embroidery could be accurately controlled in its position on the base fabric. Again, it is not possible to add colour to the fabric by using the embroidery as a resist, therefore an under-print would be used where necessary. An under-print is a base ink jet print on the fabric, done prior to the resist technique added. The under-print is a simple tonal design, which would be of a lighter tone that of the over-print, to ensure the resist technique is clearly visible. It is impossible to add a lighter colour to the design, as ink jet technology at present does not use opaque dyes, therefore the pattern has to be built up from light to dark colours. Once the embroidery is complete, the fabric would be sent through the ink jet printer (stitched onto a backing cloth for more textural surfaces). After the print was dry, the embroidery would be unpicked to reveal the resist pattern. Again this process is hand done, and therefore very time consuming. Once fully post-treated the fabric would return to its original handle, with no evidence of the stitch holes.

Using ink jet technology, the ink jetted onto the fabric can be controlled. No bleeding occurs, therefore leaving the resist marks clearly visible. The resist marks made from the embroidery are highly detailed. Figures 4.13 and 4.14 show an example of an embroidered fabric and the type of delicate resist marks that can be achieved.

Figure 4.11 (Ryall.H 2009) Amaya® Embroidery Machine, University of Huddersfield

Figure 4.12 (Ryall.H 2009) Amaya® Embroidery Machine, Stitch Pattern onto an Ink Jet Printed Fabric

Figure 4.13 (Ryall.H, 2007) CAD Embroidery (Satin Stitch) (Reactive Dyes)

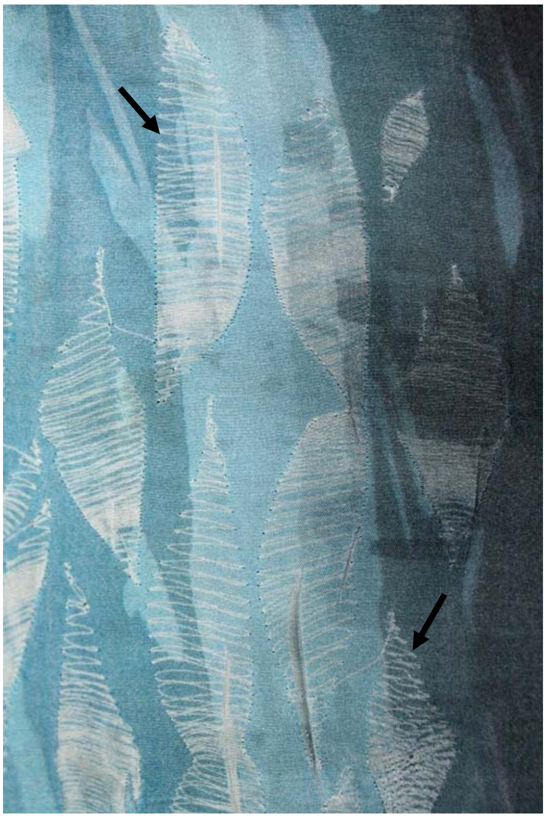


Figure 4.14 (Ryall.H, 2007) Resist Marks Created by the use of Embroidery

4.2.3.3 Printed Results

The resist techniques discussed above can all be combined to create the desired effect. These techniques rely on a hand crafted approach to develop these resist patterns. By making additions to the fabric's surface, using lace or embroidery techniques, the fabric ultimately becomes uneven and one of a kind. The printer should therefore be adapted and carefully used to ensure the highest printed result.

These results have proved to be highly successful in the generation of high quality, innovative printed textiles with both the lace and the embroidery used as a print resist. The lace, due to its density, produced more vivid printed results. However, the subtlety of the embroidery resist is impressive, and in conjunction with tonal under and overlay digital prints, the results are highly effective.

The advantages of using ink jet technology for these print effects are its ability to print large numbers of colour (gradient tones), its controllable ink flow providing sharp resist patterns, and the ability to guide the printer accurately to give the designer full control in the registration of the design. The colour can also be managed, providing tests are completed prior to printing and a method of colour management is used.

This crafted approach to using digital technology gives the textile designer full flexibility in the creation of their designs. It is a process that to some extent can be planned, but can be adjusted and manipulated to suit the customer's needs. The printer is not looked upon as merely a production method, but an integral part of the design experimentation.

The best results achieved using these physical methods of resist techniques, were to build the designs up gradually, starting with the lighter colours and building the depth of design and colour from this. Using CAD and ink jet technology it is possible to reduce the amount of dye placed down for more subtle effects and increase for more saturated and intense colours. This can be achieved using the Smart Print 3.14 ® RIP software (RA Smarts®) for the Mimaki TX2, by adjusting the percentage of the dye placed down in the fabric/dye profile before printing. The standard percentage of dye placed down (recommended by RA Smarts®) for Cotton is 230%, for silk the author recommends a reduction of 90% point decrease to 140% as discussed in section 1.7.1. However, this can be further reduced to 100% to gain paler colours, but this will ultimately have an effect on the visibility and strength of the resist technique generated. An increase of dye will increase the intensity of the colour; however, too much ink can cause the dyes to bleed, therefore losing clarity in the resist design. In the majority of the tests done on these silks, the percentage of dye placed down remained at 140% as this gave the optimum colour results required. Further design results using the methods described above, can be seen in Figures 4.15 to 4.18.

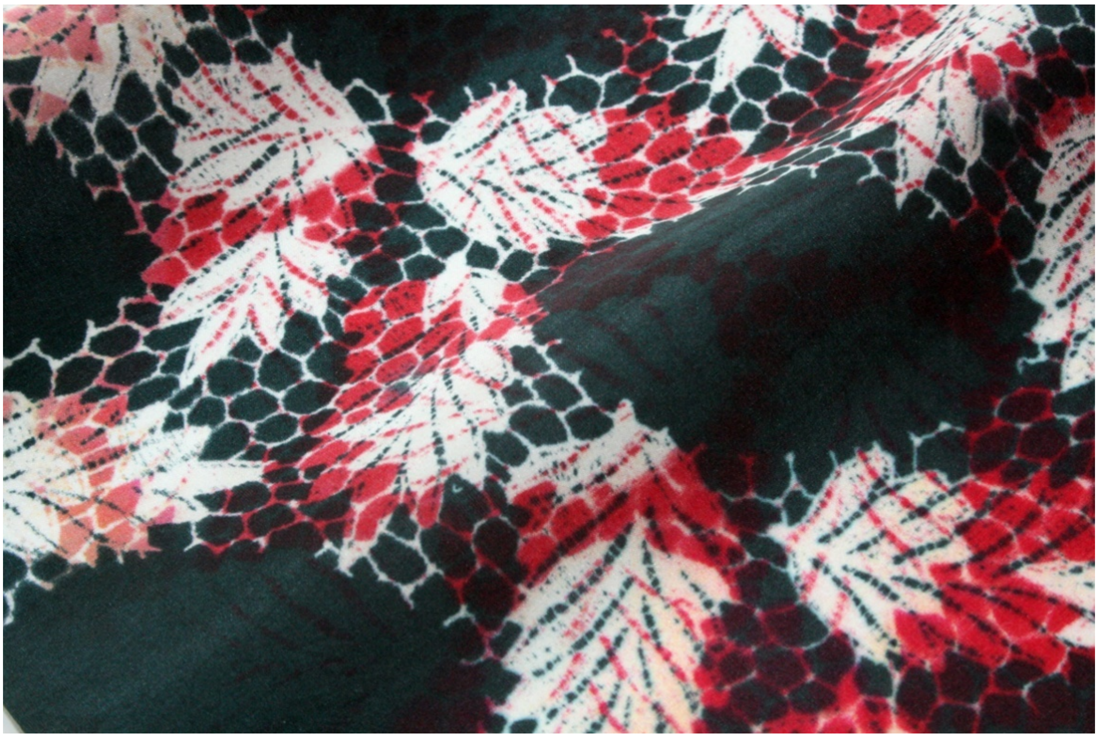


Figure 4.15 (Ryall.H, 2006) Lace Resist Print, Silk Habotai (Reactive Dyes)

Figure 4.16 (Ryall.H, 2006) Ink Jet Printed Lace Fabric (Pigment Inks)

Figure 4.17(Ryall.H, 2009) Lace Resist Print, Silk Habotai (Pigment Inks)

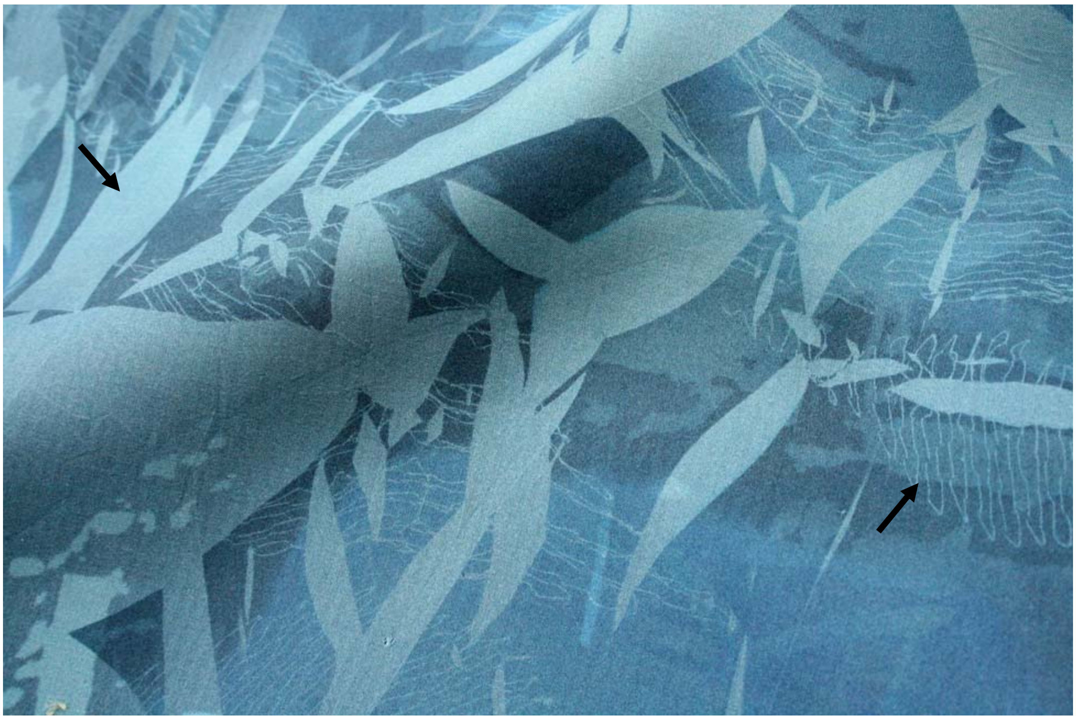


Figure 4.18(Ryall.H, 2008) Ink jet printed Silk Habotai, generated using pleating and CAD embroidery resist effects (Reactive Dyes)

4.2.4 Introduction to Resist Experiments - Pre-Manipulated Fabrics

The most common form of physical resists is tie-dyeing (shibori). The name shibori originates from the Japanese word, shiboru meaning to manipulate fabric (to ring, squeeze, and press). This technique dates back to between the sixth and eighth centuries from China. Shibori and similar techniques are found all over the world, such as Africa, China, America, India, and Europe (Gunner, 2006, p.11). This method of resist uses tying, binding and stitching techniques to manipulate the fabric prior to dyeing. The tied areas will block the dye from penetrating the fabric.

This PhD research has investigated various physical resists that can be used with ink jet technology. There are obvious restrictions that apply when using resist techniques with ink jet technology, most importantly the physicality of sending the pre-manipulated fabric through the ink jet printer. For example most shibori techniques create three dimensional fabric structures, this would be impossible to send through the ink jet printer, see Figures 4.19 and 4.20 for examples of shibori, hand tied fabric prior and post dyeing.

The manipulation of a fabric prior to printing or dyeing will directly influence the colour and pattern of the cloth. The pattern will only emerge when the manipulation technique is removed and it returns to its original form. Unless the whole fabric is dyed one colour, it is impossible to be exact in the dyeing process. Likewise, with any hand shibori resist effects, it is unfeasible to obtain exact reproducible results. Therefore, every printed or dyed fabric generated will be an original. While this process can be planned, the printed result cannot be appreciated until returning to its original form.

Building on the confidence and knowledge gained through section 4.2.3, this area of research investigated the feasibility of applying a hand crafted approach to ink jet printing, specifically examining the opportunities and benefits of shape pleating effects with digital technology.

Figure 4.19 (Ryall.H, 2008) Hand Tied Fabric before Dying (Shibori Technique)

Figure 4.20 (Ryall.H, 2008) Hand Tied Fabric, Indigo Dyed (Shibori Technique)

4.2.4.1 Pre-Manipulation Resist Techniques

Following the principles of shibori dying techniques of physically changing the fabric shape and surface, these printed fabrics were built up with a series of printed and manipulation stages.

There are four basic stages prior to fixing the dyes; the under print, fabric manipulation, over print and the removal of the manipulation technique, which could all then be repeated and built upon. These would depend on the desired effects. To some degree, these could be planned prior to printing. This approach allowed for reassessment to occur during the process and for alterations to be made where necessary to achieve the best-printed result possible.

4.2.4.2Under Print

To achieve subtle blends of colours and resist patterns, a simple tonal design would be printed onto the fabric prior to the pleating manipulation stage. With the tonal images underneath the manipulation, this would allow for a combination of both subtle and strong contrast resist patterns to occur. Often highlights of vibrant colour would also be used to add further variation and depth to design. In this area of this research, the designs were all generated as 24bit coloured images (true colour), therefore allowing for gradients and the maximum number of colours to be used. For this reason, these were not colour matched. However, all designs were tested for colour outcome to make sure no unexpected colours occurred.

4.2.4.3 Fabric Manipulation - Pleating

Once the printed fabric was dry, the fabric manipulations were applied; in this case various decorative pleating techniques were used. These were added by hand using a domestic sewing machine. Examples of the pleating technique can be seen in Figures4.21 to 4.24. The majority of these experiments were undertaken using Silk Habotai, due to its stability of running through the printer and the colour intensity that could be produced. Later experiments using Silk Chiffon were also done to demonstrate the flexibility and reproduction using lighter weight silks. Although Silks were used here, for their aesthetic qualities and for the quality of the end results, this technique is not restricted solely to Silk.

Figure 4.21(Ryall.H, 2008) Pleated ink jet printed Silk Habotai (Reactive Dyes)

Figure4.22(Ryall.H, 2008) Pleated ink jet printed Silk Habotai (Reactive Dyes)

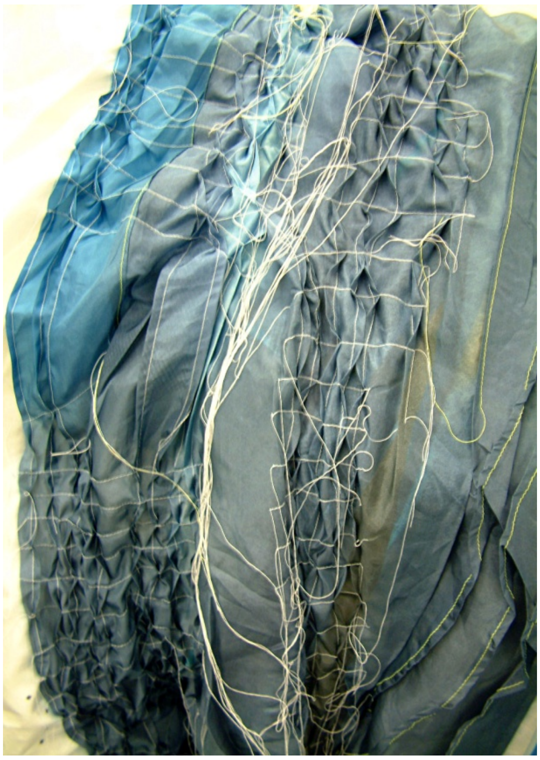


Figure 4.23 (Ryall.H, 2009) Pleated ink jet printed Silk Habotai (Reactive Dyes)

Figure 4.24(Ryall.H, 2009) Pleated ink jet printed Silk Habotai (Reactive Dyes)

Once the fabric had been pleated, the fabric became highly textured (over 1 cm in height in areas);this would be unfeasible to be sent through an ink jet printer, due to the height and uneven surface. Therefore commercial steam irons were used to flatten the fabric prior to re-printing; an example of the flattened fabric can be seen in Figure 4.25. This enabled the fabric to move smoothly through the printer and allow for clean resist marks to be made when printing. A domestic steam iron proved not to be powerful enough to flatten the fabric. After testing, this steam process did not have any lasting effect to the printed outcome; however, a layer of fabric was used to protect the ink jet print. The print head height in these experiments would vary from 7-10mm, because of the physical nature of the fabric, even once ironed, would still be uneven, therefore, it was vital to increase the height of the print heads.

To ensure ease of running the fabrics through the printer, these fabrics were then hand stitched (tacked) down onto a pre-rolled Plain Cotton backing fabric, which can be re-used to save money and fabric wastage (refer to Figure 4.26). This gave the manipulated fabric stability, allowed for good tension and sharp edges to run under the fabric retainers/guides on the printer. By hand stitching these fabrics down, the fabric could be closely examined to ensure that the surface is as flat as possible and there are no stray edges. This again can be time consuming for highly textural/manipulated fabrics and is therefore at present not commercially viable for the high street. With the addition of an adhesive belt on later version of some ink jet printers (refer to section 1.7.1, Figure 1.11) this could help with the feeding through of more textural surfaces; however, this has not been experimented with in this research due to the non-availability of this type of printer to experiment with.

The print heads were also raised to ensure that the printer would run smoothly over the uneven surface. The print heads are easy to adjust in height; these are done manually prior to printing. The height is then registered digitally for accuracy. The standard height for basic fabrics is 3-4mm, this allows the smooth running of the print heads over the print bed and fabric retainers. At present the maximum height is 10mm, this may become more flexible with future ink jet technology, allowing for more embellished surfaces to be fed through. For highly textural surfaces the print heads could be raised to the maximum of 10mm, where the surface height is smoother the head height can be raise to 7mm. The change to the height of the print heads greatly depends on the fabric that would be passing through the printer. This would be examined on an individual basis, due to the unexpected nature of each manipulated fabric. If the print head heights are raised too high unnecessarily, the sharpness of the printed resulted will be affected, leaving a blurred printed image. Where the manipulation work was only in selected areas, certain adjustments were often required to allow the fabric to remain flat. Small running stitches (approximately 2mm in length) would be added by hand to any raised areas to ensure these would not catch on the print heads. If these areas caught the running print heads, this could damage the print heads and the fabric (adding unwanted dye marks). All of these adjustments, to ensure the ease of running a highly manipulated fabric through an ink jet printer, are produced by hand and revised for each original design and are therefore unsuitable for high street commercial processes.

Figure 4.25(Ryall.H, 2009) Pleated and ironed Silk Habotai (Reactive Dyes)

Figure 4.26 (Ryall.H, 2009) Pleated and ironed Silk Chiffon stitched onto backing cloth

4.2.4.4 Over Print

Measurements were taken from the fabric to calculate the size required for the over print. To allow the resist pattern to be the strongest feature of the designs, the CAD design generally was kept very simple; in some cases a single colour gradient to white (transparent) would be used. These over prints gradually build the design of the fabric, using darker tones to that of the under print. Where two dark or similar colours meet the subtler or no resist effect will show, and where there were strong contrasting colours, vivid resist patterns would occur. These fabrics would run well through the printer, with problems only arising when fabrics were very uneven. This is demonstrated in Figure 4.27.At this stage additional overlay prints could also be added once the fabric had dried.

This method of developing resist techniques using pre-manipulated techniques can be produced using a variety of fabrics. The main limitations will be the thickness of the fabrics. Using heavy weight fabrics may cause difficulties in the manipulation stages (with domestic embroidery machines) as well as passing through the printer. Lightweight fabrics are generally better, but the amount of dye placed down should be taken into consideration (refer to section 4.2.3.3).

Only treated fabrics with reactive dyes have been used in these experiments. Although there are no differences in the actual manipulation and printing processes between reactive dyes and pigments inks, the post-treatment of the fabrics differ (refer to table 1.2, p.30). While the pigment inks require a shorter post-treatment of heat, the manipulated fabric would always need a short wash to remove the small stitch holes and shaping of the fabrics produced through the manipulation techniques used, to return the fabric to its original handle. Therefore the added benefits of the shorter post-treatment have largely been removed. Whereas, the reactive dyes already require the wash process, so no additional processes are added and also the higher intensity of colour can be achieved using reactive dyes, which was required for the designs generated in this research.

4.2.4.5 The Removal of the Embellishments

Once the printed fabric was dry, the fabric could be removed from the backing cloth. To reveal the resist pattern, the manipulation could also be removed, by unpicking the stitching where necessary. This was a time consuming process with certain manipulation techniques. At this stage the fabric could be post-treated. This would allow the fabric to return to its original handle, see Figures 4.28 and 4.29 for some of the finished results.

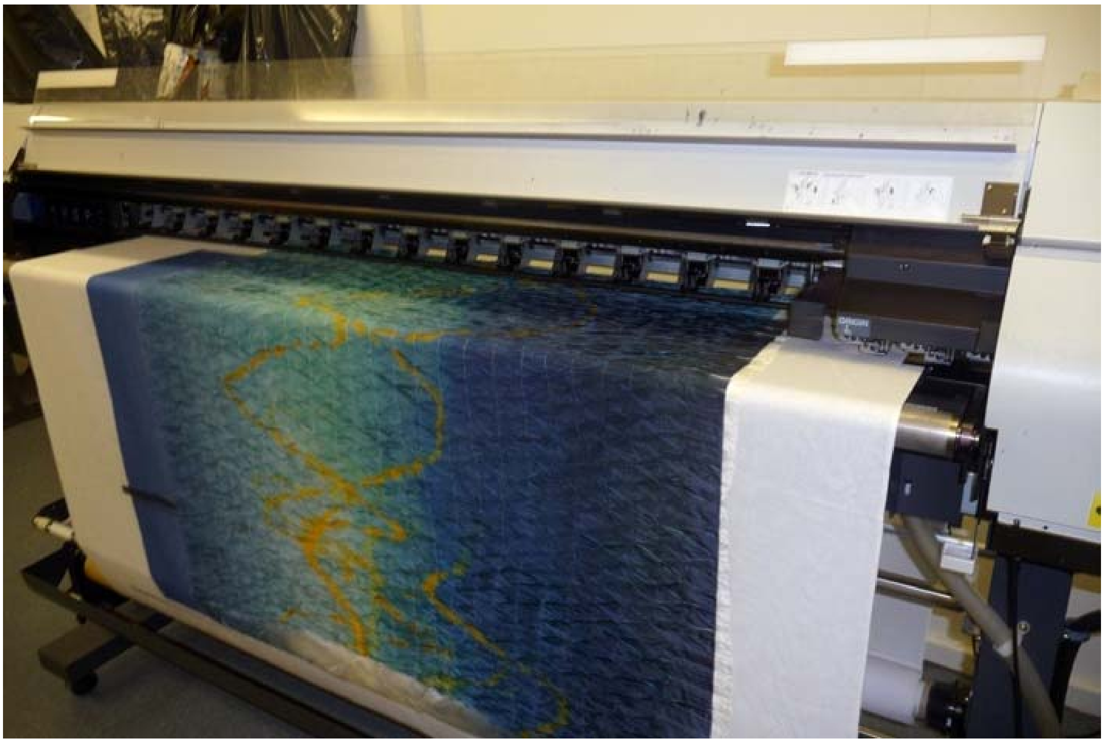


Figure 4.27(Ryall.H, 2009) 1m x 3m pre-manipulated sample digitally printed (Mimaki TX2)

Figure 4.28 (Ryall.H, 2009) Ink jet printed Silk Habotai, generated using pleating resist effects (Reactive Dyes)

Figure 4.29 (Ryall.H, 2008) Ink jet printed Silk Habotai, generated using pleating resist effects (Reactive Dyes)

Further investigations were made, where the fabric would be ironed flat (with a protective layer of fabric) and then re-printed, or the full process was repeated in new areas of the fabrics. This can further enhance the fabric and can create greater depth to the pattern. Evidence of this can be viewed in Figure 4.30.These experiments were all produced before the post-treatment stage for the fabric. The best results were generated from only twice manipulating the fabric in small areas, to allow for these intricate design elements to be appreciated in contrast to the rest of the design. This additional process can also give the designer further control in the position of the resist effects, to build up the design desired. The print overlay, for these additional manipulations, can be controlled to only print in the areas needed. This can be achieved by positioning the fabric through the printer to the exact starting point for printing. Also the size and shape of the overlay can be designed to accurately fit the place required (using Photoshop or CAD program).

When repeating this process, the time involved increases, therefore, making these even less commercially viable for the high street. However, this can greatly enhance the depth of design, adding further bespoke qualities to the fabric. For finer details and more intense pattern, smaller pleats can be added, and for a more subtle and sparse resist patterns to occur, larger (over 1cm in depth) and fewer pleats can be used, to even a single pleat line. The direction, from horizontally across the fabric, to any chosen angle by the designer, or tracing the under print, will strongly influence the design outcome. The placement of the pleats, from all over the fabrics, to top and bottom only or even scattered across the fabric, will create further decorative effects. The quantity of the manipulation added, denser areas of manipulation can generate stronger pattern, fewer pleats will produce more simplistic patterning effects, will also make strong statements to the design generated. All of these will greatly affect the printed outcome. The more stitching used the more time it will take to create and remove the manipulation.

This is a difficult process, if not impossible to re-create these techniques accurately by hand. Therefore in the production of new fabrics specifically developed for individual customer's needs, would be difficult to accurately predict the printed results using these crafted techniques. Therefore, the textile designer producing the fabrics would need to work closely with the customer and manage their needs. The consumer would have an appreciation and desire for an original printed design. Such fabrics could be used to produce exclusive Haute Couture garments. In section 4.3 of this thesis, a process has been developed whereby the results gained using these resist techniques have been scanned back into the computer and then reproduced digitally, giving the customers further alternatives and control of design outcome.

Again the combination of various techniques can create innovative resist effects. Figure 4.31 demonstrates a subtle stitch resist which has been placed onto a pre-manipulated (crushed) fabric, therefore using two of the principle resist patterns discussed in this chapter. Figure 4.32 shows the finished result after post-treatment. Although the fabric was not formally pleated, the fabric was pre-manipulated prior to the CAD embroidery (produced on the Amaya® embroidery machine) and prior to printing, therefore producing two resist marks once over printed. A simple straight stitch here was used and the fabric was crushed using a commercial steam iron.

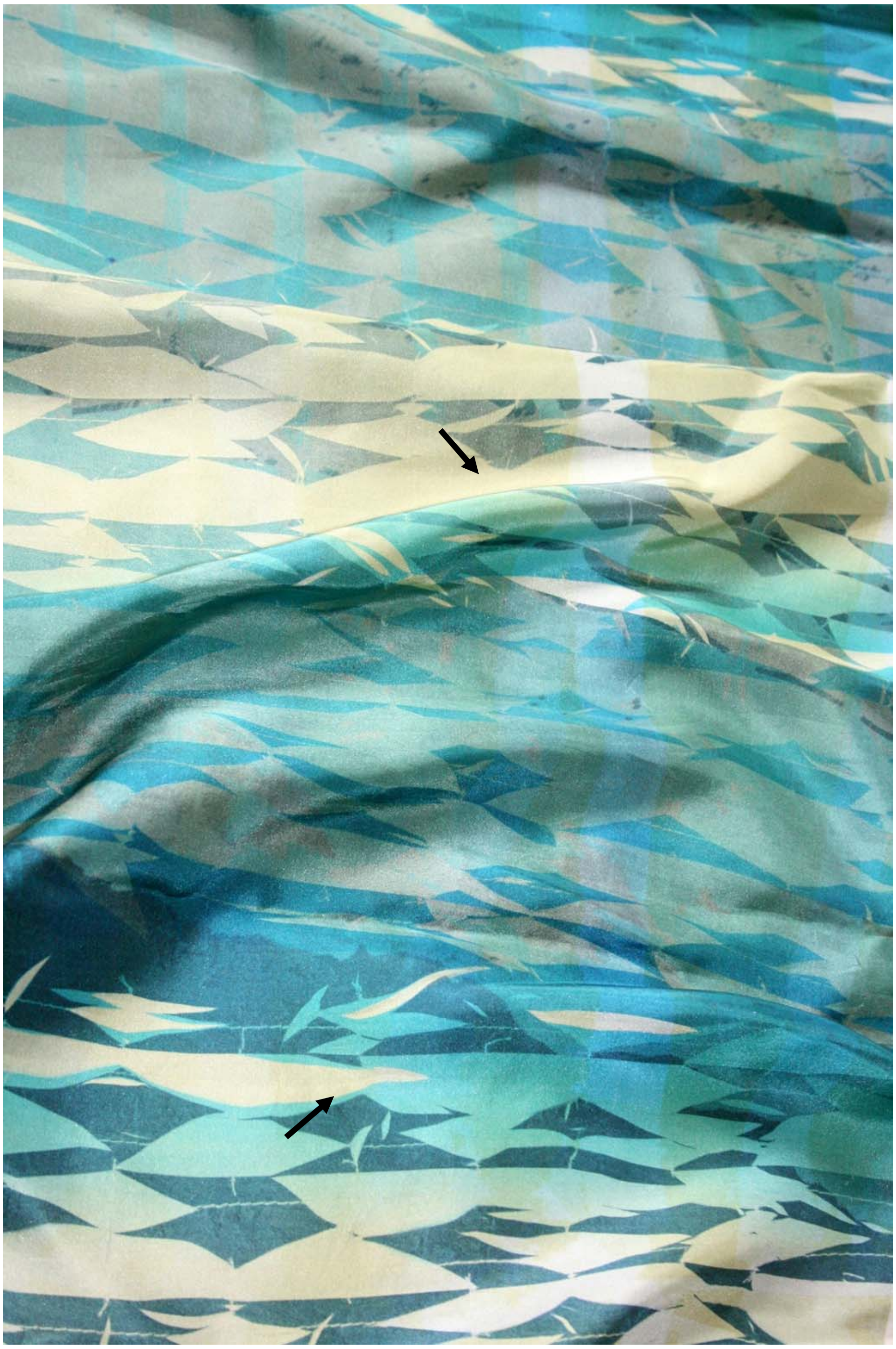


Figure 4.30 (Ryall.H, 2008) Twice manipulated, ink jet printed Silk Habotai, generated using pleating resist effects (Reactive Dyes)

Figure 4.31(Ryall.H, 2008) Ink jet printed Silk Habotai, generated using pleating and CAD embroidery resist effects (Reactive Dyes)

Figure 4.32 (Ryall.H, 2008) The finished printed fabric result shown in Figure 4.31 (Post-treated)

The combinations of lace and pre-manipulated fabrics have also been used together successfully, whereby the fabric was manipulated and ironed flat, and then pieces of lace were collaged on to the fabric (hand stitched). Figure 4.33 shows the positioning of the two resist techniques prior to printing; Figure 4.34 shows an example of the finished result. Using stitch as a resist technique will produce subtle and fine resist patterns, lace and pre-manipulated fabrics will generate stronger resist effects. These samples were generated using Silk Chiffon, as a lightweight translucent fabric was required to overlay on top of a Silk Habotai for the top front panel of the garment design shown in Figures 4.42/4.43.

4.2.4.6 Printed Results

This crafted approach to digital design has developed a new understanding for the technology. This is a creative method of producing printed textile designs, with unique properties, and utilising the technology for all its benefits.

The resist techniques researched in this section, uncover opportunities for ink jet printing on pre-manipulated materials. Using a domestic embroidery machine and hand stitching pleats into the fabric, it is possible to send through the printer hand manipulated and uneven surfaces. Certain principles and guidelines should be taken into consideration for this. The fabric once manipulated should be ironed flat using a commercial steam iron; a domestic iron does not give efficient results for this. The fabric will then need to be hand stitched onto a pre-rolled backing fabric; this gives excellent tension through the printer with the over print. The print head height should also be raised to a height of 7-10mm (depending on the contours of the fabric), but this will need to be individually assessed before printing. The over print will be designed specifically to the area that requires printing, giving further accuracy and control to the designer. Once dry from the over print, the fabric manipulation can be removed, by unpicking the stitching. The fabric can then be post-treated or ironed flat and re-manipulated. Once fully post-treated (using a softener if necessary) the fabric will return to its original handle.

A variety of digital designs were used in these experiments. These were not pre-colour matched, however, they were all tested and colour adjusted accordingly in the textile software and Photoshop, prior to printing. The most reliable (that required the least colour adjustments) were those that were in the blue colour space. These gave the most accurate results, vibrant tones and were highly appropriate to the forecasted trend. The red tones, yet still achievable, generally required further adjustment. The red tones, with no colour matching or testing, can appear more orange-brown in colour. The majority of designs were relatively simple gradient prints, with simple lines or dashes of an accent colour. This added further contrast to the printed pattern. These simple gradient digital images allowed for the resist effect to create and be the focal point of the designs, and can be simpler for the placement of the resist patterns. To build up the designs using these resist techniques, required the overprint to be a darker tone or colour for the resist effects to be most prominent. Some of the earlier samples produced also demonstrate the effectiveness of strong digital patterns that can be used in conjunction with these resist effects (see Figure 4.5).

Figure 4.33 (Ryall.H, 2009) Example of Silk Chiffon prepared for Ink jet printing, generated using pleating and lace resist effects (Reactive Dyes)

Figure 4.34 (Ryall.H, 2009) Ink jet printed Silk Chiffon, generated using pleating and lace resist effects (Reactive Dyes)

The manipulations made to the fabrics were largely using simple pleating techniques. However, another technique was experimented by crushing the fabric using a commercial steam iron. Although this technique does not require stitching to manipulate the fabric, some careful stitching is required to enable this fabric to smoothly feed through the printer.

In this chapter, the combination of all three resist techniques were researched (lace, embroidery and manipulation), using pre-manipulated materials with machine produced embroidery resist and pre-manipulated materials with lace resists. These results were particularly exciting and added further interested to the printed results.

In these experiments only reactive dyes were used, with pre-treated fabrics, as this gave the designs the colour intensity planned for by the author. The fabrics used were lightweight silks; Habotai and Chiffon, which are most appropriate for fashion products and small-scale home furnishing accessories. However, this research has focused on designing for fashion. While some initial tests of heavier weight fabrics and the use with pigment inks have been done, with promising results, future research will investigate these techniques, with the use of a wide variety of materials and all dyes available for ink jet printing (see section 5.3).

Using these selected techniques and fabrics, the printed results are very strong. The quality of the printing is high, the colour and blends of the patterning effects are highly attractive, and each unique design has great depth and excitement. Where subtle colour blends are, particularly using the lace and embroidery resists, the patterns generated can be very delicate. To fully appreciate all these resist patterns, fashion products and home accessories allow for this detail to be noticed and appreciated, making these particular resist effects most suitable for small-scale products. However, with the investigation of further resist techniques that can be applied with ink jet printing, this may open up new opportunities for these techniques to be suitable for interior textiles.

The fabrics created through this process resemble that of hand shibori work, examples of this can be seen in Figures 4.35 to 4.38. However, the same control of colour placement is harder to achieve by hand. Using CAD and digital technology the printed designs can vary greatly; from a single colour design, a simple gradient, to a highly decorative and detailed design. However, the main limitation for using digital technology is the need for a relatively flat printable surface.

The colour intensity would greatly increase by printing over the fabric more than once, without affecting the sharpness of the print. The printed fabric is visually very strong with a variety of sharp resist marks and subtle layers of pattern, which have been built up in a series of manipulation and printed stages to create the desired effect. It would be impossible to produce these results using mass production and still gain the quality and spontaneity of resist effects.

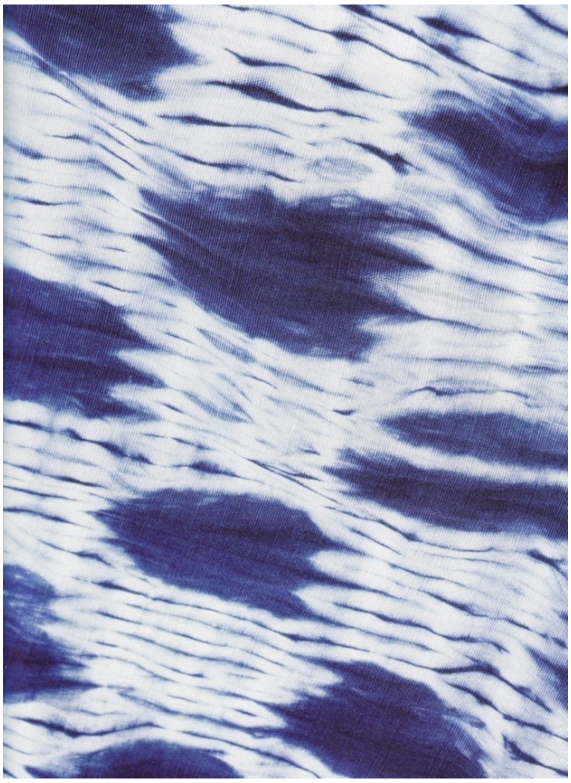


Figure 4.35 (Gunner. J, 2006) Antique African Silk Cloth, showing a version of 'mokume' (wood grain) design

Figure 4.36 (Ryall.H, 2008) Ink jet printed Silk Habotai, generated using pleating resist effects (Reactive Dyes)

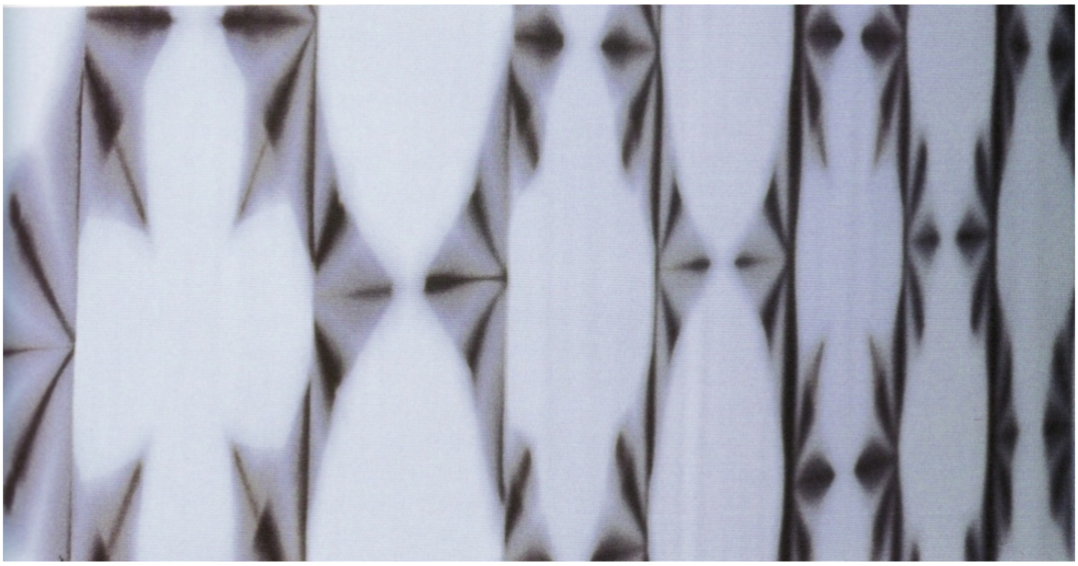


Figure 4.37(Eriken. TM, 2000) Itajime shibori on wool

Figure 4.38 (Ryall. H, 2009) Ink jet printed Silk Habotai, generated using pleating resist effects (Reactive Dyes)

This method of print production has focused on the design outcome, using physical resists by manipulating fabric with pleating and crushing techniques, and investigating the feasibility for developing these designs using ink jet technology. Although it is impossible to exactly reproduce each hand crafted digital design, this has uncovered a unique approach for the generation of hand crafted, high quality, bespoke printed textiles using digital technology. These printed fabrics can be custom made for clients and will therefore remain unique to the designer and customer. However, at this stage of research there is a high price (refer to the appendix) due to the time involved, seemingly makes these fabrics commercially unviable for bulk production – a topic reviewed and progressed in section 4.3. Fabrics generated with this amount of detail are ideal for the high-end fashion/textile market, for couture fashion. An example of this can be seen in Figures 4.42/4.43.

These designs were inspired by impulsive movement, capturing energy through the use of line, colour and placement of design; refer to Figure 4.39 for the original inspiration board. These designs explored methods of recreating the vision of movement through hand craft and ink jet technology. The colours were inspired by fashion trends for Spring/Summer 2009. These blue tones were chosen for their depth and clarity, with the accent, vibrant orange to give force and contrast to design (refer to Figure 4.40). The chosen market is for long soft summer dresses, with large quantities of strong coloured fabrics to enhance the movement in design (refer to Figure 4.41 market inspiration board).

The textiles for this fashion garment were produced using a mix of physical resist techniques. The majority of these designs creatively played with the physical resist of manipulating the fabric using pleating techniques, at various angles and sizes to add movement and diversity. Lace resist techniques add change and variety of pattern to enhance the overall design. The garment shown in Figures 4.42/4.43 has been hand crafted; each textile panel has been carefully thought out to ensure the juxtaposition of patterns and all detailing is as desired by the author. The garment design is based on a Roberto Cavalli garment from his Spring/Summer 2009 collection. This garment demonstrates the potential of these patterning techniques for fashion products. The hand crafted nature of these fabrics only allows for this garment to be generated for couture fashion/promotional and trend setting tools, as this garment would be impossible to re-produce and would be far too time consuming to make this commercially viable. This garment highlights the potential and creative use of ink jet technology in the generation of innovative, unique, bespoke printed textiles.

For the garment shown in Figures 4.42/4.43, a costing has been generated using the costing structure shown in the appendix. This does not include the garment's profit mark-up and overheads. The total price for the fabric (17m in total) is £2,412.76, which equates to an average of £141.93 per metre. With a potential profit margin up to 60% this equates to a suggested retail price of £6,000.This costing highlights the expense in generating a garment with this great detail and proves that these designs are targeted at the high-end one-off fashion market.

Figure 4.39 (Ryall. H, 2008) Design Inspiration Board

Figure 4.40 (Ryall. H, 2008) Colour Inspiration Board

Figure 4.41 (Ryall. H, 2008) Market Inspiration Board

Figure 4.42 (Ryall.H, 2010) **Silk Habotai and Chiffon** (Reactive Dyes) - Photography by Andrew Farrington

Figure 4.43 (Ryall.H, 2010) **Silk Habotai and Chiffon** (Reactive Dyes) - Photography by Andrew Farrington

4.2.5 Summary of Pre-Embellishment/Manipulation of Fabrics

These fabric results will always remain individual designs. Whilst the process and designs can be repeated, this approach to using the ink jet printer will remain hand crafted. While the use of shibori is traditionally developed by hand, it does not offer the same colour control achieved using ink jet technology. The depth of design and unexpected result could also not have been achieved solely through CAD design. It requires a combination of CAD and ink jet technology, with this hand crafted approach. The ink jet printer allows for a combination of gradient tonal effects and intense colour to be achieved. It allows for subtle blends of colour and tones, in combination to sharp resist patterns to occur. This research it not looking to replace traditional shibori techniques, these new techniques complements and explores new avenues for physical resist using digital technology.

In this research both chemical and physical resist techniques have been experimented with. The chemical resist used, was an acid resist paste, printed onto the pre-treated fabric prior to ink jet printing using reactive dyes. The optimum results for this experiment was to fix the acid resist at 150° for only 2 minutes, prior to ink jet printing. This ensured the resist paste was fixed without having any affect on the treatment on the fabric for reactive dye printing, therefore giving strong results for the resist print effect and the ink jet printed design. This technique would be suitable for commercial production; however, this would have a higher price associated due to the additional process of adding the resist paste and heat fixation. The resist technique could all be calculated as part of the original CAD design; this would save time in design and production. These results give further depth to the design on the ink jet printed fabric, therefore enhancing the bespoke aesthetic qualities.

The physical resist experiments using lace, embroidery and manipulation techniques with ink jet printing were all highly successful. The lace resists technique fed through the ink jet printer with ease. The results show clear resist patterns, which can be enhanced or softened using different CAD designs. This is directly influenced by the strength and contrast from the under to the over print in colour. There are restrictions when using the lace resists in this research, the variety of lace fabrics already available on the market to choose from, and the way the lace is placed down onto the fabric in preparation for printing. This is done by hand due to the creative nature of these designs, requiring smaller and more random placements of the resist effects.

Future research could collaborate with lace companies to design appropriate lace fabrics for each season's collections, and research could investigate the commerciality of this resist technique. Using the adhesive belts found on later versions of ink jet printers and with full width lace resist printing; it could be possible to send large quantities of the lace through the printer to produce the resist effect desired. Using smaller elements of lace would need to be hand done and therefore are not commercially viable. The lace would still need to be secured to the base fabric; involving experiments to find the best methods available for this. In addition, the extra time involved in generating the lace resist patterns using ink jet technology must be taken into consideration. The under print process and the attachment and removal of the lace will all add additional time and cost. Therefore, the market costs will be increased, but for this increase in cost will be balanced with the bespoke qualities and designs of the fabric. In 2009, it is now possible to print on lace commercially using inkjet technology with suppliers such as RA Smarts®, but the resist techniques are not at present commercially available.

The embroidery resists would be designed and produced using the Amaya® software and embroidery machine. Again these embroidered fabrics would feed the ink jet printer with ease. The resist patterns generated are delicate and subtle. Only thread was experimented for the embroidery, due to the restriction of the needles used on this embroidery machine, but the thread's thickness and type of stitch will have a strong affect on the strength of the resist produced. Due to the subtlety of the resist effect generated, these patterns would be most suitable for fashion fabrics, this is due to the scale of the fabrics required for fashion and also enabling the viewer to appreciate the fine printed detail. To view these resist effects from a distance would be difficult to fully appreciate the detail of the design, therefore making these designs worthless. It would be very time consuming to produce this resist technique on a large scale, while the embroidery can be produced by machine, the removal of the physical resist is done hand, making this not a commercial technique.

The pre-manipulated fabric resists used simple pleating and crushing techniques. These both produced strong resist pattern effects. They could be controlled by the designer; however, each design would be an original, exclusive to each customer. These would not be able to be mass produced, with the addition of this process being time consuming. This has been examined further in section 4.3. The pre-manipulated materials would need further adjustment before running through the printer; each fabric would need to be individually assessed to ensure there were no unexpected height issues under the print heads. However, raising the print heads to a maximum of 10mmcould ensure there were no difficulties to overcome. These experiments involved careful attention in assuring the manipulated fabrics, even once steam ironed flat, were smooth enough to feed through the ink jet printer. Manipulating the fabrics by hand was the most time consuming out of all the physical resists trialled. From a designers perspective using this technique gave a real excitement for experimenting in mixing craft with technology. The technique could be controlled, but the final results could not be fully planned, therefore making the process exciting and to some extent unpredictable. Currently this technique has been designed for one-off fashion garments and accessories due to the type of fabrics used, scale of design and time involved in production, thus also allowing full detail to be recognised and appreciated. Using alternative harder wearing fabrics, these could be designed for other products such as textiles for interior accessories, which are still produced in smaller quantities. The harder wearing fabrics such as Polyester and Cotton and Cotton Blends (including Cotton Velvets, Cords and Jersey) have not yet been tested for this; however, future research will explore the potential and the feasibility of using new fabrics with these resist techniques and ink jet technology.

All these techniques have been hand crafted, and individually designed. The commerciality has been discussed, however, the majority of these techniques would be difficult to reproduce in large quantities and section 4.3 discusses a process that could enable design reproduction using CAD. The strongest design results are gained through using the chemical resist trialled and the physical resists of using lace and pre-manipulated fabrics.

This innovative approach to using digital technology has enabled the production of unique, high quality, bespoke ink jet printed textiles. The textiles produced will all be original, hand crafted with depth to the design. The techniques can be mixed, combined and customised to the customer's requirements. These would be individual purchasers, retailers of one-off items and garment designers requiring specific needs for the placement of design, scale and colour, with a great appreciation for unique, hand crafted design. These designs could be ordered through an online catalogue of design techniques. This is a time consuming process, which will vary greatly on the detail and quantity required. To market this work, a website will be set up by the author and other practitioners/designers who would use these techniques, with the work being exhibited at trade fairs. To promote this idea the author would use agents as well as contacting independent design houses, fashion designers for new garment and accessory designs, which will ultimately be on sale in independent retailers. This will be targeting customers that have an appreciation for the craftsmanship, that require an individual look and demand originality in design. This will also aim for couture fashion labels, unique catwalk pieces that are trend setting, promoting the handcraftsmanship combined with digital technology. A basic costing structure has been developed for these crafted designs, although due to the nature of the processes used, these would need to individually assess. For all details on costs, please refer to appendix ii of this thesis.

This research has opened up a new area for investigation, where there are many fabric manipulation techniques and fabrics that could be combined with using digital technology. Providing the surface is flattened and the head height is adjusted, the combination of craft techniques with digital technology will be great. It requires confidence in understanding the technology's benefits and limitations, and the vision to push the future transition of textile craft and digital technology.

Although at first glance, this does not seem a commercially viable product, it encourages innovation and experimentation with hand crafted digital technology. The investigation of how to make a commercially viable product from this process will be discussed in section 4.3. This will challenge the possibility of reproducing these design elements using digital technology.

4.3 The Reproducibility and Commerciality of Resist Techniques using Digital Technology

Referring back to the process used in Chapter Two, digital technology was used to reproduce complex textile craft techniques in the generation of commercially viable designs. It uncovered a process where colour reduced images were used, allowing for accurate colour management, without affecting the image detail and quality. This process has been followed strictly in the generation of ink jet printed textile designs, using the resist effects created with pre-manipulated fabrics, lace and embroidery, in section 4.2. All the resist designs were scanned back into the computer, re-designed and re-printed.

The hand crafted fabrics produced in section 4.2 were all scanned flat back into the computer. These were all then saved, so elements could be extracted using the masks functions in Lectra® Kaledo.

Ready for the design creation, the resist effects were catalogued in a digital clipboard demonstrated in Figure 4.44. This clipboard consisted of individual resist elements, along with larger areas of designs scanned in from the fabric samples created. Using textile specialised software (Lectra® Kaledo Print) combinations of the resist techniques were collated together to create new designs.

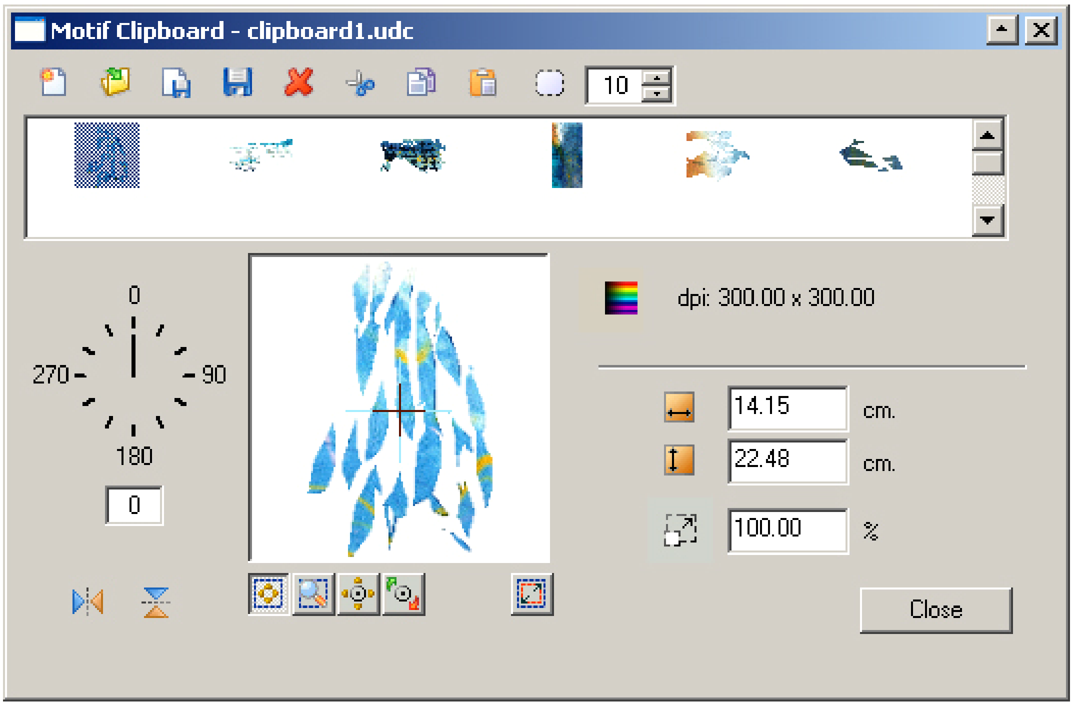


Figure 4.44 (Ryall.H, 2009) Motif Clipboard (Lectra® Kaledo Print)

This gives the designer a great deal of flexibility for creating several different designs from a variety of resist technique elements. There are many benefits when designing like this. The designs can be intricately planned, the scale can vary (providing the image quality is not affected), the placement of design can be manipulated, the designs can be placed into repeat, therefore giving greater scope to the amount printed, and instant colour-ways can be generated. However, this does not allow for the same experimentation and spontaneity of design found when applying the resist techniques by hand.

For this process to occur, it is vital to have a wide collection of hand crafted designs scanned in, in order to generate of large resource catalogue of design information. This will give the choice for fully customised fabrics. At this stage of design, the colours will still be in true colour format.

The design could remain like this; however, there will be little control over colour, relying on the colour management software, and only the option of pre testing and colour adjustment by eye. Colour reduction gives the colour control required, and saves time and money in the testing.

The method of colour reduction and matching followed from the results gained in section 2.2.2.2.3, using tones/gradients. The images were reduced in colour using Palette Builder (Lectra® Kaledo Print), also known as gradients and tones. A light and dark tone of the same colour would be selected from the design. The software would then generate a palette made from the two initial tones, by building up the tones required in between (with an option to specify the number of tones required). This would reduce the amount of colour to approximately 125 depending on the complexity of the design. From this, only the two initial tones of each group would be colour matched to a colour library, thus greatly reducing the number of colours required to be matched. This is time efficient for both the colour reduction and colour matching. By colour matching only the first and last tone in the group, a wide variety of colours are matched. If only the most commonly used colours were match, this would result in some of the vital highlighting tones not being matched. It is also worthwhile to see if any further colours that are used over 5% have been missed and to further match these odd colours, to ensure no unexpected colour outcome occurs. For some of the more complicated designs, more colours were needed, sometimes over the maximum number of colours in a reduced colour file type (256). In these cases the colour reduction was still done, however, the computer will recognise the file as a true colour file type. This made no difference to the overall process, just to the number of colours left to match to the colour library. Once the colour matching was complete, the design could be printed. If a repeated design is generated, this gives the customers full say over the quantity of fabric required.

4.3.1 Printed Results

The results from this process are impressively demonstrated in Figures4.45-4.49. In these experiments Silk Chiffon and Twill fabrics were used and were digitally printed with reactive dyes due to the availability, however, there are no restrictions when printing these designs. Once scanned in, these designs remain in a digital format; therefore they can be printed onto any fabric suitable for ink jet printing, providing they have been matched to the appropriate colour library. The designs generated are visually exciting, with plenty of variation and scope for future developments. The resist techniques are clear, and a strong impression of the aesthetic qualities achieved to that of the original. To gain these strong design results with the scanned imagery, the designer plays an important role. To build these complicated prints, the designer must have the vision to adapt the scanned imagery appropriately to achieve the desired outcome, and must have the technical abilities to use the software and colour management tools as stated in chapter 2. In creating these designs, certain aspects must be taken into consideration. These methods of scanning in the printed fabric results have many benefits of instantaneous colour, scale and placement changes that can be made, but these must be carefully altered to ensure an accurate representation to that of the original. When altering the colour, each colour or tone should be treated the same, for example only changing the hue by 20 points must be done to all colours. Keeping the same level of saturation and lightness will help to achieve a realistic result, but again if changes are made, these must be monitored for all colours. When altering the scale of the design, image quality should be controlled, to ensure no pixilation occurs, and when considering the placement of design, the design elements should be placed with in a reasonable distance to one another, or if overlapping, careful transparencies are used.

For variety within catalogue, a broad collection of design elements from hand crafted designs will need to be recorded in a digital clipboard. The colour management must also be strictly followed, allowing for high numbers of colours, to ensure the quality and detail of the original techniques remains.

Using the unique resist patterns generated in section 4.2, two designs were created to demonstrate the potential of these effects when reproduced suitable for high street production (refer to Figures 4.45 - 4.49). These experiments were trialled to explore the potential of reproducing complex, hand generated resist techniques using digital technology, with very successful results. The experiments consist of creating two designs using the elements collected from the scanned in fabrics with the hand crafted resist techniques.

It is essential that all designs have a theme, mood and colour palette, a consideration for the scale of imagery, size of design and end purpose to give focus and direction. They can be designed to the exact requirements specified by the customer. These experiments are both based on the original design theme for hand manipulated fabric collection (refer to 4.2.4.5). These are designed again for fashion fabrics, however, due to the method of production are now suitable for high street retailers. The designs are created (using the scanned imagery) directly on screen; therefore require no additional processing by hand. To put these into production (after the hand crafted designs elements are scanned in) requires a skilled CAD designer to generate the digital design, this is then reduced down in colour using the tones/gradients, colour matching the first and last tone only, then this is ready for production using ink jet printing technology. The fabric can be post-treated with steam/heat fixation and wash process (as standard, see table 1.3). These both demonstrate the aesthetic qualities to that of the original hand manipulated designs, but these can be produced commercially, as there is no individually hand crafted elements.

Once all design elements were scanned in and extracted to the clipboard, designs are easily formed. There is time involved in getting the perfect design effects and colour matching, but this can be brought down to as little as one day plus printing time. When extracting the elements from the initial scan, to obtain the perfect finish, this should be done carefully so that the edges of the elements are smooth. When combining these elements into the designs, it is important to have subtle blends from one element to another. The elements must look realistic to that of the original handcrafted fabric to retain the effectiveness; therefore placement should be taken into consideration. Colour changes must be done sympathetically, to ensure the depth of design remains, and when resizing any images, this should be done carefully, to ensure the image quality remains high. These are all designed to scale and in repeat, therefore giving full flexibility to the end amount printed. To demonstrate the possibility of producing this for short run production, a 20m printed sample will be exhibited with the other final fabrics for this PhD (see Figure 4.46).The results are highly effective and demonstrate an excellent alternative to the handcrafted fabrics. Any future research into the combination of hand crafted textile techniques used in combination with digital print technology, could also be examined for its feasibility of reproduction using the processes and methods explored in chapter 2 and section 4.3 of this research.

The process has given the opportunity for generating high quality, highly inventive, customised printed textile designs for short run production, which are commercially viable potentially for the high street markets. This method gives the designer full flexibility with the freedom of design with photographic qualities, utilising digital printing to its main advantage, yet with a method of production that gives the colour control in the design outcome. Many digital prints seen in 2009/2010, with full colour, on the high street are adjusted purely by eye, which can be a time consuming process to get all areas of colour perfected. In doing the colour alteration by eye, it is more difficult to select colour areas and to change these accurately, without having a fall-on effect on the other colours in the design. This is particularly true when the colours have many similar tones. The colour selection process relies on using replace colour functions (with changeable tolerance) and selection mask tools. This itself can be time consuming. The designs developed in this research can be easily adapted on screen to fulfil specific the customer's requirements. The customer will be able to specify the exact amount required, with no minimum orders and choose from a variety of fabrics that are suitable for ink jet printing. Some basic costs have been calculated for these designs and the process, these can be found in the appendix ii of this thesis. These designs are targeted at the bespoke textile market, for boutique shops and individual customers. With the increased use in these techniques and further development of these processes, the prices may reduce and therefore designs could aim for the high street stores and customers.

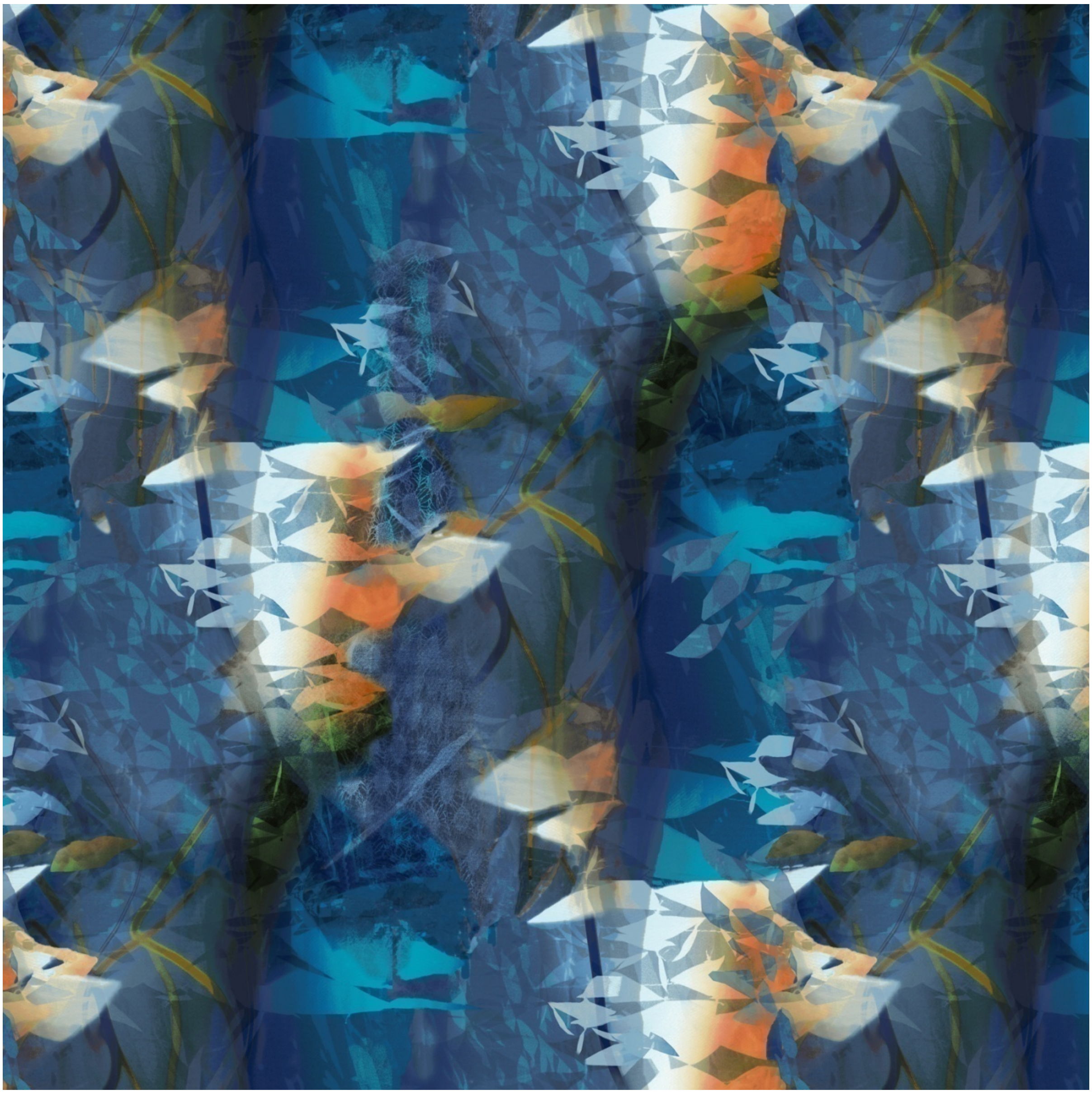


Figure 4.45 (Ryall.H, 2009) Reproductions of Resist Techniques using Textile CAD in a Completed Repeat Design (Medium Design Type)

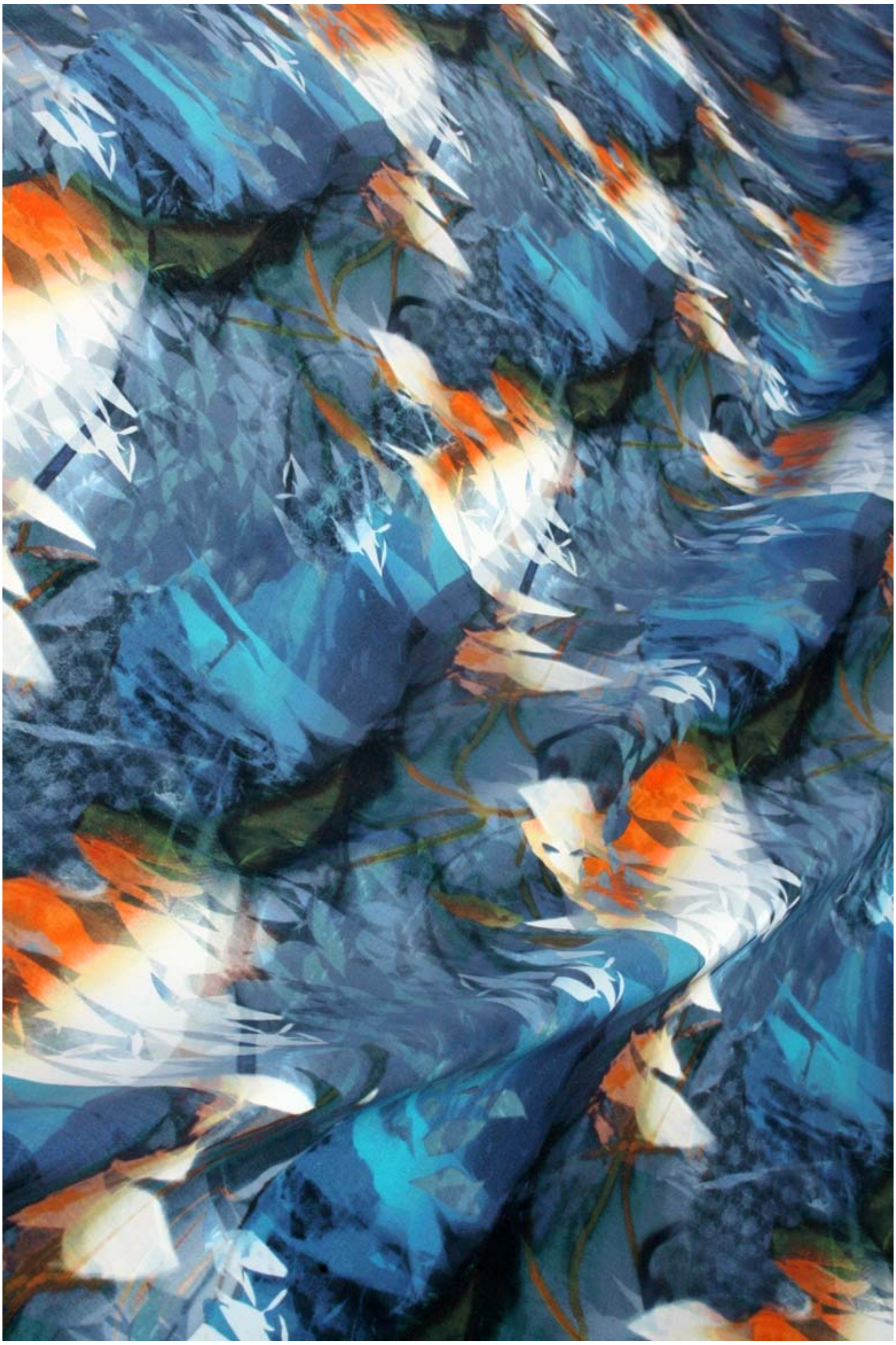


Figure 4.46 (Ryall.H, 2010) An Example of the Digitally Printed Silk Twill Fabric (20m Sample) from the Design shown in Figure 4.45 (Reactive Dyes)

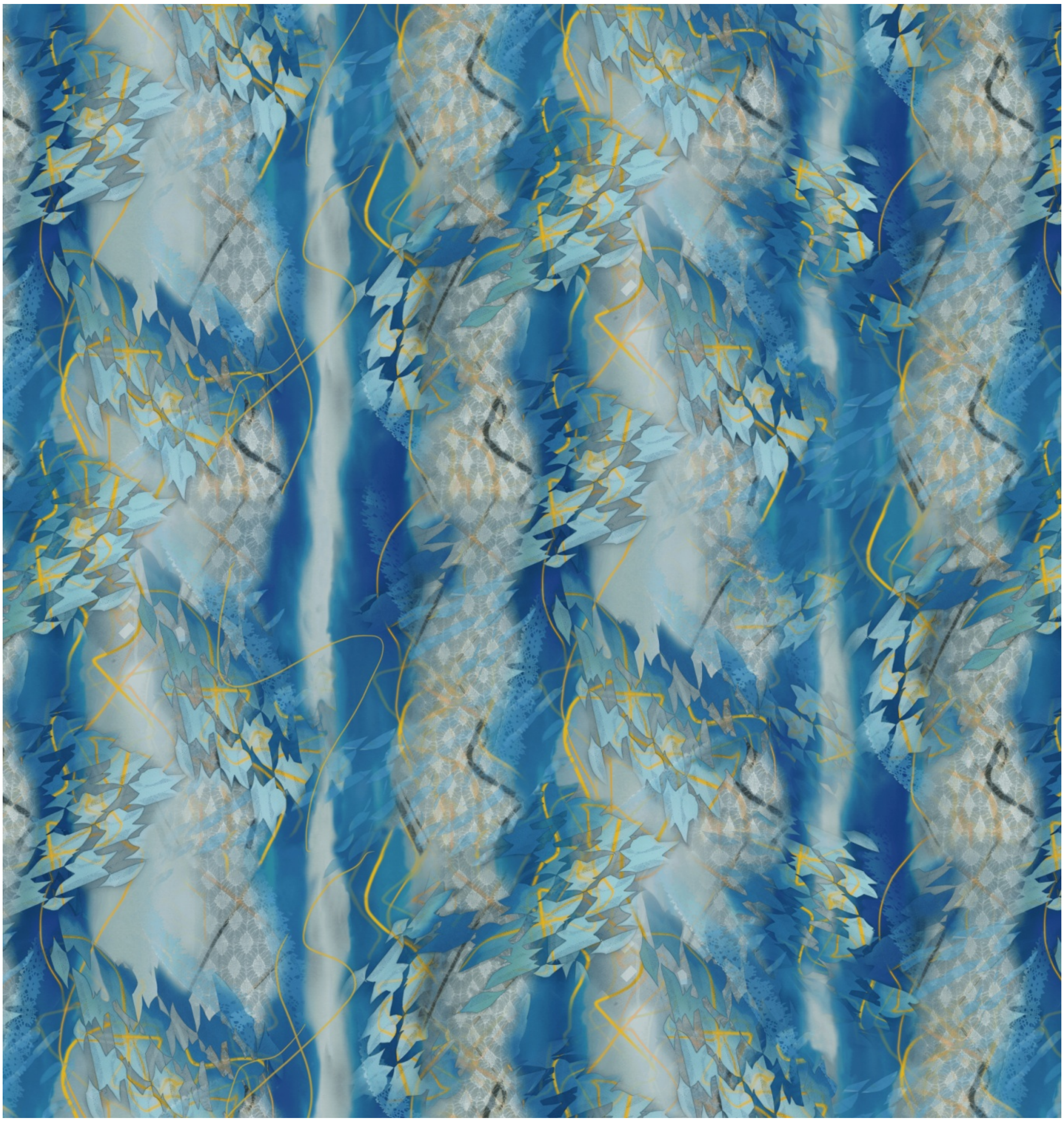


Figure 4.47 (Ryall.H, 2010) Reproductions of Resist Techniques using Textile CAD in a Completed Repeat Design (Complicated Design Type)

Figure 4.48 (Ryall.H, 2010) An Example of the Digitally Printed Silk Chiffon Fabric (3m Sample) from the Design shown in Figure 4.47

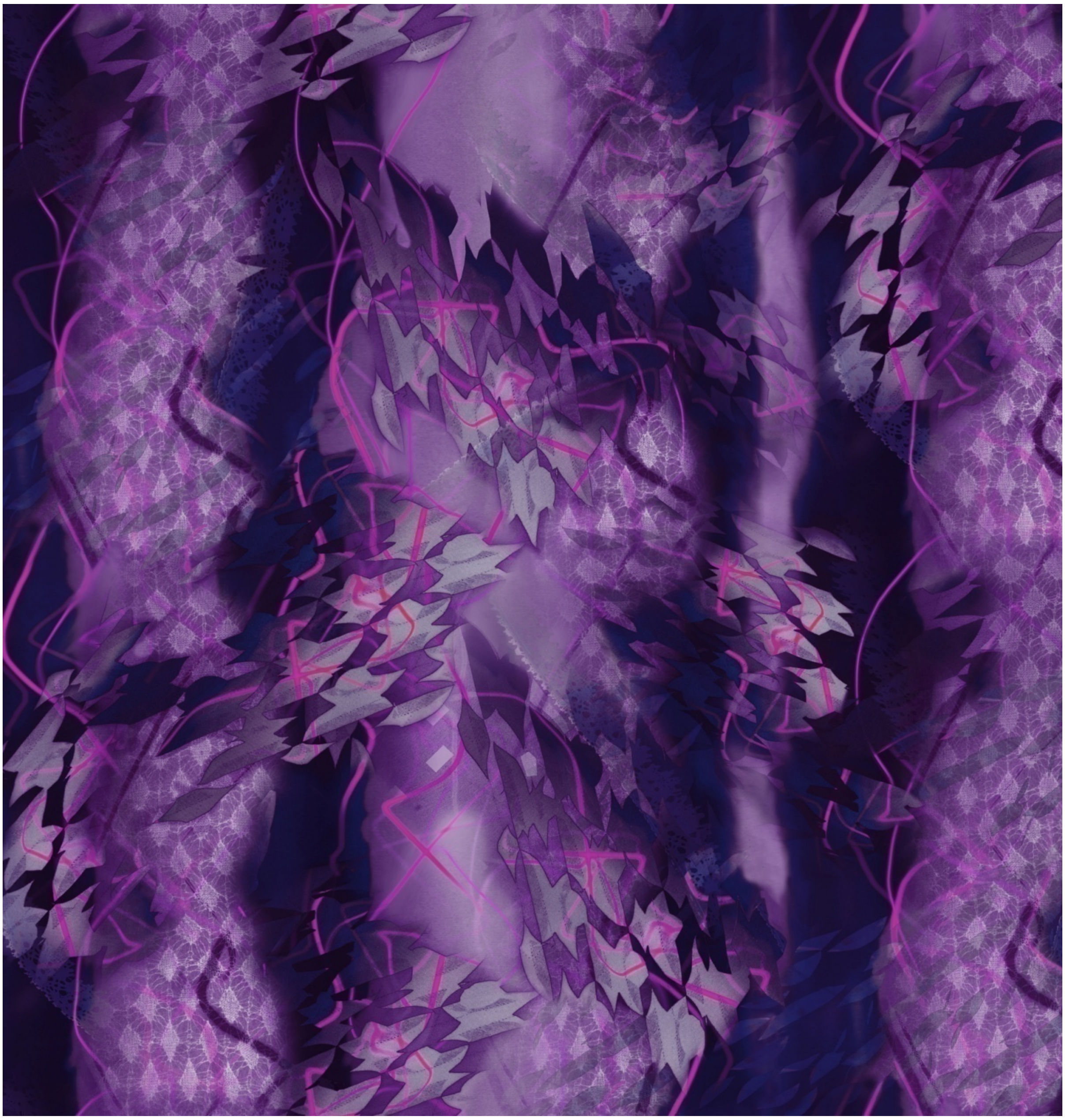


Figure 4.49 (Ryall.H, 2010) Example of Alternative Colour-way to Figure 4.47

4.4 Discussions and Conclusions

This chapter has investigated and begun to close the gap between the notion of craft and digital design for textiles. It has demonstrated the ink jet printer as a creative design tool, used to craft a design and not just a means of production. This research has examined the potential for ink jet technology in the UK textile market, by introducing hand crafted ink jet printed designs and an option for reproducing these commercially. This research has investigated two areas for printed textiles design, innovation for couture fashion and the interpretation of these innovative designs into products for mass production for designer ready-to-wear fashion fabrics.

This research has innovatively explored methods of resist that can be applied with ink jet technology. Chemical and physical hand crafted techniques have been explored using Cotton and Silk fabrics, achieving excellent resist effects, ranging from acid resist prints and pattern generated from lace, embroidery and fabric manipulations. The results from these techniques were highly exciting, while the design can be planned to some extent, the end pattern would only be revealed once all physical resists were removed, therefore making these designs experimental and unique. These experiments have focussed on using silk fabrics, due to the nature of the fabrics being relatively lightweight to feed through the printer and the appropriateness of the fabric for the fashion outcome. However, future research would explore the opportunities of using different dyestuff and materials such as Cottons, Polyester, Rayons and Wools. Using the appropriate dyestuff and fabric combinations, will allow for many possibilities for new products such as furnishings.

The crafted nature of these precise designs would be impossible to reproduce using the same techniques again; however, the range of possible effects is almost infinite, making each end result so unique and innovative. This research has demonstrated that a variety of embellished substrates can be passed through the ink jet printer with ease, opening up new opportunities for ink jet printing onto textiles, but currently the time involved in applying and removing the resists make these designs not commercial for high street production. These hand crafted designs have been generated for couture fashion; these are unique designs that establish ink jet print technology as a creative design tool for the modern textile designer.

Following this research into crafted ink jet printed designs, the author investigated methods, in which the visually exciting pattern results created using these physical resists, could be translated and re-produced for the commercial textile market for ready-to-wear fashion, with the future focus of reaching the mass market. To produce these same visual effects commercially, the results achieved from these experiments are then scanned back into CAD software. Design elements are then selected, placed in a clipboard and collaged together to form new reproducible, with the visual of hand crafted detailing, ink jet printed designs.

The hand crafted designs generated in these experiments were essential in the exploration of the imagery effects, and to really demonstrate the potential for craft design with this technology, therefore promoting and encouraging further textile craft techniques. However, to realise these as techniques into commercial designs, for the high street fashion and interiors market, it was vital to explore methods of reproducing these commercially. The management of colour is the biggest obstacle to tackle in this process. In order for the look of hand crafted fabric, it is essential to have a large number of colours. It is also vital to manage colour, so the final result is as expected from the CAD design. The method of colour reduction was studied to ensure tonal effects could be achieved, as well as controlling the colour and time involved. The strongest results came from reducing the colours using tones/gradients and only matching the lightest and darkest tone of each colour group. Not only does this demonstrate a method of reproducing the resist effects created for high street commercial production, but a future method of using photographic qualities with ink jet printing that can be colour controlled. The designs were printed onto Silk Twill and Chiffon. The results produced in this method are also high attractive and represent the aesthetic qualities to that of the original resist marks made.

This process involves a great deal of technical and creative skill which the designer will need. The re-generated designs using the scanned in resist effects involve great attention to detail to ensure the finished design looks realistic compared to the original, but the designs must be new and exciting to make these sellable products, therefore strong creative skills are required. Also technically the colour must be perfect to the design generated on screen to make these reproducible.

This research encourages the UK textile craftsperson/maker to explore new crafted techniques. These can be highly experimental and time consuming, as this process using ink jet technology and textile CAD, gives the craftsperson/maker an additional option for reproduction into the commercial textile market. This does not detract from the hand crafted artwork, but opens up the opportunity for the look of hand crafted design to reach the high street customer. For this to occur there must be a development of crafted design (refer to chapter 2) and craft techniques that can be applied with ink jet technology, to enable the growth of this area of design. These must be market driven and in keeping with current trends. This allows for textile designers to be highly experimental with the technology and to continually push the boundaries of the printed textile market.

This will also be driven by the textile print designer and craftsperson. This could be set up in two ways; the ideal solution for this type of production would be relatively small digital print bureaus/research and design units, employing fewer than 10 personnel for the design and manufacture, which would specialise in researching and producing bespoke approaches to ink jet printed designs. These bureaus would employ highly skilled textile print designer/makers that have the creative and technical skills discussed in this chapter. For the technology to be creatively pushed in new directions for the printed textile market, it is essential that these designers are both innovative thinkers for design and technology. By having the full understanding of the technology, it is easier to develop new and realistic opportunities for advancements in production methods. Each design idea can be visualised from concept through to production. The print bureaus would also have the option of some workshop facilities to enable some print paste techniques for resists and print embellishments, and appropriate post-treatment facilities. These bureaus would have a minimum of 3 ink jet printers, to give the scope and variety in dyestuffs and materials available. This type of set up would allow for small print production to be achieved, from 1m – over 500m, with the essential individual customer focus.

The smaller start up option for UK innovative textile print designers would be to work in partnership with a standing ink jet print manufacturer. Providing all colour management systems and post-treatment productions were in place, this would involve smaller set up costs while the methods of production establish themselves in the UK textile market. Future research in this area by the author, could establish these connections with the UK textile industry. The University of Huddersfield trains future textile designers to be innovative thinkers and designers, technically competent in information technology (IT)/CAD and computer aided manufacture (CAM), therefore giving them the skills to direct and employ these future methods of production. For these developments and enterprises to start, research SME (small and medium sized enterprise) grant would be investigated. The merger in April 2010 of Skillfast-UK (sector skills council for the UK's fashion and textile industries) and Skillset (sector skills council for the creative media industries) shows the importance and recognition by the government of the creative industries in the UK. Advice/cooperation/grants could also be sought from the new sector skills council. This will ultimately keep the design and manufacturing in the UK, thus helping to support the UK economy and reduce carbon emissions in the type and the export of manufacturing. This would also close the gap between consumer, designer and manufacturer, giving the customer full choice in design outcome and control in the quantity required.

The future designers will need to work alongside the customer and the ink jet print manufacturers, to ensure the technology is developing in accordance to the design criteria. Investigations should look into the possibilities of ink jet printing with various print pastes such as devoré and discharge, and should review the scope and potential possibilities of printing more textural or three-dimensional surfaces through ink jet technology. The textile designer will also need a strong understanding of the technology to ensure the reproducibility of these designs for commercial production.

The range of customers, from the high-street companies, the independent retailer to the high-end catwalk designer, will all have far greater choice in their printed designs. These products will range from fashion and interiors market, allowing for full flexibility to the amount printed. A virtual catalogue of design information can be generated to show the potential and choice to each of the customers. Each design would need to be bespoke to the customer's requirements; this involves strong CAD creative and technical skills and full understanding for the method of colour management used by the textile printer creating these designs.

Section 3

Conclusions and Recommendations

Chapter 5

Conclusion

Wide format ink jet printing for textiles will have major effects on the modern textile designer. Ink jet printing reduces the time and costs involved with sampling, allowing more printed samples to be produced for the customer and allowing a wider choice of designs and colours to be achieved. From a creative perspective, ink jet printing can give more freedom when designing, allowing more colours per design and also highly detailed, photographic imagery to be used. This area of design was previously very limited with screen printing techniques.

Although ink jet printing has its own limitations when compared to rotary screen printing for production purposes, constant developments are being made in the dyestuffs and ink jet technology to help overcome these. It is critical that all print procedures involved with ink jet printing are followed strictly in the running of the printer, including the pre and post treatments of the fabrics, ensuring that all times and temperatures used are accurate. This is important to enable consistent print quality and colour reproducibility. Tests prior to printing, such as alignment of print heads, priming of colours and colour standard trials, can help to ensure reproducible outcomes. The use of colour libraries and colour management systems will also contribute to achieving the consistent results needed.

5.1 Research Aims Revisited

Various methods in the development of innovative bespoke printed fabrics, using ink jet technology, have been extensively researched. This research has examined the strong potential for using ink jet technology for short production runs, for the generation of novel, high quality bespoke fabrics, and for the option of customisation. This research and development approach to design harnessing technology, is the way forward for the UK textile print industry, offering the opportunity to develop a niche market for high quality, high value, exclusive designs. The printing quality is high and the time and cost for short run productions are greatly reduced with ink jet printing, making them competitive with traditional printing methods. This printing process can also give the textile designer great opportunities to develop print design innovation in the generation of bespoke printed textiles.

By investigating new and pre-manipulated materials that can be digitally printed, this research has challenged the boundaries of using textile ink jet technology. This uncovered future possibilities for this technology, and while acknowledging possible limitations; it uncovered solutions to enable these pre-manipulated materials to be digitally printed. In doing so, this research has challenged and crossed the boundaries of digital and craft design, which has not been done before using digital printing.

Investigations have established suitable methods of embellishing the ink jet printed fabrics, which simplify the production and ensure that quality remains in the development of bespoke printed designs. By applying these methods, the future for small-scale production for generating bespoke printed textiles can be realised and made commercially viable.

In the process of investigating the possibilities of printing on pre-embellished and manipulated materials, this research has discovered and developed various digital resist techniques that can be applied with ink jet technology. By applying the hand crafted approach, this research has developed a collection of crafted designs that embrace the aesthetic qualities of the traditional shibori technique. These methods apply a unique and innovative process for developing bespoke fabrics using ink jet technology.

To coincide with these developments of hand crafted designs, this research has investigated the opportunities of digitally simulated hand craft techniques using ink jet technology. The photographic qualities required for the reproduction of these complex textile craft techniques, were previously unachievable using traditional printing methods. This has investigated the most efficient method of gaining high quality printed results, which resemble that of the original craft technique, with reproducible colour. It highlights the benefits of using CAD and ink jet technology and proved the feasibility of producing these for small-scale production. Elements of the processes and techniques discussed in this thesis are already being introduced into research and teaching at the University of Huddersfield, with highly successful results.

5.2 Discussions and Conclusions

The results of this research are highly successful. The research has developed a range of techniques for embellishing printed fabrics, producing results that are visually exciting and that are highly saleable. The blend of decorative embellishment techniques with ink jet printing is unlimited, allowing desired effects to be achieved at lower prices, shortened production times and with minimal wastage. The procedures must be set up prior to producing these fabrics. Once these are in place the creativity can truly begin in embellishing and enhancing the fabrics. The techniques can be used with a range of fabrics and printers, therefore giving greater scope to the result. Although the techniques described in this thesis are highly innovative, they are not overly complex to use. Thus making them accessible to textile designers in general, offering them an exciting new tool for generating distinctive and highly desirable ink jet printed fabrics and end products. The processes can be adapted by each designer's creative vision and the finished outcome will greatly depend on the designer's skill. Each designer could take this in many directions with infinitely exciting results. The ink jet print technology could be developed using these approaches to allow for more design centred intuitive approach to be fostered. These can be designed to future trends, markets, and customer requirements. These will then lead to developing the small print production market and allow for individual high quality, innovative, custom made printed fabrics. The results of this research will make a significant contribution to the future of the UK textile print industry and potentially lead to patents in relation to some techniques and processes.

As shown in these experiments, custom made bespoke fabrics can be produced utilising CAD, ink jet technology and traditional screen print techniques. However, this is only the beginning, emphasising how these techniques can be combined. The advantages of linking CAD and ink jet technology, and what they have to offer in the development of custom-made fabrics, are just beginning to be explored. This is a highly exciting time and opportunity for the UK print industry, to focus on the strong skills the UK textile designers have to offer, and to keep the production within the UK. This gives a unique chance to allow the textile industry to thrive and promote bespoke, high quality, original designs for the customers. This would allow for fashion and interior designers to develop their own small fabric runs, this also gives freedom and great choice to the customer in every aspect of their chosen designs. This is such a valuable asset to the UK print industry, which previously would only be achievable at a very high price. This gives the customer the personal choice and ownership in their design. With the appropriate design skills, the relevant textile specialist software and experience of CAD/CAM, these can be combined creatively and push the boundaries of textile sampling and custom-made fabrics, which will be commercially viable for the high street. These can also be utilised further in the development of high quality hand craft textiles, which are innovative and highly exciting.

This research demonstrates the potential to simulate textile craft techniques such as shibori using ink jet technology. Most hand-developed textile craft techniques are very time consuming and are often ‘one-off’ pieces. This work is not trying to detract from the value of ‘one-off’ textile crafted samples, but to further develop and expand some of the integral qualities commercially.

There are many advantages of using CAD and ink jet printing for the development of complex textile craft techniques. The scale of the original textile sample can vary, with small samples able to be flexed for future re-scaling, resulting in less time being required in the original development of the textile sample. Once the method of production is set up, each sample can be easily and quickly produced to a high standard. Once the samples are in a digital format they are flexible to changes, such as scale, re-colouring and repeats. The printed results are excellent using ink jet technology, with an almost photographic outcome. Digital printing is the most suitable method of production for this work, due to its high quality, flexibility and its low cost for small-scale productions.

The ideal situation for the production of these high quality bespoke fabrics would be small print bureaus. These bureaus would have specialist knowledge in the development of bespoke print textiles, and selection of equipment available such as, textile specialist software, a bank of ink jet printers (set up with various dye types), print tables, and post treatment equipment for small production runs. These print bureaus would have various decorative embellishment overlays and craft techniques catalogued to give a wide selection of choice to the customer, and the option for the customer to bring their own samples to be reproduced. These bureaus would be able to react quickly and produce small productions at reduced costs and fast speeds. There is also a significant advantage to using ink jet printing over screen printing - its sustainability. It uses lower amounts of energy, better water utilisation and effluent for disposal with lower waste of fabrics and dyes. This will become ever more important in the future. This research has also progressed techniques into areas where screen printing cannot go, and this coupled with the environmental benefits this research has proved to be highly important.

This offers a new approach to be adopted by the UK textile printing industry. The results of these smaller quantity printed textiles would be innovative and customised, offering more desirable and exclusive ranges to the printed textile market. These ranges would be able to react to the ever-increasing seasonal changes, with a lower price than that which is usually associated with high quality bespoke fabrics for short production runs. With the variety of fabrics available for ink jet technology in 2009/2010 and the new fabrics that are continually being tested, this market will only increase the desirability for these printed textile results.

This will continually push the creativity of the textile designers, therefore encouraging the design innovation for printed textiles. These innovations in designs will no longer have the high price tag attached and will be more accessible to the high street customers.

This blend of textile craft techniques and digital technology has uncovered a new opening in the textile industry, promoting design innovation, the use of specialist textile printers, and encouraging the development of new technologies; ultimately producing commercially viable, high quality bespoke printed textiles.

5.3Suggestions for Further Research

This research has investigated and explored new avenues for ink jet technology in the generation of hand crafted, bespoke printed textiles. In doing so, this research has uncovered further development opportunities for the advancement of ink jet technology in the UK textile industry.

The exploration of the combination of decorative overlay techniques with ink jet technology provides a base for further development, which could examine alternative decorative embellishment techniques and new fabrics that could be combined with ink jet technology in the production of short run commercially viable, high quality, innovative textile prints. Future research could trial the following:

- Experiment and test a wider range of fabrics/dyes, such as Polyesters, Cottons and mixed fibre materials, to examine the feasibility and results achieved.

- Investigate how these new fabrics may individually react to the digital resist processes described. Polyester could be tested to see how this fabric reacts to the heat of the steam iron, permanently changing the nature of the fabric to be crumpled and pleated.

- Test further textural qualities that can be added to the techniques and processes developed.

- Review the opportunities for new products using the techniques described, for example using the heavier weight and more durable materials could be used for accessories for interiors.
- Research how these digital resist/crafted techniques work with different makes, models and scale of ink jet printers.

- Investigate the most effective combinations of craft and digital techniques, fabrics, dyes and different designs, and once achieved new collections could be developed to promote these ideas commercially, working collaboratively with high street retailers and customers.

- Continued development in the dyestuffs and print head technology, to increase the speed and reduce the costs for production using ink jet printing. This should increase confidence and the commerciality for this to be the future for textile printing.

- Research into the print head technology could be developed further to allow for alternative print pastes to be digitally printed such as devoré and chemical resist pastes, therefore greatly increasing the flexibility of this technology. This could reduce additional production times; therefore further decreasing costs and time associated with the creation of bespoke printed textiles.

- Developments could push the scope in which uneven surfaces and potentially three-dimensional fabrics could be printed on. Therefore, this could create the potential for a variety of fabrics, such as patchwork, laser cut, heat set, non-woven and blistered knits to be digitally printed.

- Trial the adhesive belt found on the newer models of ink jet printers, to see whether this will help to secure the materials and give greater tension for running these crafted materials through the printer. Future research could explore the increased opportunities that will be created using the adhesive belts, with the techniques developed in this research.

- Investigations to trial the uneven surface height of all new materials, to make sure these will be printable.

- To work with CAD/CAM companies to investigate the future of ink jet print technology, could allow for the print head height go higher than 10mm, and ultimately to have print heads that have a sensor to automatically react and change height to the contour of the fabric.

- Research could examine more ways of treating the fabrics to make these as smooth as possible to run through the printer, thus allowing the print heads to be lowered further and gaining sharper quality prints.

- Further investigate the combination of digital resist techniques that could be investigated with the use of ink jet technology. These could involve further appliqué, pleating and binding techniques, and mechanical resist using waxes and resins.

The above could expand the area of customisation. Once the techniques have been thoroughly researched and catalogued, these will help develop the array of choice in which the customer would be able to choose from.

Crucially, for all of the above to happen, there must be a drive and vision for the modern textile designer to push the boundaries of crafts with technology. This will continue the future progression for the printed textile market, and is something that is vital to reinvigorate, or even ensure the survival of, the UK textile market. Once this has been confidently set up, future research will explore the marketing opportunities for the fabrics outside of the UK.

Section 4

Catalogue of all Fabric Designs with Processes Exhibited for PhD

6.1 Embellishment Techniques with Ink Jet Printed Designs

2003

Silk Viscose Satin

Silk Viscose Satin with Devoré Embellishment

- Calculate the shrinkage of the fabric first by ink jet printing a 10cm plain coloured square, post-treat as per standard for Silk Viscose Satin and measure the change in size.
- Ink jet print the CAD design onto fabric with reactive Dyes(taking the shrinkage into consideration by increasing the size of design to compensate for any shrinkage).
- Post-treat to standard guidelines setup for reactive dyes on Silk Viscose Satin.
- Iron and pin the fabric down to the print table, ensuring the design remains accurate to its original size.
- Develop a screen separation from the original CAD design.
- Expose the separation onto a screen.
- Accurately position the screen to the fabric and screen print through the devoré paste.
- Allow to dry, then heat to fix the paste for 1-3 minutes at 130°.
- Re-wash the fabric to remove the devoré paste and all the burnt cellulose fibres.
- Allow the fabric to dry and return to its original handle.

To control the design outcome, change the type and placement of the digital designs and devoré/print techniques.

2003		Silk Viscose Satin	Silk Viscose Satin with Devoré and Reactive Print on Reverse of the Fabric

- Calculate the shrinkage of the fabric first by ink jet printing a 10cm plain coloured square, post-treat as per standard for Silk Viscose Satin and measure the change in size.
- Ink jet print the CAD design onto fabric with reactive dyes (taking the shrinkage into consideration by increasing the size of design to compensate for any shrinkage).
- Post-treat to standard guidelines setup for reactive dyes on Silk Viscose Satin.
- Iron and pin the fabric down to the print table, ensuring the design remains accurate to its original size.
- Develop a screen separation from the original CAD design.
- Expose the separation onto a screen.
- Accurately position the screen to the fabric and screen print through the devoré paste.
- Allow to dry, then heat to fix the paste for 1-3 minutes at 130°.
- Re-wash the fabric to remove the devoré paste and all the burnt cellulose fibres.
- Allow the fabric to dry and return to its original handle.
- Re-pin the fabric down to the print table, reverse side up.
- Using a blank screen, print a solid colour reactive print paste (selected from the original colour palette) to the reverse of the fabric. Increase the paste's viscosity by 11%.
- Re-steam and wash the fabric to reveal the result.

To control the design outcome, change the type and placement of the digital designs and devoré/print techniques.

2003		Silk Viscose Velvet	Silk Viscose Velvet with Devoré Embellishment • Calculate the shrinkage of the fabric first by ink jet printing a 10cm plain coloured square, post-treat as per standard for Silk Viscose Velvet and measure the change in size. • Ink jet print the CAD design onto fabric with reactive dyes (taking the shrinkage into consideration by increasing the size of design to compensate for any shrinkage). • Post-treat to standard guidelines setup for reactive dyes on Silk Viscose Velvet. • Iron and pin the fabric down to the print table, ensuring the design remains accurate to its original size. • Develop a screen separation from the original CAD design. • Expose the separation onto a screen. • Accurately position the screen to the fabric and screen print through the devoré paste. • Allow to dry, then heat to fix the paste for 1-3 minutes at 130°. • Re-wash the fabric to remove the devoré paste and all the burnt cellulose fibres. • Allow the fabric to dry and return to its original handle. To control the design outcome, change the type and placement of the digital designs and devoré/print techniques.

2003

Silk Viscose Velvet

Silk Viscose Velvet with Devoré and Reactive Print on Reverse of the Fabric

- Calculate the shrinkage of the fabric first by ink jet printing a 10cm plain coloured square, post-treat as per standard for Silk Viscose Velvet and measure the change in size.
- Ink jet print the CAD design onto fabric with reactive dyes (taking the shrinkage into consideration by increasing the size of design to compensate for any shrinkage).
- Post-treat to standard guidelines setup for reactive dyes on Silk Viscose Velvet.
- Iron and pin the fabric down to the print table, ensuring the design remains accurate to its original size.
- Develop a screen separation from the original CAD design.
- Expose the separation onto a screen.
- Accurately position the screen to the fabric and screen print through the devoré paste.
- Allow to dry, then heat to fix the paste for 1-3 minutes at 130°.
- Re-wash the fabric to remove the devoré paste and all the burnt cellulose fibres.
- Allow the fabric to dry and return to its original handle.
- Re-pin the fabric down to the print table, reverse side up.
- Using a blank screen, print a solid colour reactive print paste (selected from the original colour palette) to the reverse of the fabric. Increase the paste’s viscosity by 11%.
- Re-steam and wash the fabric to reveal the result.

To control the design outcome, change the type and placement of the digital designs and devoré/print techniques.

6.2 Pigment Discharge Resist Paste used Prior to Ink Jet Printing

2003		Plain Cotton	Pigment Discharge Resist Paste used Prior Ink Jet Printing • Develop a screen separation from the original CAD design and expose this onto a screen. • Screen-print the coloured discharge paste onto the pre-treated fabric for reactive dye ink jet printing. • Allow to dry, then heat fix the paste for 2 minutes at 150°. • Re-roll or tack the fabric down onto a backing cloth. • Ink jet print with reactive dyes (standard head height). • Remove from roll or backing cloth. • Post-treat to standard guidelines for reactive dyes on Cotton. To control the design outcome, change the type and placement of the digital designs and resist print technique.
2003		Plain Cotton	Pigment Resist Paste used Prior Ink Jet Printing • Develop a screen separation from the original CAD design and expose this onto a screen. • Screen-print the coloured discharge paste onto the pre-treated fabric for reactive dye ink jet printing. • Allow to dry, then heat fix the paste for 2 minutes at 150°. • Re-roll or tack the fabric down onto a backing cloth. • Ink jet print with reactive dyes (standard head height). • Remove from roll or backing cloth. • Post-treat to standard guidelines for reactive dyes on Cotton. To control the design outcome, change the type and placement of the digital designs and resist print technique.

6.3 Digital Resists using Lace Fabrics with Ink Jet Technology

2006

Polyester Lace

Ink Jet Printed Lace Fabric

- Tack the lace onto a pre-rolled backing cloth prior to printing.
- Ink jet print the lace with reactive inks (raise print head height to approx 6-7mm).
- Detach the lace from the backing cloth
- Heat fix for 5mins at 150°.

To control the design outcome, change the type and placement of the digital designs and lace fabric.

2006

Poly/Cotton Lace

Plain Cotton Base

Ink Jet Printed Lace Fabric

- Tack the lace onto pre-rolled Plain Cotton fabric prior to printing.
- Ink jet print the lace with pigment inks (raise print head height to approx 6-7mm).
- Lace remains attached to base fabric, just remove from the printer.
- Heat fix for 5mins at 150°

To control the design outcome, change the type and placement of the digital designs and lace fabric.

2006

Poly/Cotton Lace

Plain Cotton Base

Ink Jet Printed Lace Fabric

- Tack the lace onto pre-rolled Plain Cotton fabric prior to printing.
- Ink jet print the lace with pigment inks (raise print head height to approx 6-7mm).
- Lace remains attached to base fabric, just remove from the printer.
- Heat fix for 5mins at 150°

To control the design outcome, change the type and placement of the digital designs and lace fabric.

2006

Poly/Cotton Lace

Plain Cotton Base

Ink Jet Printed Lace Fabric

- Tack the lace onto pre-rolled Plain Cotton fabric prior to printing.
- Ink jet print the lace with pigment inks (raise print head height to approx 6-7mm).
- Lace remains attached to base fabric, just remove from the printer.
- Heat fix for 5mins at 150°

To control the design outcome, change the type and placement of the digital designs and lace fabric.

2006

Silk Habotai

Digital Lace Resist

- Ink jet print the underlay design onto pre-treated fabric with reactive dyes.
- Once dry, tack down the lace on top of the underlay print.
- Ink jet print the overlay design with reactive dyes (raise print head height to approx 6-7mm).
- Remove the lace to reveal the resist pattern.
- Post-treat to standard guidelines for reactive dyes on Silk.

To control the design outcome, change the type and placement of the digital designs and lace fabric.

2006

Silk Habotai

Digital Lace Resist

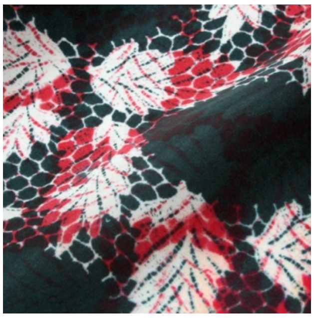
- Ink jet print the underlay design onto pre-treated fabric with reactive dyes.
- Once dry, tack down the lace on top of the underlay print.
- Ink jet print the overlay design with reactive dyes (raise print head height to approx 6-7mm).
- Remove the lace to reveal the resist pattern.
- Post-treat to standard guidelines for reactive dyes on Silk.

To control the design outcome, change the type and placement of the digital designs and lace fabric.

2006		Silk Habotai	Digital Lace Resist

- Ink jet print the underlay design onto pre-treated fabric with reactive dyes.
- Once dry, tack down the lace on top of the underlay print.
- Ink jet print the overlay design with reactive dyes (raise print head height to approx 6-7mm).
- Remove the lace to reveal the resist pattern.
- Reapply the second lace fabric.
- Ink jet print the second overlay design with reactive dyes, controlling the location of the print (keeping the print head height raised to approx 6-7mm).
- Post-treat to standard guidelines for reactive dyes on Silk.

To control the design outcome, change the type and placement of the digital designs and lace fabric.

2006		Silk Habotai	Digital Lace Resist

- Ink jet print the underlay design onto pre-treated fabric with reactive dyes.
- Re-design the lace by cutting/removing areas from it.
- Tack down the lace on top of the under print.
- Ink jet print the overlay design with reactive dyes (raise print head height to approx 6-7mm).
- Remove the lace to reveal the resist pattern.
- Post-treat to standard guidelines for reactive dyes on Silk.

To control the design outcome, change the type and placement of the digital designs and lace fabric.

2006

Silk Habotai

Digital Lace Resist

- Ink jet print the underlay design onto pre-treated fabric with reactive dyes.
- Once dry, tack down the lace on top of the underlay print.
- Ink jet print the overlay design with reactive dyes (raise print head height to approx 6-7mm).
- Remove the lace to reveal the resist pattern.
- Post-treat to standard guidelines for reactive dyes on Silk.

To control the design outcome, change the type and placement of the digital designs and lace fabric.

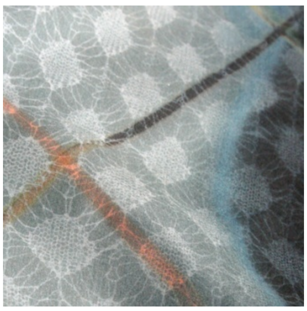
2009

1/167F30 Decitex Flat Bright Trilobal Polyester

Ink Jet Printed Lace Fabric

- Tack the lace onto a pre-rolled backing cloth prior to printing.
- Ink jet print the overlay design with pigment inks (raise print head height to approx 6-7mm).
- Remove the lace to reveal the pattern.
- Heat fix for 5mins at 150°.

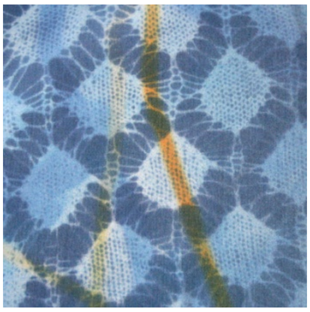
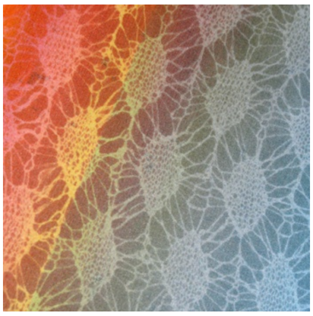
2009

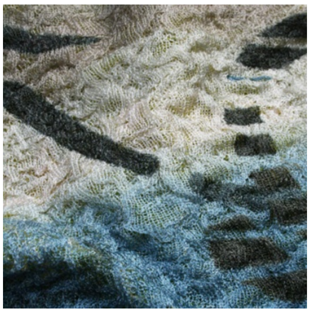


Silk Habotai

Digital Lace Resist

- Ink jet print the underlay design onto Silk fabric with pigment inks.
- Once dry, tack down the lace on top of the underlay print.
- Ink jet print the overlay design with pigment inks (raise print head height to approx 6-7mm).
- Remove the lace to reveal the resist pattern.
- Heat fix for 2-3mins at 150°.

2009		1/167F30 Decitex Flat Bright Trilobal Polyester	Ink Jet Printed Lace Fabric • Tack the lace onto a pre-rolled backing cloth prior to printing. • Ink jet print the overlay design with pigment inks (raise print head height to approx 6-7mm). • Remove the lace to reveal the pattern. • Heat fix for 5mins at 150°.
2009		Silk Habotai	Digital Lace Resist • Ink jet print the underlay design onto Silk fabric with pigment inks. • Once dry, tack down the lace on top of the underlay print. • Ink jet print the overlay design with pigment inks (raise print head height to approx 6-7mm). • Remove the lace to reveal the resist pattern. • Heat fix for 2-3mins at 150°.
2009		1/167F30 Decitex Flat Bright Trilobal Polyester	Ink Jet Printed Lace Fabric • Tack the lace onto a pre-rolled backing cloth prior to printing. • Ink jet print the overlay design with pigment inks (raise print head height to approx 6-7mm). • Remove the lace to reveal the pattern. • Heat fix for 5mins at 150°.
2009		Silk Habotai	Digital Lace Resist • Ink jet print the underlay design onto Silk fabric with pigment inks. • Once dry, tack down the lace on top of the underlay print. • Ink jet print the overlay design with pigment inks (raise print head height to approx 6-7mm). • Remove the lace to reveal the resist pattern. • Heat fix for 2-3mins at 150°.

2009		1/167F30 Decitex Flat Bright Trilobal Polyester	Ink Jet Printed Knit Fabric • Tack the knitted fabric onto a pre-rolled backing cloth prior to printing. • Ink jet print the overlay design with pigment inks (raise print head height to approx 6-7mm). • Remove the knitted fabric to reveal the pattern. • Heat fix for 5mins at 150°.

6.4 Digital Resists using Embroidery with Ink Jet Technology

2004

Plain Cotton

Digital Embroidery Resist

- Ink jet print the underlay design onto pre-treated fabric with reactive dyes.
- Develop a CAD embroidery design.
- Stitch the design out onto underlay print.
- Steam iron flat using a commercial steam iron (with a protected layer on top) and tack onto a pre-rolled backing cloth.
- Ink jet print with reactive dyes(raise print head height to approx 6-7mm).
- Remove from the backing cloth.
- Remove the stitching to reveal the resist pattern.
- Post-treat to standard guidelines for reactive dyes on Cotton.

2004

Plain Cotton

Digital Embroidery Resist

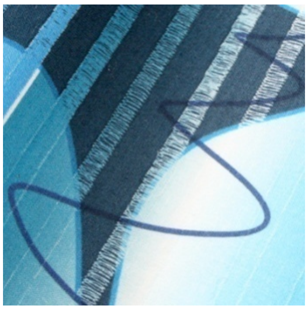
- Develop a CAD embroidery design.
- Stitch the design out onto pre-treated Cotton fabric for reactive ink jet printing.
- Steam iron flat using a commercial steam iron (with a protected layer on top) and tack onto a pre-rolled backing cloth.
- Ink jet print with reactive dyes (raise print head height to approx 6-7mm).
- Remove from the backing cloth.
- Remove the stitching to reveal the resist pattern.
- Post-treat to standard guidelines for reactive dyes on Cotton.

2004

Plain Cotton

- Develop a CAD embroidery design.
- Stitch the design out onto pre-treated Cotton fabric for reactive ink jet printing.
- Steam iron flat using a commercial steam iron (with a protected layer on top) and tack onto a pre-rolled backing cloth.
- Ink jet print with reactive dyes (raise print head height to approx 6-7mm).
- Remove from the backing cloth.
- Remove the stitching to reveal the resist pattern.
- Post-treat to standard guidelines for reactive dyes on Cotton.

2004



Plain Cotton

Digital Embroidery Resist

- Ink jet print the underlay design onto pre-treated fabric with reactive dyes.
- Develop a CAD embroidery design.
- Stitch the design out onto underlay print.
- Steam iron flat using a commercial steam iron (with a protected layer on top) and tack onto a pre-rolled backing cloth.
- Ink jet print with reactive dyes (raise print head height to approx 6-7mm).
- Remove from the backing cloth.
- Remove the stitching to reveal the resist pattern.
- Post-treat to standard guidelines for reactive dyes on Cotton.

2005

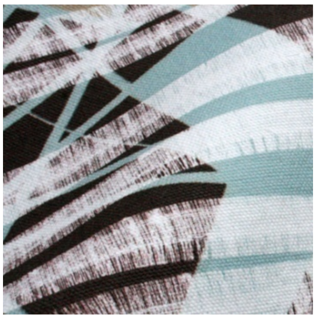
Linen

Rayon Thread

Ink Jet Printed CAD Embroidery

- Develop a CAD embroidery design.
- Stitch the design out onto an untreated fabric.
- Steam iron flat using a commercial steam iron (with a protected layer on top) and tack onto a pre-rolled backing cloth.
- Ink jet print with pigment inks (raise print head height to approx 6-7mm).
- Heat fix for 5mins at 150°.

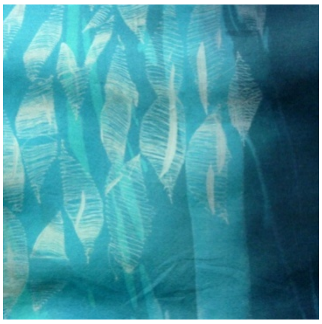
2006



Recycled Cotton

Digital Resist

- Tack down the additional fabric overlay to act as a resist.
- Ink jet print the overlay design with pigment inks (raise print head height to approx 6-7mm).
- Remove the fabric overlays to reveal the resist pattern.
- Heat fix for 5mins at 150°.

2007  Silk Habotai

Digital Embroidery Resist

- Ink jet print the underlay design onto pre-treated fabric with reactive dyes.
- Develop a CAD embroidery design.
- Stitch the design out onto underlay print.
- Steam iron flat using a commercial steam iron (with a protected layer on top) and tack onto a pre-rolled backing cloth.
- Ink jet print with reactive dyes(raise print head height to approx 6-7mm).
- Remove from the backing cloth.
- Remove the stitching to reveal the resist pattern.
- Post-treat to standard guidelines for reactive dyes on Silk.

To control the design outcome, change the type and placement of the digital designs and embroidery techniques.

2007  Silk Habotai

Digital Embroidery Resist

- Ink jet print the underlay design onto pre-treated fabric with reactive dyes.
- Develop a CAD embroidery design.
- Stitch the design out onto underlay print.
- Steam iron flat using a commercial steam iron (with a protected layer on top) and tack onto a pre-rolled backing cloth.
- Ink jet print with reactive dyes (raise print head height to approx 6-7mm).
- Remove from the backing cloth.
- Remove the stitching to reveal the resist pattern.
- Post-treat to standard guidelines for reactive dyes on Silk.

To control the design outcome, change the type and placement of the digital designs and embroidery techniques.

6.5 Digital Resists using Pre-manipulated Fabrics with Ink Jet Technology

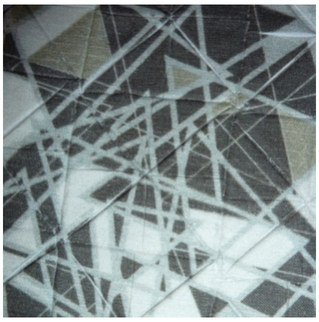
2005

Plain Cotton

Ink Jet Printed Patchwork

- Create the patchwork design by hand.
- Steam iron flat using a commercial steam iron and tack down the patchwork fabric onto a pre-rolled backing cloth.
- Ink jet print the patchwork design with pigment inks (raise print head height to approx 8-10mm).
- Remove from the backing cloth.
- Heat fix for 5mins at 150°.

2005



Plain Cotton

Ink Jet Printed Patchwork

- Create the patchwork design by hand.
- Steam iron flat using a commercial steam iron and tack down the patchwork fabric onto a pre-rolled backing cloth.
- Ink jet print the patchwork design with pigment inks (raise print head height to approx 8-10mm).
- Remove from the backing cloth.
- Heat fix for 5mins at 150°.

2005

Plain Cotton

Ink Jet Printed Patchwork

- Create the patchwork design by hand.
- Steam iron flat using a commercial steam iron and tack down the patchwork fabric onto a pre-rolled backing cloth.
- Ink jet print the patchwork design with pigment inks (raise print head height to approx 8-10mm).
- Remove from the backing cloth.
- Heat fix for 5mins at 150°.

2005

Plain Cotton

Ink Jet Printed Pleated Cotton

- Pleat the fabric using a domestic embroidery machine.
- Steam iron flat using a commercial steam iron and tack down the fabric onto a pre-rolled backing cloth.
- Ink jet print the pleated fabric with pigment inks (raise print head height to approx 7-8mm).
- Remove from the backing cloth.
- Heat fix for 5mins at 150°.

2005

Linen

Ink Jet Printed Pleated Linen

- Pleat the fabric using a domestic embroidery machine.
- Steam iron flat using a commercial steam iron and tack down the fabric onto a pre-rolled backing cloth.
- Ink jet print the pleated fabric with pigment inks (raise print head height to approx 8-9mm).
- Remove from the backing cloth.
- Heat fix for 5mins at 150°.

2005

Linen

Ink Jet Printed Pleated Linen

- Pleat the fabric using a domestic embroidery machine.
- Steam iron flat using a commercial steam iron and tack down the fabric onto a pre-rolled backing cloth.
- Ink jet print the pleated fabric with pigment inks (raise print head height to approx 8-9mm).
- Remove from the backing cloth.
- Remove the stitching to reveal the resist pattern.
- Heat fix for 5mins at 150°.

2008		Silk Habotai	Digital Resist – Pre-manipulated Fabric • Ink jet print an underlay design onto pre-treated fabric with reactive dyes. • Pleat the fabric using a domestic embroidery machine. • Steam iron flat using a commercial steam iron (with a protected layer on top) and tack onto a pre-rolled backing cloth. • Ink jet print the pleated fabric with reactive dyes (raise print head height to approx 6-8mm). • Remove from the backing cloth. • Remove the stitching to reveal the resist pattern. • Post-treat to standard guidelines for reactive dyes on Silk. To control the design outcome, change the type and placement of the digital designs and pleating techniques.
2008		Silk Habotai	Digital Resist – Embroidered/Pre-manipulated Fabric • Ink jet print an underlay design onto pre-treated fabric with reactive dyes. • Crush the fabric using a commercial steam iron (with a protected layer on top). • Develop a CAD embroidery design. • Stitch the design out onto the crushed underlay print. • Steam iron flat using a commercial steam iron (with a protected layer on top) and tack onto a pre-rolled backing cloth. • Ink jet print the pleated fabric with reactive dyes (raise print head height to approx 6-8mm). • Remove from the backing cloth. • Remove the stitching to reveal the resist pattern. • Post-treat to standard guidelines for reactive dyes on Silk. To control the design outcome, change the type and placement of the digital designs and pleating/embroidery techniques.

2008

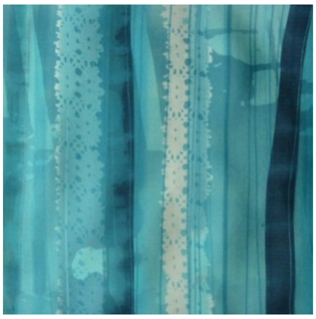
Silk Habotai

Digital Resist – Embroidered/Pre-manipulated Fabric

- Ink jet print an underlay design onto pre-treated fabric with reactive dyes.
- Crush the fabric using a commercial steam iron (with a protected layer on top).
- Develop a CAD embroidery design.
- Stitch the design out onto the crushed underlay print.
- Steam iron flat using a commercial steam iron (with a protected layer on top) and tack onto a pre-rolled backing cloth.
- Ink jet print the pleated fabric with reactive dyes (raise print head height to approx 6-8mm).
- Remove from the backing cloth.
- Remove the stitching to reveal the resist pattern.
- Post-treat to standard guidelines for reactive dyes on Silk.

To control the design outcome, change the type and placement of the digital designs and pleating/embroidery techniques.

2008

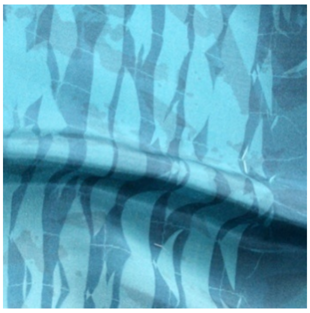


Silk Habotai

Digital Resist – Lace/Pre-manipulated Fabric

- Ink jet print an underlay design onto pre-treated fabric with reactive dyes.
- Pleat the fabric using a domestic embroidery machine and tack down the lace by hand.
- Steam iron flat using a commercial steam iron (with a protected layer on top) and tack onto a pre-rolled backing cloth.
- Ink jet print the pleated fabric with reactive dyes (raise print head height to approx 6-8mm).
- Remove from the backing cloth.
- Remove the stitching to reveal the resist pattern.
- Post-treat to standard guidelines for reactive dyes on Silk

To control the design outcome, change the type and placement of the digital designs, lace used and pleating techniques.

2008		Silk Habotai	Digital Resist – Pre-manipulated Fabric • Ink jet print an underlay design onto pre-treated fabric with reactive dyes. • Pleat the fabric using a domestic embroidery machine. • Steam iron flat using a commercial steam iron (with a protected layer on top) and tack onto a pre-rolled backing cloth. • Ink jet print the pleated fabric with reactive dyes (raise print head height to approx 8-10mm). • Remove from the backing cloth. • Remove the stitching to reveal the resist pattern. • Post-treat to standard guidelines for reactive dyes on Silk. To control the design outcome, change the type and placement of the digital designs and pleating techniques.
2008		Silk Habotai	Digital Resist – Pre-manipulated Fabric • Ink jet print an underlay design onto pre-treated fabric with reactive dyes. • Pleat the fabric using a domestic embroidery machine. • Steam iron flat using a commercial steam iron (with a protected layer on top) and tack onto a pre-rolled backing cloth. • Ink jet print the pleated fabric with reactive dyes (raise print head height to approx 8-10mm). • Remove from the backing cloth. • Remove the stitching to reveal the resist pattern. • Post-treat to standard guidelines for reactive dyes on Silk. To control the design outcome, change the type and placement of the digital designs and pleating techniques.

2008

Silk Habotai

Digital Resist – Pre-manipulated Fabric

- Ink jet print an underlay design onto pre-treated fabric with reactive dyes.
- Pleat the fabric using a domestic embroidery machine.
- Steam iron flat using a commercial steam iron (with a protected layer on top) and tack onto a pre-rolled backing cloth.
- Ink jet print the pleated fabric with reactive dyes (raise print head height to approx 8-10mm).
- Remove from the backing cloth.
- Remove the stitching to reveal the resist pattern.
- Post-treat to standard guidelines for reactive dyes on Silk.

To control the design outcome, change the type and placement of the digital designs and pleating techniques.

2008

Silk Habotai

Digital Resist – Pre-manipulated Fabric

- Ink jet print an underlay design onto pre-treated fabric with reactive dyes.
- Pleat the fabric using a domestic embroidery machine.
- Steam iron flat using a commercial steam iron (with a protected layer on top) and tack onto a pre-rolled backing cloth.
- Ink jet print the pleated fabric with reactive dyes (raise print head height to approx 8-10mm).
- Remove from the backing cloth.
- Remove the stitching to reveal the resist pattern.
- Post-treat to standard guidelines for reactive dyes on Silk.

To control the design outcome, change the type and placement of the digital designs and pleating techniques.

2008		Silk Habotai	Digital Resist – Pre-manipulated Fabric • Ink jet print an underlay design onto pre-treated fabric with reactive dyes. • Pleat the fabric using a domestic embroidery machine. • Steam iron flat using a commercial steam iron (with a protected layer on top) and tack onto a pre-rolled backing cloth. • Ink jet print the pleated fabric with reactive dyes (raise print head height to approx 8-10mm). • Remove from the backing cloth. • Remove the stitching to reveal the resist pattern. • Repeat stage 1-6 again in selected areas. • Post-treat to standard guidelines for reactive dyes on Silk. To control the design outcome, change the type and placement of the digital designs and pleating techniques.
2008		Silk Habotai	Digital Resist – Pre-manipulated Fabric • Ink jet print an underlay design onto pre-treated fabric with reactive dyes. • Pleat the fabric using a domestic embroidery machine. • Steam iron flat using a commercial steam iron (with a protected layer on top) and tack onto a pre-rolled backing cloth. • Ink jet print the pleated fabric with reactive dyes (raise print head height to approx 8-10mm). • Remove from the backing cloth. • Remove the stitching to reveal the resist pattern. • Post-treat to standard guidelines for reactive dyes on Silk. To control the design outcome, change the type and placement of the digital designs and pleating techniques.

2009

Silk Habotai

Digital Resist – Pre-manipulated Fabric

- Ink jet print an underlay design onto pre-treated fabric with reactive dyes.
- Pleat the fabric using a domestic embroidery machine.
- Steam iron flat using a commercial steam iron (with a protected layer on top) and tack onto a pre-rolled backing cloth.
- Ink jet print the pleated fabric with reactive dyes (raise print head height to approx 8-10mm).
- Remove from the backing cloth.
- Remove the stitching to reveal the resist pattern.
- Post-treat to standard guidelines for reactive dyes on Silk.

To control the design outcome, change the type and placement of the digital designs and pleating techniques.

2009

Silk Habotai

Digital Resist – Pre-manipulated Fabric

- Ink jet print an underlay design onto pre-treated fabric with reactive dyes.
- Pleat the fabric using a domestic embroidery machine.
- Steam iron flat using a commercial steam iron (with a protected layer on top) and tack onto a pre-rolled backing cloth.
- Ink jet print the pleated fabric with reactive dyes (raise print head height to approx 8-10mm).
- Remove from the backing cloth.
- Remove the stitching to reveal the resist pattern.
- Post-treat to standard guidelines for reactive dyes on Silk.

To control the design outcome, change the type and placement of the digital designs and pleating techniques.

2009

Silk Habotai

Digital Resist – Pre-manipulated Fabric

- Ink jet print an underlay design onto pre-treated fabric with reactive dyes.
- Pleat the fabric using a domestic embroidery machine.
- Steam iron flat using a commercial steam iron (with a protected layer on top) and tack onto a pre-rolled backing cloth.
- Ink jet print the pleated fabric with reactive dyes (raise print head height to approx 8-10mm).
- Remove from the backing cloth.
- Remove the stitching to reveal the resist pattern.
- Post-treat to standard guidelines for reactive dyes on Silk.

To control the design outcome, change the type and placement of the digital designs and pleating techniques.

2009

Silk Habotai

Digital Resist – Pre-manipulated Fabric

- Ink jet print an underlay design onto pre-treated fabric with reactive dyes.
- Pleat the fabric using a domestic embroidery machine.
- Steam iron flat using a commercial steam iron (with a protected layer on top) and tack onto a pre-rolled backing cloth.
- Ink jet print the pleated fabric with reactive dyes (raise print head height to approx 8-10mm).
- Remove from the backing cloth.
- Remove the stitching to reveal the resist pattern.
- Post-treat to standard guidelines for reactive dyes on Silk.

To control the design outcome, change the type and placement of the digital designs and pleating techniques.

6.6 Digitally Simulated Hand Craft Techniques using Ink Jet Technology

2005

Silk Crepe de Chine

Simulated Craft

- Develop a hand crafted textile patchwork design.
- Scan this into Photoshop at minimum 200dpi.
- Bring this scan into the textile specialist software.
- Place the design in repeat to develop a new true colour design.
- Colour reduce the repeated design using tones.
- Colour match to a colour library the first and last tones.
- Ink jet print this colour matched file onto pre-treated Silk Crepe de Chine with reactive dyes.
- Post-treat to standard guidelines for reactive dyes on Silk.

2005

Cotton Jersey

Simulated Craft

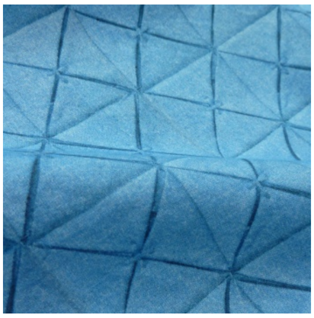
- Develop a hand crafted textile patchwork design.
- Scan this into Photoshop at minimum 200dpi.
- Bring this scan into the textile specialist software.
- Place the design in repeat to develop a new true colour design.
- Colour reduce the repeated design using tones.
- Colour match to a colour library the first and last tones.
- Ink jet print this colour matched file onto pre-treated Cotton Jersey with reactive dyes.
- Post-treat to standard guidelines for reactive dyes on Cotton.

2005

Plain Cotton

Simulated Craft– Colour-way

- Develop a hand crafted textile patchwork design.
- Scan this into Photoshop at minimum 200dpi.
- Bring this scan into the textile specialist software.
- Place the design in repeat to develop a new true colour design.
- Re-colour to produce a new colour-way.
- Colour reduce the repeated design using tones.
- Colour match to a colour library the first and last tones.
- Ink jet print this colour matched file onto pre-treated Plain Cotton with reactive dyes.
- Post-treat to standard guidelines for reactive dyes on Cotton.

2005		Plain Cotton	Simulated Craft • Develop a hand crafted textile patchwork design. • Scan this into Photoshop at minimum 200dpi. • Bring this scan into the textile specialist software. • Place the design in repeat to develop a new true colour design. • Colour reduce the repeated design using tones. • Colour match to a colour library the first and last tones. • Ink jet print this colour matched file onto pre-treated Plain Cotton with reactive dyes. • Post-treat to standard guidelines for reactive dyes on Cotton.
2005		Silk Crepe de Chine	Simulated Craft– Colour-way • Develop a hand crafted textile patchwork design. • Scan this into Photoshop at minimum 200dpi. • Bring this scan into the textile specialist software. • Place the design in repeat to develop a new true colour design. • Re-colour to produce a new colour-way. • Colour reduce the repeated design using tones. • Colour match to a colour library the first and last tones. • Ink jet print this colour matched file onto pre-treated Silk Crepe de Chine with reactive dyes. • Post-treat to standard guidelines for reactive dyes on Silk.
2005		Cotton Satin	Simulated Craft • Develop a hand crafted textile embroidered design. • Scan this into Photoshop at minimum 200dpi. • Bring this scan into the textile specialist software. • Extract an area of the embroidered design and paste this onto and plain coloured background. • Colour reduce the repeated design using tones. • Colour match to a colour library the first and last tones. • Ink jet print this colour matched file onto pre-treated Cotton Satin with reactive dyes. Post-treat to standard guidelines for reactive dyes on Cotton.

2005

Cotton Satin

Simulated Craft

- Develop a hand crafted textile embroidered design.
- Scan this into Photoshop at minimum 200dpi.
- Bring this scan into the textile specialist software.
- Extract an area of the embroidered design and paste this onto and plain coloured background.
- Place the design in repeat to develop a new true colour design.
- Re-colour to produce a new colour-way.
- Colour reduce the repeated design using tones.
- Colour match to a colour library the first and last tones.
- Ink jet print this colour matched file onto pre-treated Cotton Satin with reactive dyes.

Post-treat to standard guidelines for reactive dyes on Cotton.

2005

Plain Cotton

Simulated Craft

- Develop a hand crafted textile pleated design.
- Scan this into Photoshop at minimum 200dpi.
- Bring this scan into the textile specialist software.
- Place the design in repeat to develop a new true colour design.
- Colour reduce the repeated design using tones.
- Colour match to a colour library the first and last tones.
- Ink jet print this colour matched file onto pre-treated Plain Cotton with reactive dyes.
- Post-treat to standard guidelines for reactive dyes on Cotton.

2005

Cotton Jersey

Simulated Craft– Colour-way

- Develop a hand crafted textile pleated design.
- Scan this into Photoshop at minimum 200dpi.
- Bring this scan into the textile specialist software.
- Place the design in repeat to develop a new true colour design.
- Re-colour to produce a new colour-way.
- Colour reduce the repeated design using tones.
- Colour match to a colour library the first and last tones.
- Ink jet print this colour matched file onto pre-treated Cotton Jersey with reactive dyes.
- Post-treat to standard guidelines for reactive dyes on Cotton.

2005  Silk Crepe de Chine

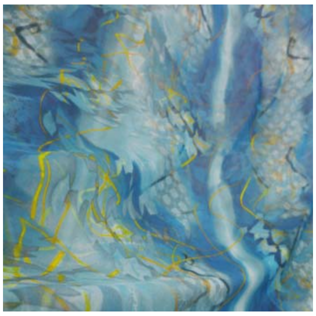
Simulated Craft

- Develop a crafted textile embroidered design.
- Scan this into Photoshop at minimum 200dpi.
- Bring this scan into the textile specialist software.
- Place the design in repeat to develop a new true colour design.
- Colour reduce the repeated design using tones.
- Colour match to a colour library the first and last tones.
- Ink jet print this colour matched file onto pre-treated Silk Crepe de Chine with reactive dyes.
- Post-treat to standard guidelines for reactive dyes on Silk.

2010  Silk Twill

Simulated Craft

- Develop a range of crafted designs as shown in previous elements in the catalogue.
- Scan these into Photoshop at minimum 200dpi.
- Bring these scans into the textile specialist software.
- Select areas using the mask tools and save these into a clipboard.
- Develop a new true colour design from a range of scanned crafted elements.
- Place the design in repeat.
- Colour reduce the repeated design using tones.
- Colour match to a colour library the first and last tones.
- Ink jet print this colour matched file onto pre-treated Silk Twill with reactive dyes.
- Post-treat to standard guidelines for reactive dyes on Silk.

2010  Silk Chiffon

Simulated Craft

- From the clipboard of selected crafted design elements develop a new design.
- Place the design in repeat.
- Colour reduce the repeated design using tones.
- Colour match to a colour library the first and last tones.
- Ink jet print this colour matched file onto pre-treated Silk Chiffon with reactive dyes.
- Post-treat to standard guidelines for reactive dyes on Silk.

References

Bailey, M., Sunley, C. (1994) 'Index to Textile Auxiliaries', *International Dyer*, 14. Bradford: World Textile Publications Ltd, p.120

Cahill, V. (2006) 'The Evolution and Progression of Digital Printing of Textiles', in Ujiie, H. (ed.)*Digital Printing of Textiles,* Cambridge: Woodhead Publishers, pp.1-15

Dawson, TL. (2003) 'Ink Jet Printing of Textiles – An Overview of its Development and the Principles Behind Ink Drop Formation and Deposition' in Dawson, TL., Glover, B. (ed.) *Ink jet Printing on Textiles, SDC Textile Ink Jet Printing - Technical Monograph*, Bradford: Society of Dyers and Colourists, pp. 1-12

Eriken, TM. (2000) *Memory on Cloth: Shibori Now*. London: Kodansha International. p.54

Fenton, H., Romano, F. (1998a) 'Binary Continuous', *On Demand Printing -The Revolution in Digital and Customized Printing*, pp.149-150

Fernades, LC. (2009) *Digital Textile Design*. London: Laurence King Publishing Ltd p.147

Gregory, P. (2003) 'Ink jet Printing on Textiles' in Dawson, TL, Glover, B. (ed.) *Ink jet Printing on Textiles, SDC Textile Ink Jet Printing - Technical Monograph*, pp.69-97

Grimshaw, J. (2010) 'Market Developments in Low and High-Volume Digital Printing', *Digital Textile*, 1, p.24

Gunner, J. (2006) *Shibori for Textile Artists*. London: Batsford.

Hees, U., Freche, M., Provost, J., Kluge, M., Weiser, J. (2003) 'Ink-textile Interactions in Ink Jet Printing – The Role of Pre-treatments', in Dawson, TL. and Glover, B. (ed.) *Ink jet Printing on Textiles, SDC Textile Ink Jet Printing - Technical Monograph*, pp 44-56

http://www.askoxford.com/concise_oed/craft?view=uk (no date) (Accessed: November 2009)

http://www.just-style.com/article.aspx?id=97071 (2007) 'Digital textile Printing on Growth Trajectory' (Accessed: 17 July 2009)

http://www.ukinvest.gov.uk/Business-&-Consumer-Services/100404/en-GB.html (2010) 'UK Creative Industries Opportunities' (Accessed 6 May 2010)

Hue, PL. and Le Technologies Inc. (1998) 'Progress and Trends in Ink-jet Printing Technology', *Journal of Imaging Science and Technology - Society for Imaging and Science and Technology*.42 (2) [Online]. Available at: http://www.imaging.org/ist/resources/tutorials/inkjet.cfm (Accessed: 2002)

Jones, S. (2010) Conversation with Simon Jones from Dawsons®, 5 August.

Kobayashi, H. (2006a) 'Mimaki TX2-1600 Textile Path', in Ujiie, H. (ed.)*Digital Printing of Textiles,* Cambridge: Woodhead Publishers, pp.107-115

Lawrence, G. (2002) *Digital Printing and Traditional Surface Design Techniques.* MSc Thesis. North Carolina State University [Online]. Available at: http://www.worldcat.org/title/digital-printing-and-traditional-surface-design-techniques/oclc/51088843?title=&detail=&page=frame&linktype=digitalObject&url=http%3A%2F%2Fwww.lib.ncsu.edu%2Ftheses%2Favailable%2Fetd-11042002-171805%2Funrestricted%2Fetd.pdf%26checksum%3D5dd1c0edf4bf97ad533ed431e21487f2 (Accessed 15 June 2009)

Loser, E., Tobler, HP. (2006) 'ICC Color Management for Digital Ink Jet Textile Printing', in Ujiie, H. (ed.) *Digital Printing of Textiles,* Cambridge: Woodhead Publishers, pp. 180-198

Mighall, M. (2009) Conversation with Magnus Mighall from RA Smarts®, 8 July.

Mighall, M. (2010) Email Magnus Mighall from RA Smarts®, 9 March.

Miles, L. (1994) *Textile Printing – 2nd Edition*. Bradford: Society of Dyers and Colorists.

Mimaki. (2009) 'Work Flow Comparisons for Conventional and Digital Printing' (no date) Available at: http://www.mimaki.co.jp/english/tx/system/ (Accessed 10 August 2009)

Mulla, R. (2009) Conversation with Raf Mulla, Applications Manager from X-rite® 3 July.

Raymond, M. (2006a) 'Industrial Production Printers – DuPont Artistri™ 2020 Textile Printing System', in Ujiie, H. (ed.)*Digital Printing of Textiles,* Cambridge: Woodhead Publishers, pp. 69-83

Ripley, S. (2004)*An investigation into chemical resist style printing and its use in the development of print designs.* Unpublished PhD Thesis. University of Huddersfield, p.4.

Storey, J. (1978) *The Thames and Hudson Manual of Dyes and Fabrics*. London: Thames and Hudson Ltd.

Tait, N. (2008) 'Digital Printing in Action in Asia', *International Dyer*, Great Britain; World Textile Publications Ltd, 193 (5), pp. 22–24

Textile Asia (2009) 'Dyes for Ink Jet Printing of Textiles', *Textile Asia*; Vol.40, p. 29

Thornton, A. (1994) *International Dyer's Index to Textile Auxiliaries*. 14th edn. West Yorkshire: World Textile Publications Ltd, p.120.

Wells, K. (1997) *Fabric Dying and Printing*. London: Conran Octopus Limited, p.125

Willoughby, A. (2008) *Textiles Now*. London: Laurence King Publishing Ltd. p.206

X-rite ® (2004) *The Color Guide and Glossary,* pp.15-34

Quotations

http://www.just-style.com/article.aspx?id=97071 (2007) 'Digital textile Printing on Growth Trajectory' (Accessed: 17 July 2009)

http://www.askoxford.com/concise_oed/embellish?view=uk (no date) (Accessed: November 2009)

Bibliography

Brito, K. (2002) *Shibori, Creating Color and Texture on Silk*. Great Britain: Watson-Guptill Publications.

Borman, K., Dehghani, A., Dennis, K., Jahanshah, F., Wang, J. (2004) *International Journal of Clothing Science and Technology*, 16 (1/2),Bingley: Emerald Group Publishing Limited.

Bowles, M., Isaac, C. (2009) *Digital Textile Design*. London: Laurence King Publishing Ltd.

Burton, R. (2005) 'Creativity, Method and Process in Digital Fabric Printing: a 21st Century Paintbrush', *Digital Creativity*,16 (4),Oxon: Routledge, and Taylor and Francis Group.

Carter, R. (2002) *Digital Color and Type*. Switzerland: RotoVision SA.

Chrisment, A. (2006) *Color and Colormetry - Fourth Edition*. Datacolor. Paris: Edition 3C.

Colchester, C. (2007) *Textiles Today, a Global Survey of Trends and Traditions*. London: Thames and Hudson Ltd.

Cole, D. (2008) *Textiles Now*. London: Laurence King Publishing Ltd.

Dawson, TL.,Glover, B. (2003) *Ink jet Printing on Textiles, SDC Textile Ink Jet Printing - Technical Monograph*, Bradford: Society of Dyers and Colourists.

Earley, R. (2007) *Ever and Again: Experimental Recycled Textiles.* TED (Textiles Environment Design) Exhibition held at The Triangle Gallery, Chelsea College of Art & Design, London October 2007 [Exhibition Catalogue].

Eriken, TM. (2000) 'Itajime Shibori on Wool', *Memory on Cloth: Shibori Now*. London: Kodansha International.

Fenton, HM., Romano, FJ. (1998) *On-Demand Printing - Second Edition*. Upper Saddle River: Graphic Arts Technical Foundation.

Goddard, N. (1992) *The creation and development of printed designs on cotton fabrics incorporating 'bleeder style' and related techniques.* Unpublished M.Phil Thesis. University of Huddersfield.

Grimshaw, J. (2010) ‘Market Developments in Low and High-Volume Digital Printing’, *Digital Textile*, 1.

Gunner, J. (2006) *Shibori for Textile Artists*. London: Batsford.

Hodge, Brooke (2006) Skin and Bones: Parallel Practices in Fashion and Architecture . London: Thames and Hudson Ltd.

Kendal, T. (2001) *The Fabric and Yarn Dyer’s Handbook*. London: Collins and Brown Limited.

McCarty, C.,McQuai, M. (1998) *Structure and Surface, Contemporary Japanese Textiles*. New York: The Museum of Modern Art.

McNamara, A.,Snelling, P. (1995) *Design and Practice for Printed Textiles*. Oxford: Oxford University Press.

Mestha, LK. (2009) *Control of Color Imaging Systems*. London: CRC Press, and Taylor and Francis Group.

Miles, L. (1994) *Textile Printing – 2nd Edition*. Bradford: Society of Dyers and Colorists.

Quinn, B. (2009) *Textile Designers at the Cutting Edge*. London: Laurence King Publishing Ltd.

Ripley, S. (2004)*An investigation into chemical resist style printing and its use in the development of print designs.* Unpublished PhDThesis. University of Huddersfield.

Storey, J. (1978) *The Thames and Hudson Manual of Dyes and Fabrics*. London: Thames and Hudson Ltd.

Thornton, A. (1994) *International Dyer’s Index to Textile Auxiliaries*. 14th edn. West Yorkshire: World Textile Publications Ltd.

Treadaway, C. (2004) *Journal of Textile and Apparel, Technology and Management*.4 (1), North Carolina State University.

Ujiie, H. (2006) *Digital Printing of Textiles*.Cambridge: Woodhead Publishing Limited.

Wada, YI. (2002) *Memory on Cloth, Shibori Now*.London: Kodansha International Ltd.

Wells, K. (1997) *Fabric Dying and Printing*. London: Conran Octopus Limited.

Xin, JH. (2006) *Total Colour Management in Textiles*. Cambridge: Woodhead Publishing.

X-rite(2007) *A Guide to Understanding Color Communication*. X-rite.

X-rite (no date) *Cook Book, Soft-Proofing Settings, Adobe Software*. X-rite.

X-rite(2004) *The Color Guide and Glossary*. X-rite.

Websites

www.just-style.com

www.inkdropprinting.com

www.internationaldyer.com

www.melaniebowles.co.uk

www.mimaki.co.jp/english

www.sdc.org.uk

www.techexchange.com

www.tedresearch.net

Section 5

Appendix

Appendix I

Research publications and conference outputs from the research

2002 Paper presentation and publication: ''The Use of Wide Format Ink Jet Printers for Textile Print Sampling'
World Textile Conference, 2nd Autex Conference, Bruges, Belgium, 1-3 July 2002

2003 Paper presentation and publication: 'The Use of Embellishment Techniques with Ink Jet Printed Repeated Designs'
INTEDEC 2003: International Textile Design and Engineering Conference, Edinburgh/Galashiels, UK, 22-24 September 2003

2005 Paper presentation and publication: 'The Commercial Realisation of Complex Textile Craft Techniques by CAD and Ink Jet Printing'
ARCHTEX, Krakow, Poland, September 2005

2006 Paper published: Craftily Using Ink Jet' Textiles Journal, Vol.33 No.2, 2006, pg 20-22.

The Use of Wide Format Ink Jet Printers for Textile Sampling

World Textile Conference, 2nd AutexConference, Bruges, Belgium, 1-3 July 2002

The Use of Wide Format Ink Jet Printers for Textile Print Sampling

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ABSTRACT

This paper is based on research work for an M.Phil and on three years experience of using digital printing on textile substrates in the University.

The paper will start by discussing the current uses of digital ink jet printers on textile fabrics. It will cover the practical problems associated with such systems for creative textile design and will highlight the limitations and advantages of using an ink jet printer in a design environment.

In doing so, the paper will cover the following areas:

1. *Sourcing of fabric and dyes has been investigated and their pre-treatment.*

2. The importance of print procedures will be discussed to obtain the most consistent results, highlighted by the need for control.

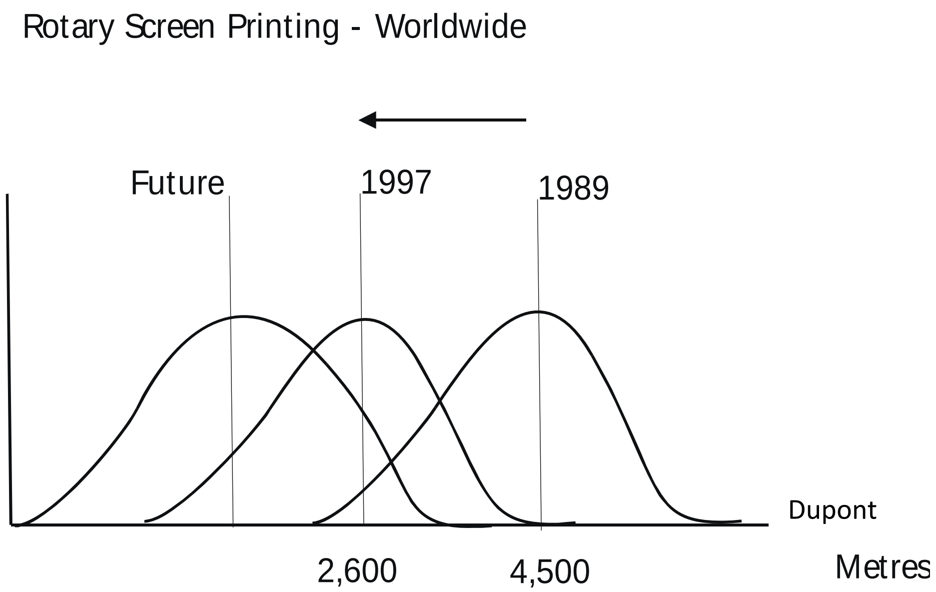
3. *Methods of improving colour reproducibility will be described, in the first instance by using colour libraries but also by the use of colour management systems.*

4. *The conclusion will relate to the present and future influence of digital printing of* textiles on the creative textile designer.

INTRODUCTION

The first and most widely used ink jet printer in the textile industry was used for carpet and upholstery printing. The 'Millitron' ink jet printer used continuous technology with course drop sizes with a maximum resolution of about 20 dots per inch, this enabled large quantities of dye to be printed for heavyweight fabrics. It used eight spot colours and could print up to 20 square yards per minute. *(1)*

The textile industry today is driven by time, having to meet the demands of the customer and the resulting short lead times. The industry needs to be flexible to change, as the customer may want to make style alterations and have shorter run print productions (fig 1). Ink jet printing for textiles is moving the scope of what's possible to manufacture: it can produce photographic imagery and is flexible to changes. Printing can be stopped instantly, alterations made to the design on screen, or alter a design completely in response to customer needs and set off again to print. Ink jet printing is currently restricted from the use in bulk production due to: the speed of printing being too slow, the restricted range of inks and the need for specially prepared fabrics. Ink jet is being used for some small production printing but this is still under development.



Average Print Run Length
Fig 1 *(2)*

Digital printing for textiles has also given the textile designer greater flexibility in the designs that can be produced. With the ability now to design digitally there is an opportunity for ink jet printing directly onto fabric. Also with the movement of much of the bulk textile printing industry to the Far East, in order for print companies to survive there is a need to examine printing techniques and the functioning of the printing processes. There is the need for more original designs and shorter fashion cycles in response to retail demands and seasonal trends. Ink jet printing can cover these needs. *(3)*

'A screen must be made for each colour in a design. Making these screens is costly and time consuming. In fact, more than half of the total production time is spent on engraving and sampling. The printer takes a risk every time he engraves screens, as only 40-60% of any new patterns generate enough production orders to cover the costs incurred. With shorter run lengths, machinery downtime is also extended due to frequent change over of designs. Incoming production orders will then cover less and less of these sampling costs. One solution to minimising the costs associated with sampling is to remove the screens from the sampling stage altogether. This has been, to some extent, achievable in recent years by the implementation of digital printing processes.' ('A Universal Approach to Ink Jet Printing Textile Fabrics', S Ervine, B Siegel, and K Siemensmeyer. BASF. Textile Chemist and Colorist and American Dyestuff Reporter. Oct 2000. Vol.32, No.10)

Conventional screen manufacture can often take between 6 to 16 weeks and cost up to
22,000 € with all manpower and materials included for a 3-yd printed sample. *(4)*

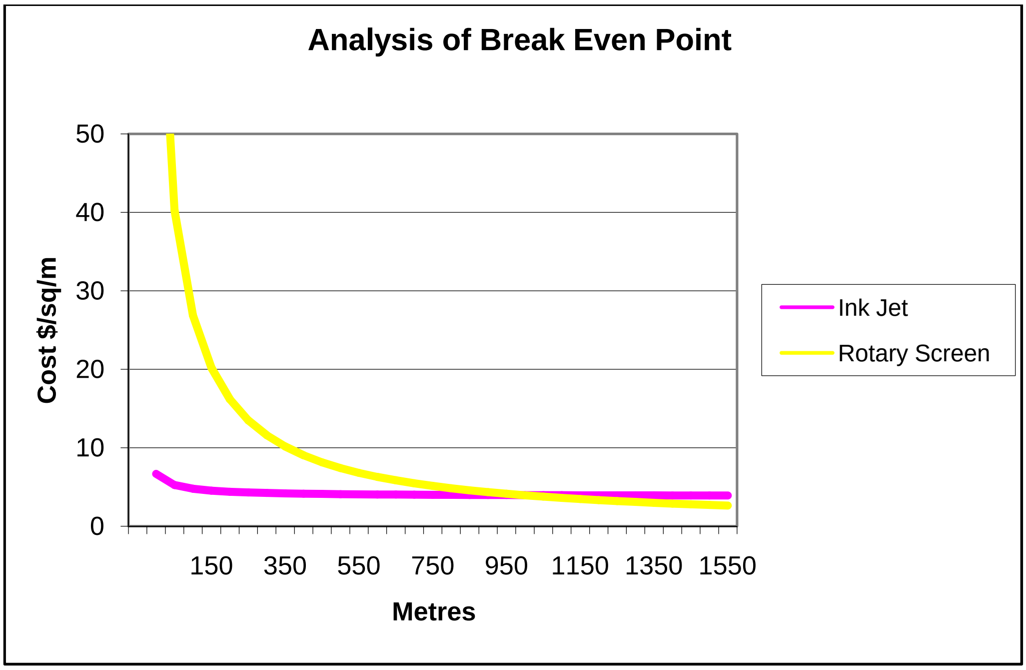


Fig 2 *(5)*

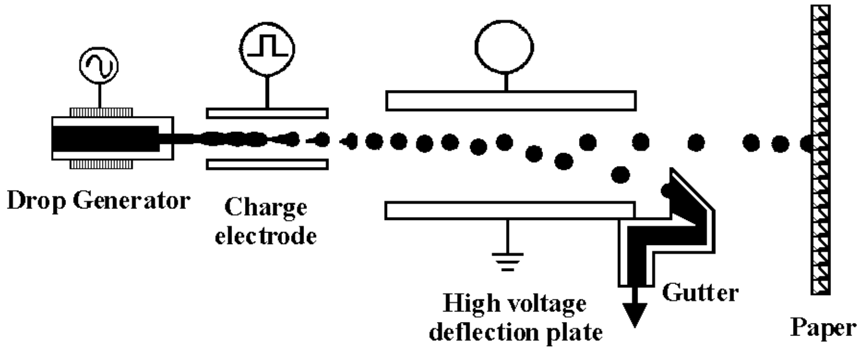
Ink jet printing is ideal for sampling; it can save time and money, as no colour separations need to be done or screens engraved (fig 2). It can also reduce wastage, as there is no excess fabric or dye used. Ink jet technology prints where needed and on demand.

INK JET TECHNOLOGY

There are two systems of ink jet printing: **Continuous** and **Drop on Demand**.
The continuous method uses a constant stream of ink, which is printed onto a rotating drum with substrate on it, the excess drops of ink pass through the fabric or get pumped into a reservoir and reused.

There are two types of continuous printing: **Binary Continuous** and **Multilevel Continuous ink jet** (fig 3 and 4).
Both methods are known for their fast speeds and their reliability. Both have advantages. The multilevel ink jet method has a limitation to the number of inks available, as the ink must have low viscosity, but it has faster printing speeds as it can print over a large area with one print pass. This method uses charged drops for printing and is able to control several different dot positions per nozzle. The uncharged drops are re-circulated into the reservoir. On the other hand, the Binary ink jet method is not limited to the number of dyes available and is able to use a wide range of dye chemistries for a variety of substrates. This method uses the uncharged drops for printing and the charged drops are pumped back through to the reservoir. There is only one dot location printed per nozzle. *(6)*

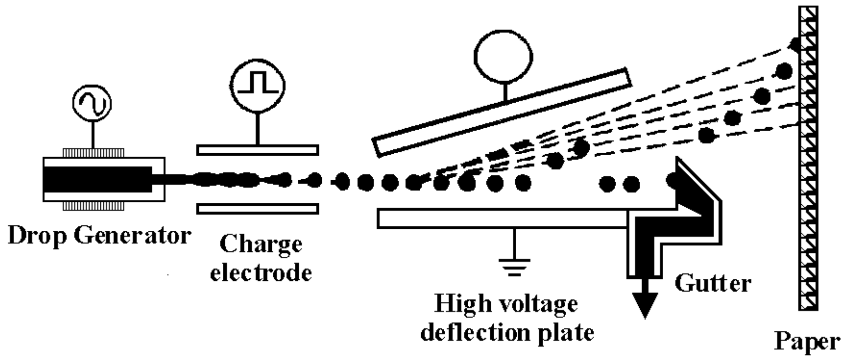
Binary Continuous



Continuous ink-jet: A binary-deflection system

Fig. 3 *(7)*

Multilevel Continuous



Continuous ink-jet: Amultiple-deflection system

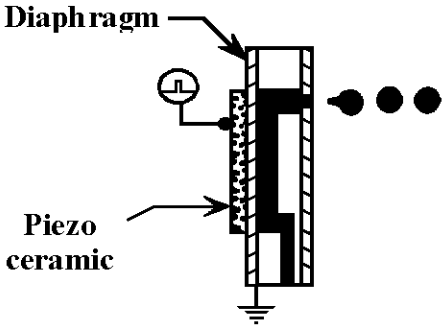
Fig. 4 *(8)*

Continuous systems have longer print head lives than other ink jet print methods. These printers are generally more expensive, but have higher reliability and are cost effective when producing larger print volumes.

Although continuous ink jet printing is still being developed, the relatively new Drop on Demand printing (D.O.D) is becoming popular (Dupont 3210).

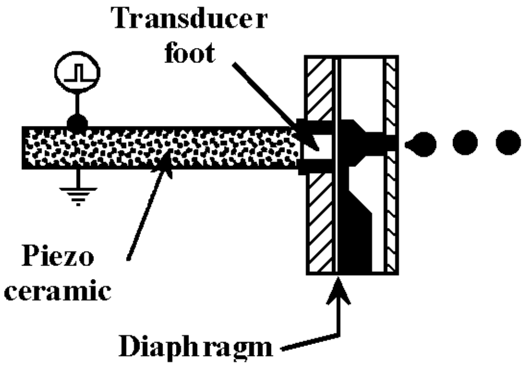
Piezoelectric ink jet (fig 5 and 6) printing was invented in 1972. This method of printing works by sending an electric current to piezo crystal at the back of the ink reservoir. The crystal then flexes which creates a drop of ink, which is squirted out of the nozzle and onto the medium. *(9)*

The advantages of the piezo ink jet are that there is more freedom of ink drop size and shape, which can produce higher resolutions prints; it is also quicker than the thermal method as the ink does not need to be cooled and reheated after each rotation. There are a wider variety of inks and dyes available for piezoelectric printing since it can cope with higher viscosities. The advantage claimed by thermal ink jet is reliability. At present the piezo technology would appear to be the favoured approach for textile applications.



A bend-mode piezoelectric ink-jet design.

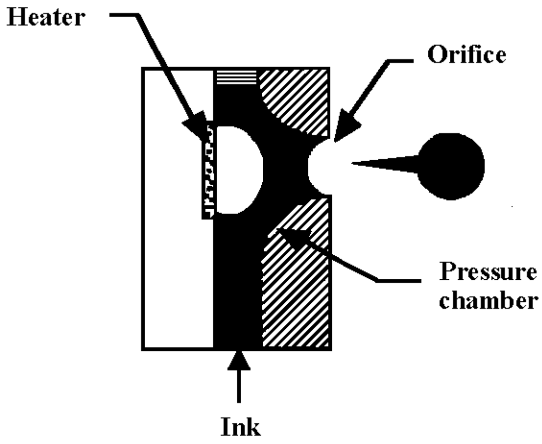
Fig. 5 *(10)*



A push-mode piezoelectric ink-jet design.

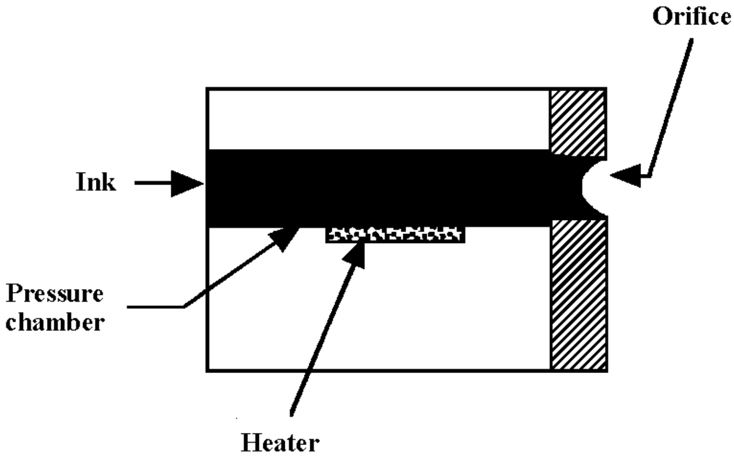
Fig.6 *(11)*

Thermal ink jet (Fig 7 and 8) printing was developed in 1979 by Canon. *(12)* The dye inside the print head is heated up which creates a pressure and forms a bubble. The build up of pressure pushes the bubble out of the nozzle. The bubble is ejected and bursts onto the substrate as the heating element starts to cool, causing a vacuum, which draws more ink from the reservoir to repeat the rotation. *(13)*



A roof-shooter thermal ink-jet.

Fig.7 *(14)*



A side-shooter thermal ink-jet.

Fig. 8 *(15)*

Ink jet printing produces an image by jetting dots of coloured ink onto a medium. With some ink jet printers having only 4 colours: cyan, magenta, yellow and black (C.M.Y.K), the colour gamut is more limited (fig 9) when compared to conventional printing. The process used to produce the colour spectrum using a small number of colours is called 'Dithering'. Although this process increases the amount of achievable colours, it can also decrease the image clarity producing uneven dotty colours. *(16)* Since pale colours are a problem to achieve, later printers also used half strength inks so a range of 7 or 8 ink headed printers have become available. Certain colours are still lie outside the printers gamut, so on some printers there is an option of replacing the Magenta with say an Orange. Increasing the number of dye colours in the ink jet printers will increase the number of achievable colours i.e. stretching to larger colour gamut from CMYK to Pantone.

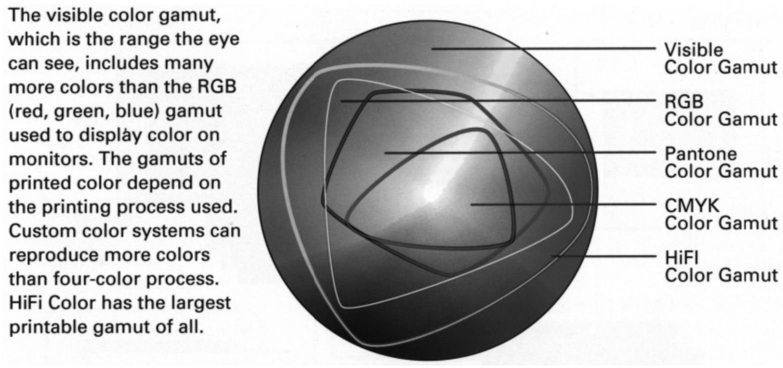


Fig.9 *(17)*

The resolution of the ink heads is also important. The early machines used a resolution of 300dpi whereas the later versions go to 600dpi or above. Greater the resolution slower the print speed, so there is often a judgement to be made on speed or quality if mark.

DYES

For ink jet printing onto fabric, special dyes/inks have to be used. Also most fabrics used have to be pre-treated. Certain dyes are formulated for the different types of print heads used i.e. thermal and piezo. Also some printers require paper backing on the fabric to soak up any excess dye, other printers tend to have a trough where the surplus dye can be held. Both of these methods stop the dye from smudging over the rest of the fabric.

There are currently four different dye and ink types available for use in ink jet printing: **Reactive**, **Acid**, **Disperse** and **Pigment**. They each are used for specific textile requirements and they enable a wide variety of fabrics to be used.

1 ***Reactive Dyes:*** used on Cotton and Viscose; they can also be used on Wool and Silk. The dye reacts with the cellulose to form strong vibrant colours. For the chemical reaction to occur an alkali has to be applied as a pre-treatment and a post-treatment of heat was needed for fixation. This method does not tamper with the reactive dye or the print head if put in the dyestuff itself. If the alkali were put into the dyestuff, the reaction would take place before printing, producing very poor colours. A washing process is then required to remove any excess dye. *(18)*

2 ***Acid dyes:*** used on silk and wool, and polyamide fibres. They produce high quality results and cover only a small part of the textile market, but it is still an important area for ink jet printing. The fabrics do need to be pre-treated to enable sharpness of print without bleeding. Steam fixation is needed and also a washing off process to loose any unfixed dye. *(19)*

3 ***Disperse Dyes:*** used on Polyester. These dyes can be printed onto transfer paper and, using a heat press, transferred onto fabric, or printed directly onto a pre-treated fabric. Again steam fixation and a wash off process are required, if printed directly onto the fabric. *(20)*

4 ***Pigment Inks:*** used on most fibres. These inks are currently used in about 50% of the conventional textile printing industry today. No pre-treatment is required to the fabric, and only a short heat post-treatment, for fixation of the inks. The main limitation of using pigment inks is that a binder is required. The binder allows for the fixation of the inks to produce satisfactory colourfastness. In ink jet printing the binder can be applied directly into the inks before printing, or it needs to be applied as part of the post-treatment to the fabric. Which application method used depends on the ink jet print heads being used. *(21)*

Reactive dyes at present give excellent colour outcomes, with plenty of vibrancy. They are also the dyes that are most readily available for ink jet printing and in particular for thermal print heads.

Pigment inks for thermal ink jet printing have a separate binder, which is applied after printing. This is because the method by which thermal technology works does not allow the binder to go through the print head, whereas piezo print heads can have the binder included in the ink. *(22)* The use of pigment inks will save time, because no pre-treatment is needed to the fabrics. This also saves money and only needs a short heat post-treatment fixation. It is also more environmentally friendly because no washing off is needed or chemical padding in the pre-treatment of the fabric. Pigment inks are more flexible in the fabrics that can be used due to their being no pre-treatment; there is no limitation to where the fabrics can be supplied, although some pre-treatment will be need to enable the fabric to feed through the printer straight and steadily.

FABRICS

There are wide ranges of fabrics available with pre-treatment for ink jet printing. The pre-treatment depends on the dye used and the end use of fabric.

Table 1 *Dyes and Fabric*

Dye/Ink Type	Dye Colours Available	Fabric Availability
Reactive Dyes	Cyan, Magenta, Yellow *(greenish yellow),* Black, Navy, Red, Orange, Golden Yellow. ½ strength colours: Cyan, Magenta, and Black.	**Cottons:** Cotton Satin, Cotton Poplin, Cotton Twill, Cotton Drill, Cotton Jersey, Cotton Sheeting, Cotton Voile, Canvas **Cotton Mixtures -** 50% Cotton, 50% Linen **Silks -** Silk Crepe de Chine, Silk Twill, Silk Satin, Silk Habotai, Silk Georgette, Silk Organza **Silk Mixtures –** Silk Viscose Velvet *(Devoré Fabric)* Silk Viscose Satin *(Devoré Fabric)* **Viscose Georgette, Wool, Calico**
Acid Dyes	Cyan, Magenta, Yellow, Black, Orange, Green, Blue, Red and Grey.	**Cottons –** ***Cotton Satin, Cotton Poplin, Cotton Voile, Cotton Sheeting*** **Silks –** Silk Chiffon, Silk Georgette, Silk Crepe de Chine, Silk Organza, Silk Twill, Silk Satin, Silk Habotai Wool Delaine
Disperse Dyes	Yellow, Reds, Blues, Turquoise, Black and Grey.	*For the use of transfer printing, no pre-treatment is required for the fabric, just the use of heat transfer paper.* *Pre treated fabric is needed for direct ink jet printing.*
Pigment Dyes	Yellow, Golden Yellow, Red, Blue, Black, Navy, Green and Orange.	No pre-treatment needed.

The fabrics when used with reactive dyes have generally been very successful, producing strong vibrant colours. Poorer results have been achieved from Cotton Poplins used from different suppliers. The colour results produced were lacking in vibrancy and some colour areas were proving hard to achieve, whereas the other fabrics tried e.g. Cotton Satin, gave high quality results in both colour and finish. Some fabrics fed through the printer with greater ease, these generally being ones with paper backing or heavier weight fabrics. Finer fabrics, without paper backing, had a greater tendency to slip and move unevenly through the printer. This is where the use of fabric feed roller is beneficial with printers that do not require fabrics with paper backing. Fabric prices vary with the supplier, although ones with paper backing are more expensive. The choice of fabrics available is increasing along with the number of suppliers, particularly in the U.K.

PRE TREATMENT

Most fabrics are pre treated, either by the manufacturer or by the user. The pre treatment recipe for each dye and fabric is available from the dyestuff manufacturer.

The fabric needs to be pre treated to allow maximum colour yield, clarity of image and quick drying time. Pre-treatment helps to control the size of the ink drops jetted onto the fabric, ensuring that minimum bleeding occurs. The chemical padding and (on some fabric types) paper backing stiffens the fabric enabling the fabric to run smoothly and evenly through the printer. The compatibility of the dyes and fabrics can vary, depending on the printer used.

The fabric range and pre-treatment will vary from each supplier, so it is always important to do trials on all products first. The compatibility can differ with the use of different dyes, fabric types and suppliers.

POST TREATMENT

Consistency with colour and print quality is essential with all textile printing and it is important to keep the consistency throughout the printing process. So when using ink jet technology for sample printing it is crucial for colour control and reproducibility from sampling through to bulk production. Ink jet printing can save time and money in the sampling stages of the designs, but for this there must be consistent strong colour and print results.

In this research only reactive dyes have been studied so far, but discussions with users of other dyes indicate that acid dyes have similar, if not worse, problems.

Steaming

Reactive dyes require a post-treatment of steaming or heat fixation and a washing process. In this research standard steam conditions have been investigated when using reactive dyes. Dry heat fixation processes such as baking have not yet been investigated in this research, but will be done so that colour comparisons can be made.
Steam conditions do appear to have a very strong effect on the ink jet printed outcome. If steam conditions change or do not reach standard settings of temperature and humidity, varying results may occur. In this research so far four steamers have been used, three star steamers (taking loads of about 10m) and one sample steamer (taking roughly A3 sized fabric samples). The sample steamer is pressurised and uses direct steam.
The star steamers used different steaming methods; using direct and indirect steam. ‘Direct steam’ is where steam is pumped straight inside the steamer, whereas ‘indirect steam’ is when steam is pumped through a coiled pipe at the base of steamer, which lies in water. Each method produced different results with colour strength. The steaming stage is critical for reproducibility of colour. Standard steam times can be achieved as a general for all fabrics, although this may vary for specifics.

Table 2 **Steam Temperatures**

	Temperature
Small Sample Steamer (Direct Steam)	All Steaming was done at 102°C
Star Steamer 1 (Indirect Steam)	No temperature measurements were able to be taken
Star Steamer 2 (Direct Steam)	After 3 minutes - 100°C 5 minutes - 106°C 8 minutes - 107°C 10 minutes - 107°C 14 minutes - 107°C
Star Steamer 3 (The option of both Direct and Indirect Steam)	After 3 minutes - 103°C 5 minutes - 103°C 8 minutes - 104°C 10 minutes - 105°C 14 minutes - 105°C

The recommended steam temperature from Encad is 102°C for all fabrics and the steam time varies a little: Cotton and Viscose for 8 – 15 minutes and Silks for 15 – 30 minutes. *(23)* This research started by looking at steam conditions under which reactive dyes, for ink jet printing, gave best colours and image results. All steam trials were printed on Cotton (non-optic) and once a wide gamut of colours was achievable, various other fabric trials were carried out. Tests were produced experimenting with steam times, to see what colour outcomes and differences came from steaming the fabrics at various times.

It is possible to measure the strength of colour using a colour spectrometer to get accurate data on colour outcome. Using ΔE, ΔL, ΔC, ΔH (Light, Chroma, and Hue angle) colour spaces provides an understanding of the varying colour changes that occur after different steaming times. Table 3 shows a comparison of 5 and 15 minutes steaming, with the standard 10 minutes steam time. There is a discernible difference visually in time of steaming.

Table 3 Colour Comparisons

Colour	Steam Time (Star Steamer 3 – Direct Steam)				
	5 Minutes		10 Minutes	15 Minutes	
	ΔE			**ΔE**	
Blue	**1.359**	Lighter, greener, less blue.	Standard	**1.147**	Darker, less green, bluer
Red	**2.607**	Lighter, less red, yellow.	Standard	**0.380**	Redder, less yellow
Green	**1.054**	Lighter, greener yellow.	Standard	**1.191**	Darker, less green, less yellow
Yellow	**0.895**	Darker, greener yellow.	Standard	**0.563**	Darker, less yellow.

The table shows the colours are lighter with shorter steam times and darker with longer steam times. The yellow is the exception, as the colour is slightly darker with a shorter steam time than the standard. With the longer steam time it behaved in a similar way to the other colours. The largest difference at 5 minutes was the red, however in comparison it had the smallest difference after the standard 10 minutes.

The Washing Off

The washing of the fabrics occurs after steaming and it enables any excess dye to be removed that had not fixed in the steaming process and removes any auxiliary chemicals used in the pre-treatment of the fabric. It is again a very important factor for reproducible image and colour results. If the washing process was done incorrectly, image clarity may be affected and problems such as back staining or the fading of colours may occur. The general recommendations for the washing off of reactive dyes are 2 cold washes, 1-2 hot washes and cold water rinse.

COLOUR MANAGEMENT

'Not only must you select from a broad range of ink jet printers covering a spectrum of ink types, performance characteristics, and price tags, you must choose from a dizzying array of media as well. Compatibility with equipment and inks, ability of the printer RIP to adjust to new ink/media combinations, suitability of the media for the particular applications, image durability, and warranties are just a few of the issues you face in making your media selections.' ('Inkjet Media, Shopping with eyes opened'. T. Frecska, Screen-printing Magazine. www.screenweb.com)

Ink jet printing was developed from wide-bodied paper printers designed for posters and banners. These have long established methods of obtaining full colour reproduction from the secondary colours of CMYK, known as process colours. Textiles have used a spot colour method where by the actual colour in the form of dyes is used.

CMYK is a 4-color printing process using 3 subtractive colour primaries with black, cyan, magenta, and yellow. The colour limitations of CMYK lie in the difficulty to reproduce bright reds, greens, and blues, as well as many of the colours required by the textile industry. The CMYK process is improved by including extra colours that cannot be reproduced by dithering or mixing cyan, magenta, and yellow.

The strongest complaints about digitally printed fabric from the textile industry are the visible dither of colours and limited colour gamuts compared to traditional textile screen-printing. With the introduction of 7, 8, and even 12-colour digital printers into the market, these systems come closer to achieving the results desired by the textile industry. As a general rule, the greater the number of colours (not print heads) that are in a printer, the larger the number of colours that can be reproduced. For example, a 12-colour printer with 10 individual colours and 2 light shades will provide a much larger colour gamut than a 12-colour printer using CMYK with light shades. It is important, however, to have a balance of colourants to light shades to eliminate visible dither. (Refer to Figure 9)

In paper printing, the method of obtaining good colour reproducibility is to colour profile the monitor, scanner and printer to the independent lab system. This can be integrated into the graphic software or into the printer driver or the more sophisticated printer RIP. For paper printing the use of this profile or calibration (ICC profile) this is straightforward and has been used for some time.
In the case of printing using textile inks such as reactive, acid, or disperse, the full potential of these colour spaces are not realised until the colours have reacted with the fabric, which occurs during post-processing such as steaming and washing. Furthermore, there is the problem of substrate; fabric printing has to encompass ecru wool and Cotton, bleached Cotton and Silk.

Digital textile printing colour management software must answer three key questions. First, what is the colour gamut (range of printable colours) of the system, taking into account the printer, inks and fabric used. Are the desired colours inside the digital printer's colour gamut? And finally, how can the system produce all of the colours that are within the colour gamut?

It is important to understand which colours are attainable within the limits of specific printers and ink sets. If a printer is incapable of producing a desired colour, no amount of colour management can make it possible. In addition, there are some colours that can be displayed on an RGB monitor, but are not printable using a CMYK device, and *vice versa* (CMYK representing the Cyan, Magenta, Yellow and Black inks used in process colour printing).

Various software packages offer different levels of profiling capabilities, from supporting standard ICC profiles created in third-party profiling software, to vendor supplied profiles, to end user capability to create custom profiles using proprietary colour systems.
Software Solutions

Textile specific software is available to manipulate images, which usually include flat and continuous tone designs; ability of colour separation and a powerful repeat function. In addition, later versions include colour management.

On the other hand, software RIP for digital printing of textiles from a graphic package should be able to accept textile industry file formats from CAD design and screen separation programs and accept common graphic file formats.

- Print Layout functions such as step & repeat, design co-ordinates and colourways, colour chips, multi-image placement, scaling, rotating, spooling or batching.

- The RIP for both inputs should be able to manage expanded ink sets beyond CMYK, depending upon the printer. Ink control functions manage higher ink densities required for colour saturation of fabric.

- Handle colour catalogues, colour palettes, and/or Pantone Textile Colour System.
  Profiling supplied by vendor or custom profiling capability.

- Colour gamut visualisation and comparison to see if target colour is attainable. Screen Print Simulation features if digital output needs to match to production.

- Capability to link colour data to the textile mill's colour kitchen.

Digitally printed fabric is often seen as too good to be reproduced by traditional screen-printing techniques. It is helpful to have screen simulation features to bridge the gap between digital and screen-printed fabrics. Several software vendors have incorporated features useful in simulating and matching to screen printed production fabric, such as simulating screen resolution, raster simulation, or screen mesh size; colour mixing, colour overprinting, and colour trapping; incorporating gradation curves for tonal separations; and even profiling the textile printing mill's colour space.

However, since with digital printing there is no need to colour separate and as the commercial graphic packages become more flexible, there will be a move towards packages such as PhotoShop and CorelDraw and a reliance on the software RIP to do much of the textile work.

There are many commercial textile RIPs available, which use ICC Colour Profiles and have the option of recalibrating the profile. Claims are made for their accuracy but in the author's opinion, there is more work required to prove this.

Most users print out a colour library. Using the specific fabric, the dyes and selecting the necessary profile, the full gamut of colours are printed out, and are post treated by the accepted method. This library is then used to correct the colours on the design colours on screen.

CONCLUSION

Wide format ink jet printing for textiles will have major effects on the modern textile designer. Ink jet printing reduces the time and costs involved with sampling, meaning more printed samples can be produced for the customer allowing a wider choice in designs and colours to be achieved. From a creative perspective, ink jet printing can give more freedom when designing, allowing more colours per design and also highly detailed, photographic imagery to be used. This area of design was previously very limited when screen-printing.

Although ink jet printing has its own limitations when compared to rotary screen-printing for production purposes, constant developments are being made in fabric pre-treatment, dyestuffs and ink jet technology. New developments in this area are under trial whereby 3 metre widths can be printed at speeds of 30-100 linear metres per hour, dependant upon the quality of print needed. (Dupont 3210 Ink Jet printer, Dorma 2002). This printer is now suitable for small print productions, for which ink jet printing was previously unsuitable.

It is critical that all print procedures involved with ink jet printing are followed strictly in the running of the printer (environment/conditions) including the pre and post treatments of the fabrics, ensuring that all times and temperatures used are accurate. This is important to enable consistent print quality and colour reproducibility. Tests prior to printing, such as alignment of print heads, priming of colours and colour standard trials can help to ensure reproducible outcomes. The use of colour libraries and colour management systems will also contribute to achieving the consistent results needed.

REFERENCES

(1) Hu Q, Li X, Tincher W C: Ink Jet Systems for Printing Fabric. Textile Chemist and Colorist. Vol.30. No.5. (May 1998) pp. 24-27. The American Association of Textile Chemists and Colorists.

(2) Dupont: Dupont Presentation 2001

(3) Ervine S, Siemensmeyer K, Siegel B: A Simple, Universal Approach to Ink Jet Textile Fabrics. Textile Chemist and Colorist and American Dyestuff Reporter. Vol.32. No.10. (Oct 2000) pp. 26-27.

(4) Cook F L: Textile Printing Enters the Technological Revolution. Textile World. (1995). www.industryclick.com

(5) Cederholm H: MSc Dissertation. University of Huddersfield. (2001).

(6) Cahill V: Introduction to Digital Printing Technology. www.textileindustries.com

(7) Le Technologies, Inc., Beaverton, Oregon: Progress and Trends in Ink-jet Printing Technology. Journal of Imaging Science and Technology. Vol.42. No.1. (Jan/Feb 1998) Part 2. Society for Imaging and Science and Technology.

(8) Le Technologies, Inc., Beaverton, Oregon: Progress and Trends in Ink-jet Printing Technology. Journal of Imaging Science and Technology. Vol.42. No.1. (Jan/Feb 1998) Part 2. Society for Imaging and Science and Technology.

(9) PC Tech: The PC Technology Guide – Inkjet Printers. Input – Output/Inkjet Printers. (June 2001) pp.1-8.www.pctechguide.com

(10) Le Technologies, Inc., Beaverton, Oregon: Progress and Trends in Ink-jet Printing Technology. Journal of Imaging Science and Technology. Vol.42. No.1. (Jan/Feb 1998) Part 2.Society for Imaging and Science and Technology.

(11) Le Technologies, Inc., Beaverton, Oregon: Progress and Trends in Ink-jet Printing Technology. Journal of Imaging Science and Technology. Vol.42. No.1. (Jan/Feb 1998) Part 2.Society for Imaging and Science and Technology.

(12) Le Technologies, Inc., Beaverton, Oregon: Progress and Trends in Ink-jet Printing Technology. Journal of Imaging Science and Technology. Vol.42. No.1. (Jan/Feb 1998) Part 2.Society for Imaging and Science and Technology.

(13) PC Tech: The PC Technology Guide – Inkjet Printers. Input – Output/Inkjet Printers. (June 2001) pp.1-8.www.pctechguide.com

(14) Le Technologies, Inc., Beaverton, Oregon: Progress and Trends in Ink-jet Printing Technology. Journal of Imaging Science and Technology. Vol.42. No.1. (Jan/Feb 1998) Part 2.Society for Imaging and Science and Technology.

(15) Le Technologies, Inc., Beaverton, Oregon: Progress and Trends in Ink-jet Printing Technology. Journal of Imaging Science and Technology. Vol.42. No.1. (Jan/Feb 1998) Part 2.Society for Imaging and Science and Technology.

(16) Work RA, Kane JP: Developments in Jet Inks for Textile Printing. www.techexchange.com

(17) AGFA: A Guide to Color Separation. Digital Pre-press. (1995) pp.9

(18) Ervine S, Siemensmeyer K, Siegel B: A Simple, Universal Approach to Ink Jet Textile Fabrics. Textile Chemist and Colorist and American Dyestuff Reporter. Vol.32. No.10. (Oct 2000) pp. 26-27.
BASF: Reactive Inks. Technical Data for Reactive Dye Inks for Ink Jet Printing. BASF Colorants. (Oct 2000)

(19) Ervine S, Siemensmeyer K, Siegel B: A Simple, Universal Approach to Ink Jet Textile Fabrics. Textile Chemist and Colorist and American Dyestuff Reporter. Vol.32. No.10. (Oct 2000) pp. 26-27.

(20) Ervine S, Siemensmeyer K, Siegel B: A Simple, Universal Approach to Ink Jet Textile Fabrics. Textile Chemist and Colorist and American Dyestuff Reporter. Vol.32. No.10. (Oct 2000) pp. 26-27.

BASF: Bafixan Inks, Technical Data for Disperse dye Inks for Ink Jet Printing. BASF Colorant. (May 2000)

(21) Ervine S, Siemensmeyer K, Siegel B: A Simple, Universal Approach to Ink Jet Textile

Fabrics. Textile Chemist and Colorist and American Dyestuff Reporter. Vol.32. No.10. (Oct 2000) pp. 26-27.

BASF: Helizarin Inks. Technical Data for Pigments Inks For Ink Jet Printing on Textile. BASF Colorants. (Dec 2000)

(22) BASF: Helizarin Inks. Technical Data for Pigments Inks For Ink Jet Printing on Textile. BASF Colorants. (Dec 2000)

(23) ENCAD: Encad Digital Textile System, Technical Data. Pre and Post-Processing for ENCAD REACTA Inks. Version.1.

The Use of Embellishment Techniques with Ink Jet Printed Repeated Designs

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THE USE OF EMBELLISHMENT TECHNIQUES WITH INK JET PRINTED REPEATED DESIGNS

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ABSTRACT

This paper will discuss the use of devoré printing as an additional design feature to ink jet printed fabrics. Ink jet printed fabrics are an ideal basis for bespoke fabrics to be generated in small-scale productions. To begin with this paper will discuss the production of ink jet printed fabrics in repeat using textile CAD software. The original design will include all embellishments as part of the original repeat; as an overlay.

Before the application of a devoré effect, the ink jet printed fabric will need to be finished conventionally, then the shrinkage which occurs can be taken into consideration and the overlay modified in repeat.

To conclude the paper will discuss the extension of this process into other possible methods of embellishment such as overprinting and resist techniques, which can be used with ink jet printing onto textiles. These techniques will display alternative methods for producing high quality customised fabrics.

1. INTRODUCTION TO INK JET PRINTING

The textile industry today is driven by time, having to meet the constant demands of the customer for new products and the resulting short lead times. The industry needs to be flexible to change, as the customer may want to make style alterations and have shorter print run productions (figure 1). Ink jet printing for textiles is moving the scope of what's possible to manufacture: it can produce photographic imagery and is flexible to changes. Printing can be stopped instantly; alterations made to the design on screen, or alter a design completely in response to customer needs and set off again to print. Ink jet printing is currently restricted from the use in bulk production due to: the speed of printing being too slow, the restricted range of inks. Ink jet is being used for some small production printing but this is still under development.

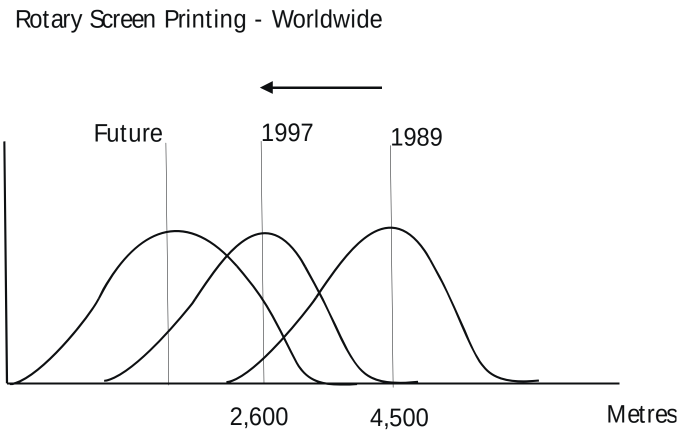

Figure 1: Average Print Run Length (Dupont, 2001)

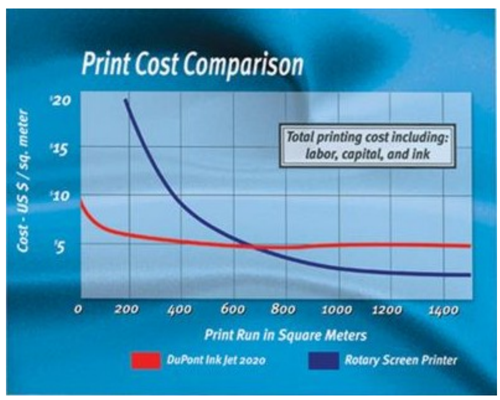

Figure 2 (Dupont, 2003)

Digital printing for textiles has also given the textile designer greater flexibility in the designs that can be produced. With the movement of much of the bulk textile printing industry to the Far East, in order for print companies to survive there is a need to examine printing techniques and the function of the printing processes. There is the need for more original designs and shorter fashion cycles in response to retail demands and seasonal trends. Ink jet printing can cover these needs. (Ervine S, Seimensmeyer K, Seigel B, 2000))

Ink jet printing is ideal for sampling; it can save time and money, as no colour separations need to be done or screens engraved. It can also reduce wastage, as there is no excess fabric or dye used. Ink jet technology prints where needed and on demand. Within 2 years the break even point has been considerably reduced from 1000m to less than 700m (Figure 2).

1.1. INK JET TECHNOLOGY

There are two systems of ink jet printing: **Continuous** and **Drop on Demand**.

The continuous method uses a constant stream of ink, which is printed onto a rotating drum with substrate on it; the excess drops of ink pass through the fabric or get pumped into a reservoir and reused. The DOD methods works by squirting tiny drops of ink through the print head nozzles.

There are two types of continuous printing: **Binary Continuous** and **Multilevel Continuous ink jet.** Both methods are known for their high speeds and their reliability. Both have advantages. The multilevel ink jet method has a limitation to the number of inks available, as the ink must have low viscosity, but it has faster printing speeds as it can print over a large area with one print pass. On the other hand, the binary ink jet method is not limited to the number of dyes available and is able to use a wide range of dye chemistries for a variety of substrates. (Cahill V)

Continuous systems have longer print head lives than other ink jet print methods. These printers are generally more expensive, but have higher reliability and are cost effective when producing larger print volumes.

Although continuous ink jet printing is still being developed, the relatively new Drop on Demand printing (D.O.D) is becoming popular. There are two methods of D.O.D technology; Piezo and Thermal.

Piezoelectric ink jet printing was invented in 1972. This method of D.O.D printing works by sending an electric current to piezo crystal at the back of the ink reservoir. The crystal then flexes which creates a drop of ink, which is squirted out of the nozzle and onto the medium. (PC Tech, 2001)

The advantages of the piezo ink jet are that there is more freedom of ink drop size and shape, which can produce higher resolutions prints; it is also quicker than the thermal method as the ink does not need to be cooled and reheated after each rotation. There is a wider variety of inks and dyes available for piezoelectric printing since it can cope with higher viscosities. At present the piezo technology would appear to be the favoured approach for textile applications.

Thermal ink jet printing was developed in 1979 by Canon. (Le Technologies Inc, 1998) The dye inside the print head is heated which creates a pressure and forms a bubble. The build up of pressure pushes the bubble out of the nozzle. The bubble is ejected and bursts onto the substrate as the heating element starts to cool, causing a vacuum, which draws more ink from the reservoir. (PC Tech, 2001)

Ink jet printing produces an image by jetting dots of coloured ink onto a medium. With some ink jet printers having only 4 colours: cyan, magenta, yellow and black (C.M.Y.K), the colour gamut is more limited when compared to conventional printing. The process used to produce the colour spectrum using a small number of colours is called ‘dithering’. Although this process increases the number of achievable colours, it can also decrease the image clarity producing uneven ‘dotty’ colours. (Work RA) Since pale colours were a problem to achieve, printers now have the option to run with half strength inks. Available now on the market there is the option of a 16 headed printer allowing either faster printing times by doubling up the colours, or running to interchangeable dye types through the printer; for example 8 with reactive dyes and 8 holding pigment inks. Certain colours still lie outside the printer’s gamut, so on some printers there is an option of replacing the magenta with say an orange. Increasing the number of dye colours in the ink jet printers will increase the number of achievable colours i.e. stretching to larger colour gamut from CMYK to Pantone.

The resolution of the ink heads is also important. The early machines used a resolution of 300dpi whereas the later versions go to 720dpi or above. The greater the resolution, the slower the print speed, so there is often a judgement to be made on speed or quality of mark.

1.2. DYES

For ink jet printing onto fabric, special dyes/inks have to be used. Also most fabrics used have to be pre-treated in order to accept the dyes. Certain dyes are formulated for the different types of print heads used i.e. thermal and piezo. Also some printers require paper backing on the fabric to soak up any excess dye while other printers tend to have a trough where the surplus dye can be held. Both of these methods stop the dye from smudging over the rest of the fabric.

There are currently four different dye and ink types available for use in ink jet printing: **Reactive**, **Acid**, **Disperse** and **Pigment**. They are each used for specific textile requirements and they enable a wide variety of fabrics to be used.

Reactive Dyes: used on Cotton and Viscose; they can also be used on wool and silk. In the steamer, the dye reacts with the cellulose to form strong vibrant colours. For the chemical reaction to occur an alkali has to be applied as a pre-treatment to the fabric and a post-treatment of heat is needed for fixation. A washing process is then required to remove any excess dye. (Ervine S, Seimensmeyer K, Seigel B, 2000, BASF 2000)

Acid dyes: used on silk and wool, and polyamide fibres. They produce high quality results and cover only a small part of the textile market, but it is still an important area for ink jet printing. The fabrics do need to be pre-treated to enable sharpness of print without bleeding. Steam fixation is needed and also a washing off process to remove any unfixed dye. (Ervine S, Seimensmeyer K, Seigel B, 2000)

Disperse Dyes: used on Polyester. These dyes can be printed onto transfer paper and using a heat press, transferred onto fabric, or printed directly onto a pre-treated fabric. Again steam fixation and a wash off process are required, if printed directly onto the fabric. (Ervine S, Seimensmeyer K, Seigel B, 2000, BASF, 2000*)*

Pigment Inks: used on most fibres. These inks are currently used in about 50% of the conventional textile printing industry. No pre-treatment is required to the fabric, and only a short heat post-treatment is needed, for fixation of the inks. The main limitation of using pigment inks is that a binder is required. (Ervine S, Seimensmeyer K, Seigel B, 2000, BASF)

The modern 16-head printers have the option to be run in a variety of ways; either using a large number of dye colours enabling a wider colour gamut, to run 2 print heads of each colour allowing for faster printing speeds, or to separate the print heads for more than one dyestuff. These would be run separately and cut out any complications and time involved with changing the dyestuffs from one to another.

1.3. FABRICS

There are wide ranges of fabrics available with pre-treatment for ink jet printing. The pre-treatment depends on the dye used and the end use of the fabric. Providing that the right equipment is available or for a small charge per metre of fabric, it is now possible to have any fabric custom treated for ink jet printing. This enables the reactive dyes to fix to the fabric and to achieve maximum colour output as possible, and also widens the scope for producing customised fabrics.

The fabrics when used with reactive dyes generally have been very successful, producing strong vibrant colours. Poorer results have been achieved from Cotton Poplins used from different suppliers. The colour results produced were lacking in vibrancy and some colour areas were proving hard to achieve, whereas the other fabrics tried e.g. Satin, gave high quality results in both colour and finish.

Some fabrics fed through the printer with greater ease, generally heavier weight fabrics. Also the fabric must be well rolled in order for it to run through the printer evenly. Finer fabrics and those with a Satin finish have a greater tendency to slip and move unevenly through the printer. This is where the use of fabric feed roller is beneficial. The choice of fabrics ready pre-treated for the use with ink jet printing is increasing along with the number of suppliers, particularly in the U.K.

2. PRELIMINARY EXPERIMENTS

2.1. PRINT QUALITY AND COLOUR REPRODUCIBILTY

Consistency with colour and print quality is essential to all textile printing, and it is important to keep the consistency throughout the printing process. So when using ink jet technology for sample printing it is crucial for colour control and reproducibility to be maintained from sampling through to bulk production. Ink jet printing can save time and money in the sampling stages of the designs, but for this there must be consistent strong colour and print results.

From the experiments carried out to date in this research, it has been shown that all fabrics must be tested before use as the colour outcomes may vary with the use of different fabrics. There are several other aspects that must be taken into consideration for reproducible results and these can be controlled within the printing and processing stages; for instance the storage and post-treatment of the fabrics. This research has been studying post-treatment conditions required for ink jet printed fabrics.

2.2. PRE TREATMENT

Most fabrics are pre treated, either by the manufacturer or by the user. The pre treatment recipe for each dye and fabric is available from the dyestuff manufacturer. The fabric needs to be pre treated to allow maximum colour yield, clarity of image and quick drying time. Pre-treatment helps to control the size of the ink drops jetted onto the fabric, ensuring that minimum bleeding occurs. The chemical padding stiffens the fabric enabling the fabric to run smoothly and evenly through the printer. The compatibility of the dyes and fabrics can vary, depending on the printer used. Problems can arise when fabrics have not been treated correctly; when the fabrics are unevenly padded and that are finished with a bowing weft line.

2.3. POST TREATMENT

In this research only reactive dyes have been studied so far, but discussions with users of other dyes indicate that acid dyes have similar, if not worse, problems.

2.3.1. Steaming

Reactive dyes require a post-treatment of steaming or heat fixation and a washing process. In this research standard steam conditions have been investigated when using reactive dyes. Dry heat fixation processes such as baking have not yet been investigated in this research, but will be done so that colour comparisons can be made. Steam conditions do appear to have a very strong influence on the ink jet printed outcome. If steam conditions change or do not reach standard settings of temperature and humidity, varying results may occur. In this research so far four steamers have been used, three star steamers (taking loads of about 10m) and one sample steamer (taking roughly A3 sized fabric samples). The star steamers used different steaming methods, direct and indirect steam. The sample steamer is pressurised and uses direct steam.

The recommended steam temperature from Encad and many other manufacturers is 102°C for all fabrics and with variable steam time given: these can range from approximately 7 - 15 minutes for Cotton and Viscose to 15 – 30 minutes for silks. (BASF, 2000, ENCAD)This research started by looking at steam conditions under which reactive dyes, for ink jet printing, gave best colours and image results. All steam trials were printed on Cotton (non-optic) and once a wide gamut of colours was achievable, various other fabric trials were carried out. Tests were carried out using a range of steam times to see the effect of steam time on colour outcome. Shorter steam times produced weaker colours; steaming for 10 minutes produced the optimum colour results. This was consistent with all steamers.

2.3.2. Washing Off

The washing of the fabrics occurs after steaming and it enables any excess dye to be removed together with any auxiliary chemicals used in the pre-treatment of the fabric. It is again a very important factor for reproducible image and colour results. If the washing process was done incorrectly, image clarity may be affected and problems such as back staining or the fading of colours may occur. The general recommendations for the washing off of reactive dyes are 2 cold washes, 1-2 hot washes and a cold water rinse. The wash process now used in this research has reduced the work load and the quantity of machinery involved. An industrial washing machine is used whereby a wash has been set up for ink jet fabrics. It allows the specific temperatures for the various fabrics to be set as required.

3. THE USE OF COLOUR MANAGEMENT AND SOFTWARE WITH INK JET PRINTING

Ink jet printing was developed from wide-bodied paper printers designed for posters and banners. These have long established methods of obtaining full colour reproduction from the secondary colours of CMYK, known as process colours. Textiles have used a spot colour method whereby the actual colour in the form of dyes is used.

With the use of the various dyes there are some limitations to the printable colours that are obtainable. Also the full potential of these colour spaces is not visible until the fixation of the dyes, whereby the colours become a great deal brighter. (Gordon S, 2001)

Textile specific software is available to manipulate images, which usually include flat and continuous tone designs; ability of colour separation and a powerful repeat function. In addition, later versions include colour management.

On the other hand, RIP Software for digital printing of textiles from a graphic package should be able to accept textile industry file formats from CAD design and screen separation programs and accept common graphic file formats. The RIP for both inputs should be able to manage expanded ink sets beyond CMYK, depending upon the printer. Ink control functions manage higher ink densities required for colour saturation of fabric. However, since with digital printing there is no need to colour separate and as the commercial graphic packages become more flexible, there will be a move towards packages such as PhotoShop and CorelDraw and a reliance on the software RIP to do much of the textile work.

There are many commercial textile RIPs available, which use ICC Colour Profiles and have the option of recalibrating the profile. Claims are made for their accuracy but in the author's opinion, there is more work required to prove this.

4. EMBELLISHMENT TECHNIQUES

There are many techniques that can be used with printed fabrics to enhance the design and the fabric's quality and these have been well researched within the traditional printed textiles area. Many techniques can be used to develop the texture, colour and the nature of the fabric using overlays. These techniques can include the use of embroidery, lacquers, Expantex, foils, burnout effects such as devoré, discharge printing, and resist methods of printing and dyeing such as using wax and binding techniques.

Previous work has been produced developing effects, combining the use of ink jet technology with traditional surface techniques. This work has concentrated on developing the connection between the two areas and reintroducing craftsmanship to the textile industry. (Hill-Campbell J)

With the use of CAD and CAM within the textile industry, short run printing is continually being developed. Ink jet printing has enabled a reduction in costs and times required to expand this market area. Another advantage of using ink jet printing for short run print lengths is the possibility of generating high quality, innovative, bespoke fabrics at lower prices and at shorter production times. But again for this development in the textile market to occur, certain process and problems have to be overcome. Initially the ink jet printer will need to be set up, assigning the correct pre and post-treatments for the fabrics and the method of colour management to be used. The use of the correct design software is important and particularly the benefits that can be gained with the use of textile specific software as already discuss earlier in this paper.

This research has been concentrating on setting up a strict process to be followed for the creation of embellished ink jet printed fabrics. The designs used are generated in repeat at a traditional design size used in industry of 64cm or a division of this. Although a specific repeat size is unnecessary for the use of ink jet printing, this allows the option of later generating the design using traditional printing methods. Also repeated designs gives more scope to the amount of printed fabric by increasing and decreasing the number of repeats using the CAD software or the Textile RIP.

Again, although reducing the number of colours per design is unnecessary for ink jet printing, working in reduced colour enables the colours to be matched prior to printing, thus cutting out any colour trials that would usually need to be done. With the use of accurate colour reduction using the CAD software, excellent results can be achieved, still obtaining 3 dimensional and photographic qualities.

To be able to prepare all equipment and information ready for applying the embellishment technique to the ink jet printed fabric, the overlay is calculated as part of the original CAD design. From either, a single colour separation or a design motif in the original design, an overlay can be extracted. This can later be used for developing a screen or can be fed into the relevant software. For instance a single colour separation can be used to generate a screen ready for a print overlay or transferred into an embroidery package ready for production. For this to occur certain requirements must be applied, such as the separation must be cleaned making sure there are no stray pixels and that the edges are smooth. Lines may also be required to be of a certain thickness for a print or embroidered area to be noticeable or feasibly produced.

The fabric shrinkage will need to be taken into consideration to enable accurate registration between the printed fabrics and the embellishment overlay. This measurement will need to be taken after the printed fabric has been post-treated. A study has been done in this research to gain the shrinkage information on three fabrics at present: white Cotton, Silk/Viscose Velvet, and Silk/Viscose Satin. Previous tests had been done to gather information on whether the wash method and temperature had any effect on the amount of shrinkage to the fabric, and no difference was seen.

From the information gathered, the necessary alterations to the CAD design and overlay were able to be made prior to printing, so that the result after the embellishments are applied is a 32 x 32 cm design. This information will need to be gathered for any fabric used for printing and embellishment.

When using a printed embellishment overlay, the ink jet printed fabric will need to be pinned down on a backing cloth on the print table. This ensures that the fabric is kept taut and is square. Again this is essential for accurate registration. Techniques such as devoré, pigment ink, lacquer and more have been tested and have produced some very promising outcomes with good registration. Some of the best results were gained from the use of devoré on the Silk/Viscose Velvet and Satin fabrics.

Figure 4: Silk Viscose Satin with devoré embellishment *(18)*

Figure 5: Silk Viscose Velvet with devoré embellishment *(19)*

After the devoré technique has been applied to these fabrics very little colour can be seen left on the silk mesh as the ink is unable to penetrate all the pile when ink jet printed. To enable a colour to be applied to these areas, a reactive dye paste was used on the reverse of the fabric. The colour was originally matched to the CAD design and a recipe was developed using the Datacolor recipe prediction system. The dye paste was pulled through a blank screen cutting out any registration problems that may occur again. An 11% increase in viscosity to the dye paste was required to ensure that the dye would not bleed and affect the other colours in the design.

Figure 6: Silk Viscose Satin with devoré and reactive print on reverse of fabric *(20)*

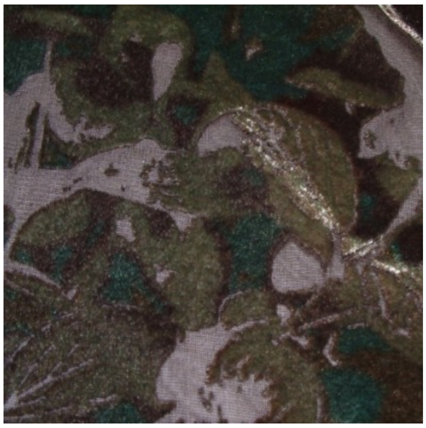

Figure 7: Silk Viscose Velvet with devoré and reactive print on reverse of fabric *(21)*

Resist techniques have also been experimented with when using ink jet printing. First a pigment print has been used to resist the reactive dyes used with ink jet printing and this had little effect, the results showing only over print effect with no resisting occurring. Experiments in developing the resist paste were then carried out. Rather than using a general pigment paste, discharge paste was used, as this can cope better with the use of acids. In this case a tartaric acid was added to the paste. The acid affects the alkali (sodium carbonate) used in the pre-treatment of the fabric for the reactive dyes, causing the reactive dyes once printed not to fix to the fabric leaving the resist print. Also in one experiment a reactive resist agent was used, to the same 8 % quantity as the acid. This did not make any difference to the resist print. Pigment inks were used to colour the resist paste.

The process started with the resist paste being printed onto the pre-treated fabric. Once dry, the paste was heat fixed. The fabric was then fed through the ink jet printer and post-treated with a steam fixation and wash process as usual. Varying heat temperatures and times were experimented with for the fixation of the resist print paste. The original temperature tried was 150° for 5 minutes; this was according to the fixation of the pigment inks. Although there was excellent fixation of the resist paste, the heat process appeared to have an effect on the colour outcome of the ink jet printed design, causing patchy faded areas and less vibrant colours in general.

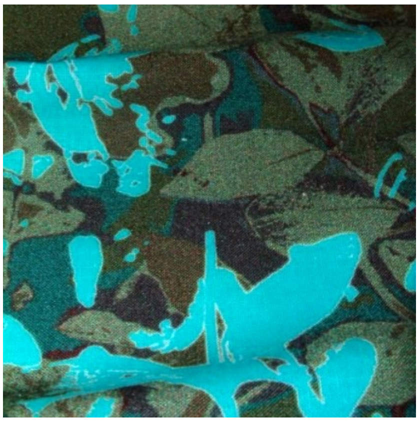

Figure 8: Resist printing *(22)*

Later trials were done at lower temperatures for longer times. This resulted in accurate colour outcome for the ink jet printed areas, but the resist paste colour was not fixed sufficiently. The most effective outcome came from baking the fabric at the higher temperature of 150° for only 2 minutes. This allowed the resist print paste to be fixed properly without damaging the pre-treatment to the fabric for the ink jet print.

Once these processes from design through to finished product are complete, this printing process can be applied, adapted and enhanced to develop a collection of unique embellished fabrics. Effects such as the use of various fabrics and more than one overlay can be applied and there is a possibility of combining various embellishment techniques. Advancing the colour of the devoréd fabrics on the reverse has introduced the possibility of generating fabrics with design qualities on both sides of the fabrics. The registration can be matched by reversing the overlay.

By applying these additional features to the ink jet printed designs, the printed textiles market has the opportunity to develop the area of customisation. The customer will be able to choose from a variety of techniques and overlays, which will be constantly increasing in number, to generate their desired effect. The outcome will be of high quality, bespoke fabrics.

5. CONCLUSION

Wide format ink jet printing for textiles will have major effects on the modern textile designer. Ink jet printing reduces the time and costs involved with sampling, meaning more printed samples can be produced for the customer allowing a wider choice in designs and colours to be achieved. From a creative perspective, ink jet printing can give more freedom when designing, allowing more colours per design and also highly detailed, photographic imagery to be used. This area of design was previously very limited when screen printing.

Although ink jet printing has its own limitations when compared to rotary screen-printing for production purposes, constant developments are being made in fabric pre-treatment, dyestuffs and ink jet technology. It is critical that all print procedures involved with ink jet printing are followed strictly in the running of the printer (environment/conditions) including the pre and post treatments of the fabrics, ensuring that all times and temperatures used are accurate. This is important to enable consistent print quality and colour reproducibility. Tests prior to printing, such as alignment of print heads, priming of colours and colour standard trials can help to ensure reproducible outcomes. The use of colour libraries and colour management systems will also contribute to achieving the consistent results needed.

The blend of embellishment techniques with ink jet printing is unlimited, allowing desired effects to be achieved at lower prices, shortened production times and with minimal wastage. The procedures must be set up prior to producing these fabrics. Once these are in place the creativity can truly begin in embellishing and enhancing the fabrics. These will then lead on to developing the small print production market and allow for individual custom made printed fabrics.

REFERENCES

BASF, 2000, *Reactive Inks - Technical Data for Reactive Dye Inks for Ink Jet Printing*, BASF Colorants

BASF, 2000, *Bafixan Inks - Technical Data for Disperse dye Inks for Ink Jet Printing*, BASF Colorant

BASF, 2000, *Helizarin Inks - Technical Data for Pigments Inks for Ink Jet Printing on Textile*, BASF Colorants

Cahill V, *Introduction to Digital Printing Technology,*www.textileindustries.com

Dupont, 2001, Dupont Presentation

DuPont, 2003, *DuPont Ink Jet 2020 Printer,*www.dupont.com/inkjet

ENCAD, *Encad Digital Textile System, Technical Data*, Pre and Post-Processing for ENCAD REACTA Inks, Version.1

Ervine S, Siemensmeyer K, Siegel B, 2000, *A Simple, Universal Approach to Ink Jet Textile Fabrics*, Textile Chemist and Colorist and American Dyestuff Reporter, Vol.32, No.10, pp.26-27

Gordon S, 2001, *Color Management and RIP Software for Digital Textile Printing*. Kimberly-Clark Corporation, www.techexchange.com

Hill-Campbell J, *Combining Traditional Textile Techniques with Digital Fabric Printing,*www.techexchange.com
Kitao Y, 1999, *Ink-Jet Printing Will Branch off into the YMCK System and the Special Colour System,* Kyoto Municipal Textile Research Institute, www.textileinfo.com

Le Technologies, Inc., 1998, *Progress and Trends in Ink-jet Printing Technology*, Journal of Imaging Science and Technology, Society for Imaging and Science and Technology, Vol.42, No.1.
PC Tech, 2001, *The PC Technology Guide – Inkjet Printers. Input– Output/Inkjet Printers*, www.pctechguide.com
Ross T, 2001, *A Primer in Digital Textile Printing*, www.techexchange.com

Work RA, Kane JP, *Developments in Jet Inks for Textile Printing,*www.techexchange.com

The Commercial Realisation of Complex Textile Craft Techniques by CAD and Ink Jet Printing

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THE COMMERCIAL REALISATION OF COMPLEX TEXTILE CRAFT TECHNIQUES BY CAD AND INK JET PRINTING

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Abstract

There are many techniques in textile crafts which are virtually impossible to produce commercially, for example hand and computer generated embroidered textiles and hand knotted woven fabrics. With the growing interest in the consumer market in the UK particular for textile craft products, it is becoming increasingly important to develop reproducible techniques to enable these products to be made to a commercially acceptable level.

With the capability of ink jet printing being able to print at high resolution and in almost true colour, it is possible to simulate these techniques on fabric. In doing so, accurate colour representation must be achieved; the method of colour management used will be examined.

This paper will start by discussing textile CAD systems and comparing them to general graphic software. It will describe the steps required to obtain identical images of the textile craft onto a CAD system, with the correct resolution, number of colours and size.

1. Introduction to Ink Jet Printing

The textile industry today is driven by time, having to meet the constant demands of the customer for new products and the resulting short lead times. The industry needs to be flexible to change, as the customer may want to make style alterations and have shorter print run productions. Ink jet printing for textiles is moving the scope of what's possible to manufacture: it can produce photographic imagery and is flexible to changes. Printing can be stopped instantly; alterations made to the design on screen, or alter a design completely in response to customer needs and set off again to print. Ink jet printing is currently restricted from the use in bulk production due to: the speed of printing being too slow, the restricted range of inks.

Digital printing for textiles has also given the textile designer greater flexibility in the designs that can be produced. With the movement of much of the bulk textile printing industry to the Far East, in order for print companies to survive there is a need to examine printing techniques and the function of the printing processes. There is the need for more original designs and shorter fashion cycles in response to retail demands and seasonal trends. Ink jet printing can cover these needs. (Ervine S, Seimensmeyer K, Seigel B, 2000) [1]

Ink jet printing is ideal for sampling; it can save time and money, as no colour separations need to be done or screens engraved. It can also reduce wastage, as there is no excess fabric or dye used. Ink jet technology prints where needed and on demand.

Ink jet printing produces an image by jetting dots of coloured ink onto a medium. With some ink jet printers having only 4 colours: cyan, magenta, yellow and black (C.M.Y.K), the colour gamut is more limited when compared to conventional printing. The process used to produce the colour spectrum using a small number of colours is called 'dithering'. Although this process increases the number of achievable colours, it can also decrease the image clarity producing uneven 'dotty' colours. (Work RA) [2] Since pale colours were a problem to achieve, printers now have the option to run with half strength inks. Available now on the market there is the option of a 16 headed printer allowing either faster printing times by doubling up the colours, or running to interchangeable dye types through the printer; for example 8 with reactive dyes and 8 holding pigment inks. Certain colours still lie outside the printer's gamut, so on some printers there is an option of replacing the magenta with say an orange. Increasing the number of dye colours in the ink jet printers will increase the number of achievable colours i.e. stretching to larger colour gamut from CMYK to Pantone.

2. PRELIMINARY EXPERIMENTS

2.1. PRINT QUALITY AND COLOUR REPRODUCIBILTY

Consistency with colour and print quality is essential to all textile printing, and it is important to keep the consistency throughout the printing process. So when using ink jet technology for sample printing it is crucial for colour control and reproducibility to be maintained from sampling through to bulk production. Ink jet printing can save time and money in the sampling stages of the designs, but for this there must be consistent strong colour and print results.

There are several aspects that must be taken into consideration for reproducible results and these can be controlled within the printing and processing stages; for instance the storage and post-treatment of the fabrics. This research has been studying post-treatment conditions required for ink jet printed fabrics. Most fabrics are pre treated, either by the manufacturer or by the user. The pre treatment recipe for each dye and fabric is available from the dyestuff manufacturer. The fabric needs to be pre treated to allow maximum colour yield, clarity of image and quick drying time. Pre-treatment helps to control the size of the ink drops jetted onto the fabric, ensuring that minimum bleeding occurs. The chemical padding stiffens the fabric enabling the fabric to run smoothly and evenly through the printer.
In this research only reactive dyes have been studied so far, reactive dyes require a post-treatment of steaming or heat fixation and a washing process. In this research standard steam conditions have been investigated when using reactive dyes. Steam conditions do appear to have a very strong influence on the ink jet printed outcome. If steam conditions change or do not reach standard settings of temperature and humidity, varying results may occur.

The recommended steam temperature from manufacturers is 102°C for all fabrics and with variable steam time given: these can range from approximately 7 - 15 minutes for Cotton and Viscose to 15 – 30 minutes for silks. (BASF, 2000, ENCAD) [3,4]This research started by looking at steam conditions under which reactive dyes, for ink jet printing, gave best colours and image results. All steam trials were printed on Cotton (non-optic) and once a wide gamut of colours was achievable, various other fabric trials were carried out. Tests were carried out using a range of steam times to see the effect of steam time on colour outcome. Shorter steam times produced weaker colours; steaming for 10 minutes produced the optimum colour results. This was consistent with all steamers.

The washing of the fabrics occurs after steaming and it enables any excess dye to be removed together with any auxiliary chemicals used in the pre-treatment of the fabric. It is again a very important factor for reproducible image and colour results. If the washing process was done incorrectly, image clarity may be affected and problems such as back staining or the fading of colours may occur.

3. EXPERIMENTAL EMBELLISHMENT TECHNIQUES WITH INK JET PRINTING

There are many techniques that can be used with printed fabrics to enhance the design and the fabric's quality and these have been well researched within the traditional printed textiles area. Many techniques can be used to develop the texture, colour and the nature of the fabric using overlays. These techniques can include the use of embroidery, lacquers, expandex, foils, burnout effects such as devoré, discharge printing, and resist methods of printing and dyeing such as using wax and binding techniques.

Previous work has been produced developing effects, combining the use of ink jet technology with traditional surface techniques. This work has concentrated on developing the connection between the two areas and reintroducing craftsmanship to the textile industry. (Hill-Campbell J) [5]

With the use of CAD and CAM within the textile industry, short run printing is continually being developed. Ink jet printing has enabled a reduction in costs and times required to expand this market area. Another advantage of using ink jet printing for short run print lengths is the possibility of generating high quality, innovative, bespoke fabrics at lower prices and at shorter production times. But again for this development in the textile market to occur, certain process and problems have to be overcome. Initially the ink jet printer will need to be set up, assigning the correct pre and post-treatments for the fabrics and the method of colour management to be used. The use of the correct design software is important and particularly the benefits that can be gained with the use of textile specific software as already discuss earlier in this paper.

This research has been concentrating on setting up a strict process to be followed for the creation of embellished ink jet printed fabrics. The designs used are generated in repeat at a traditional design size used in industry of 64cm or a division of this. Although a specific repeat size is unnecessary for the use of ink jet printing, this allows the option of later generating the design using traditional printing methods. Also repeated designs gives more scope to the amount of printed fabric by increasing and decreasing the number of repeats using the CAD software or the Textile RIP.

Again, although reducing the number of colours per design is unnecessary for ink jet printing, working in reduced colour enables the colours to be matched prior to printing, thus cutting out any colour trials that would usually need to be done. With the use of accurate colour reduction using the CAD software, excellent results can be achieved, still obtaining 3 dimensional and photographic qualities.

To be able to prepare all equipment and information ready for applying the embellishment technique to the ink jet printed fabric, the overlay is calculated as part of the original CAD design. From either, a single colour separation or a design motif in the original design, an overlay can be extracted. This can later be used for developing a screen or can be fed into the relevant software. For instance a single colour separation can be used to generate a screen ready for a print overlay or transferred into an embroidery package ready for production. For this to occur certain requirements must be applied, such as the separation must be cleaned making sure there are no stray pixels and that the edges are smooth. Lines may also be required to be of a certain thickness for a print or embroidered area to be noticeable or feasibly produced.

The fabric shrinkage will need to be taken into consideration to enable accurate registration between the printed fabrics and the embellishment overlay. This measurement will need to be taken after the printed fabric has been post-treated. A study has been done in this research to gain the shrinkage information on three fabrics at present: white Cotton, Silk/Viscose Velvet, and Silk/Viscose Satin. Previous tests had been done to gather information on whether the wash method and temperature had any effect on the amount of shrinkage to the fabric, and no difference was seen.

From the information gathered, the necessary alterations to the CAD design and overlay were able to be made prior to printing, so that the result after the embellishments are applied is a 32 x 32 cm design. This information will need to be gathered for any fabric used for printing and embellishment.

When using a printed embellishment overlay, the ink jet printed fabric will need to be pinned down on a backing cloth on the print table. This ensures that the fabric is kept taut and is square. Again this is essential for accurate registration. Techniques such as devoré, pigment ink, lacquer and more have been tested and have produced some very promising outcomes with good registration. Some of the best results were gained from the use of devoré on the Silk/Viscose Velvet and Satin fabrics.

After the devoré technique has been applied to these fabrics very little colour can be seen left on the silk mesh as the ink is unable to penetrate all the pile when ink jet printed. To enable a colour to be applied to these areas, a reactive dye paste was used on the reverse of the fabric. The colour was originally matched to the CAD design and a recipe was developed using the Datacolor recipe prediction system. The dye paste was pulled through a blank screen cutting out any registration problems that may occur again. An 11% increase in viscosity to the dye paste was required to ensure that the dye would not bleed and affect the other colours in the design.

Resist techniques have also been experimented with when using ink jet printing. First a pigment print has been used to resist the reactive dyes used with ink jet printing and this had little effect, the results showing only over print effect with no resisting occurring. Experiments in developing the resist paste were then carried out. Rather than using a general pigment paste, discharge paste was used, as this can cope better with the use of acids. In this case a tartaric acid was added to the paste. The acid affects the alkali (sodium carbonate) used in the pre-treatment of the fabric for the reactive dyes, causing the reactive dyes once printed not to fix to the fabric leaving the resist print. Also in one experiment a reactive resist agent was used, to the same 8 % quantity as the acid. This did not make any difference to the resist print. Pigment inks were used to colour the resist paste.

The process started with the resist paste being printed onto the pre-treated fabric. Once dry, the paste was heat fixed. The fabric was then fed through the ink jet printer and post-treated with a steam fixation and wash process as usual. Varying heat temperatures and times were experimented with for the fixation of the resist print paste. The original temperature tried was 150° for 5 minutes; this was according to the fixation of the pigment inks. Although there was excellent fixation of the resist paste, the heat process appeared to have an effect on the colour outcome of the ink jet printed design, causing patchy faded areas and less vibrant colours in general.

Later trials were done at lower temperatures for longer times. This resulted in accurate colour outcome for the ink jet printed areas, but the resist paste colour was not fixed sufficiently. The most effective outcome came from baking the fabric at the higher temperature of 150° for only 2 minutes. This allowed the resist print paste to be fixed properly without damaging the pre-treatment to the fabric for the ink jet print.

Once these processes from design through to finished product are complete, this printing process can be applied, adapted and enhanced to develop a collection of unique embellished fabrics. Effects such as the use of various fabrics and more than one overlay can be applied and there is a possibility of combining various embellishment techniques. Advancing the colour of the devoréd fabrics on the reverse has introduced the possibility of generating fabrics with design qualities on both sides of the fabrics. The registration can be matched by reversing the overlay.

By applying these additional features to the ink jet printed designs, the printed textiles market has the opportunity to develop the area of customisation. The customer will be able to choose from a variety of techniques and overlays, which will be constantly increasing in number, to generate their desired effect. The outcome will be of high quality, bespoke fabrics.

The blend of embellishment techniques with ink jet printing is unlimited, allowing desired effects to be achieved at lower prices, shortened production times and with minimal wastage. The procedures must be set up prior to producing these fabrics. Once these are in place the creativity can truly begin in embellishing and enhancing the fabrics. These will then lead on to developing the small print production market and allow for individual custom made printed fabrics.

4. THE PRODUCTION OF COMPLEX TEXTILE CRAFT TECHNIQUES USING CAD AND INK JET TECHNOLOGY

The aim of this research is to achieve an accurate representation of hand-developed craft techniques using CAD software and textile ink jet technology, and to study the problems that may arise with this and to produce high quality printed fabric results. They will need to be commercially viable and in doing so the beginnings of a catalogue will be generated allowing for choice in custom made printed textiles. The process will be documented for future production of simulated craft techniques onto printed fabrics, resulting in the discussion of the use of colour management, CAD software and potential uses.

Research has been done in this area of textiles analysing the reproduction of aesthetic qualities associated with traditional hand surface design techniques of batik and discharge, investigating whether these could be achieved using graphics programs and digital printing technology. (Lawrence, G 2002) [6]

Selections of craft generated techniques were gathered from varying specialist textile craft practitioners of embroidery and weave as a basis for this research. Future work will examine the possibilities of this process being applied to generate high quality simulations of other textile craft techniques. The textile samples of varying sizes (some as little as only 50x80mm) were scanned in at high resolution (400dpi). Scanning in at the higher resolution gives more flexibility for future resizing. All resizing should be considered before colour reduction for the highest quality of image to be achieved.

4.1 The Use of Colour Management and Software with Ink Jet Printing

Ink jet printing was developed from wide-bodied paper printers designed for posters and banners. These have long established methods of obtaining full colour reproduction from the secondary colours of CMYK, known as process colours. Textiles have used a spot colour method whereby the actual colour in the form of dyes is used.

With the use of the various dyes there are some limitations to the printable colours that are achievable. Also the full potential of these colour spaces is not visible until the fixation of the dyes, whereby the colours become a great deal brighter. (Gordon S, 2001) [7]

Textile specific software is available to manipulate images, which usually include flat and continuous tone designs; ability of colour separation, a powerful repeat function and colour management.

On the other hand, RIP Software for digital printing of textiles from a graphic package should be able to accept textile industry file formats from CAD design, screen separation programs and accept common graphic file formats. The RIP for both inputs should be able to manage expanded ink sets beyond CMYK, depending upon the printer. Ink control functions manage higher ink densities required for colour saturation of fabric. However, since with digital printing there is no need to colour separate and as the commercial graphic packages become more flexible, there will be a move towards packages such as PhotoShop and CorelDraw, with a reliance on the software RIP to do much of the textile work.

In this work, only textile specialist software 'Lectra U4ia' has been used. This software enabled an efficient work process to be developed with all the advantages it has to offer, particularly for printed textiles. Colour reduction can be achieved accurately, image clipboard can be used for building up a large database of craft techniques and the 'repeats' function for the option of one-off craft techniques to be thrown quickly and effectively into repeat.

In connection with the textile specialized software, a colour library was used as the method of colour management in this research. This allowed for the correct colour to be chosen by eye. There is always some noticeable limitation with the printable colour using ink jet technology. This due to the set of dye colours used the printer, which can mean certain colours will lie outside the printers colour gamut. This was an important factor affecting this research.

4.2 Colour Reduction

When producing digital representations of textile craft techniques, the image quality and colour standards must be accurate to the finished sample. High image quality can be obtained through scanning at an appropriate resolution, but colour must be examined in greater depth. When printing the true colour image with no colour alterations made, the printed outcome was unacceptable with harsh and unsubtle colours. This proved the importance of using a method of colour management, in doing so the reduction of colour is critical in this work. The colour reduced file must be perfect to that of the original.

Precise colour reduction can be obtained many ways. This can be done automatically using most general CAD software by specifying the number of colours required to remain in the design (those that are most frequently used). More accurately it can either be achieved by; specifying the actual colours you wish to remain in the design or by using 'palette builder' to select particular colours. For example, choosing a light and a dark tone, then specifying the additional number of tones between the two colours, and finally allowing the software to automatically fill in these tones. This is then repeated to gather all colours tones required in the design, which can be done by using textile specialized software only.

It was still important to keep large numbers of colours in each image to project a realistic version of the original crafted sample, to an almost photographic quality. Large numbers of colours in designs usually means a great deal of time spentcolour matching all colours. This work has looked at ways in which to limit the number of colours that require matching and still achieving excellent colour results.

4.2.1. Colour Reduction Method 1 – Most Common

This method works by selecting the number of colours that you wish to remain in the design/image as described earlier. It is very quick to complete and sometimes achieves promising results, however from experience this is rare. In these experiments the images were reduced in colour to the maximum allowance in a reduced colour window (255). If at this stage the image was an accurate representation to the original, colour matching would be considered to ensure the required printed colour outcome. However, it was not feasible to colour match 255 colours. Therefore, the colour palette was re-organised to show the colours ranging from the most to the least frequently used, which allowed for the most commonly used colours (over 1%) to be easily identified. However, it quickly became apparent that colour matching at the above 1% threshold would not achieve the desired standard, as many key colours would not be matched. Therefore logic would suggest lowering the threshold, ultimately increasing the number of colours required for matching, moving ever closer to the infeasible number of 255.

4.2.2. Colour Reduction Method 3 – Individual Colour Selection

This method was not used in this research due to it being very time consuming when selecting large quantities of colours.

4.2.3. Colour Reduction Method 3 - Tones

Using ‘Palette Builder’ (Lectra U4ia) as described early as ‘tones’, can be found in textile specialist software. This proved to be the most successful process for colour reduction. It requires only 2 colours to be selected at any one time (typically a light and dark tone of the same colour). The software then builds up the palette based on the optional number of tones selected between the 2 tones/colours chosen initially. This method is time efficient and flexible as only a small number of colours need to be selected, each with a wide range of tones, and groups of colours can be added and deleted as necessary. With careful selection, an accurate representation can be achieved easily.
Two experiments in colour matching were undertaken. They examined ways in which to achieve the best colour results possible and considered the time involved.
In experiment one only the initial two tones/colours in each group were colour matched, which resulted in a smaller proportion of colours needing to be matched. For example, out of 125 colours only 50 colours were matched.
In the 2nd experiment the reduced palette was re-organised into a range of the most to least frequently used colours (an automatic function available with textile specialist software). This made it clearly visible for matching all colours used over 1%.

4.2.4. Printed Results

The strongest results achieved were those colour matched using method 3 and in accordance to the method described in experiment 1. By matching the initial two tones/colours in each group, a wider range of colours were matched.
For example, if the most frequently used colours in a textile craft sample are the pale cream and grey tones with the occasional red, yellow, and blue, matching all colours used over 1%, would not reach enough of the latter colours. This suggests that more colours would need to be matched, thus extending the amount of time required or leaving unexpected colour results after printing.
Achieving excellent colour outcome in this work is essential to enable an accurate representation of that of the original. Colour matching is essential for this to occur, however, some colours are still unachievable. In this research a Mimaki TX2 has been used. Eight reactive dye colours are used; Cyan, magenta, yellow, black, grey, light magenta, blue and golden yellow. However, even with this number of dyes available some colours are still unobtainable. A possibility of improving the colour outcome would be to change the dye colours as necessary. Image quality is also essential to achieving strong printed results. The printer was set to print at a resolution of 720 dpi, this allowed for high quality prints to be produced.
The printed results are very strong in this research. They show an accurate representation of a variety of textile craft techniques. Once each sample is recorded in a digital format and the above work has been applied, the crafted samples become very flexible as to their future uses. They can be custom made and commercially viable in small scale production using ink jet technology. For example, some images lend themselves to be thrown into a repeat, which gives the customer the

option of the amount of printed fabric they require. Using CAD software small areas can be simply extracted out of the original sample and dropped onto plain background or even accurately positioned onto another design. The colours are inter-changeable to customer needs and alternative colour-ways are easily done. Examples of these can be seen below.

5. CONCLUSION

Wide format ink jet printing for textiles will have major effects on the modern textile designer. Ink jet printing reduces the time and costs involved with sampling, allowing more printed samples to be produced for the customer, providing a wider choice in designs and colours to be achieved. From a creative perspective, ink jet printing can give more freedom when designing, allowing more colours per design and also highly detailed, photographic imagery to be used. This area of design was previously very limited when screen printing.

As shown in the initial experiments, custom made bespoke fabrics can be produced utilising CAD, Ink jet technology and traditional screen print techniques. However, this is only the beginning to how these techniques can be combined together. The advantages of linking CAD and ink jet technology, and what they have to offer in developing custom-made fabrics, are just beginning to be explored. With the appropriate design skills, the relevant textile specialist software and experience of CAD/CAM these can be combined creatively and push the boundaries of textile sampling and custom-made fabrics. They can also be used as a high quality production method of hand-developed creative textile craft samples.

Most hand-developed textile craft techniques are very time consuming to make and are often ‘one-off’ pieces. This work is not trying to distract from the value of ‘one-off’ textile crafted samples, but to further develop and expand some of these qualities commercially.

Today there is a new era emerging and it is called Mass Customisation. Mass Customisation takes the best of the craft era, when customers had products built to their specifications but only the elite could afford them, with the best of the mass production era, when everybody could get the same product because it was affordable. (Fralix, M 2001) [8]

There are many advantages of using CAD and ink jet printing for the development of complex textile craft techniques. The scale of the original textile sample can vary; small samples can be used with flexibility for future re-scaling. This means there is less time involved with the original development of the textile sample. Once the method of production is set up each sample can be easily and quickly produced to a high standard. Once the samples are in a digital format they are flexible to changes, such as scale, re-colouring and repeats. The printed results are excellent using ink jet technology, with an almost photographic outcome. Digital printing is the most suitable method of production for this work due to its high quality, flexibility and its low cost for small scale productions.

6. BIBLIOGRAPHY

[1] Ervine S, Siemensmeyer K, Siegel B, 2000, *A Simple, Universal Approach to Ink Jet Textile Fabrics*,
Textile Chemist and Colorist and American Dyestuff Reporter, Vol.32, No.10, pp.26-27

[2] Work RA, Kane JP, *Developments in Jet Inks for Textile Printing,*www.techexchange.com

[3] BASF, 2000, *Reactive Inks - Technical Data for Reactive Dye Inks for Ink Jet Printing*, BASF Colorants

BASF, 2000, *Bafixan Inks - Technical Data for Disperse dye Inks for Ink Jet Printing*, BASF Colorants

BASF, 2000, *Helizarin Inks - Technical Data for Pigments Inks for Ink Jet Printing on Textile*, BASF

[4] ENCAD, *Encad Digital Textile System, Technical Data*, Pre and Post-Processing for ENCAD REACTA Inks, Version.1

[5] Hill-Campbell J, *Combining Traditional Textile Techniques with Digital Fabric Printing,* www.techexchange.com

[6] Lawrence G, 2002, *Digital Printing and Traditional Surface Design Techniques - Thesis*. www.worldcatlibraries.org

[7] Gordon S, 2001, *Color Management and RIP Software for Digital Textile Printing*. Kimberly-Clark Corporation, www.techexchange.com

[8] Fralix MT, 2001, *From Mass Production to Mass Customisation,* Journal of Textile and Apparel, Technology and Management, Vol. 1, Issue 2

Craftily Using Ink Jet

Textiles, 2006

Craftily Using Ink Jet

Many craft techniques exist which are virtually impossible to reproduce on a commercial basis. Helen Woodget and John Pearson, in the Department of Design, at the University of Huddersfield, UK look at the capabilities of ink jet printing and review requirements to obtain identical textile craft images using a CAD system.

With the growing interest on the consumer market for textile craft products, it is becoming increasingly important to develop reproducible techniques to enable these products to be made to a commercially acceptable level. With the capability of ink jet printing being able to print at high and in almost true colour, it is possible to simulate these techniques on fabric. In doing so, accurate colour representation must be achieved; the method of colour management used is reviewed.

Complex Textile Craft Techniques Research has already been carried out in this area of textiles by analysing the reproduction of aesthetic qualities associated with the traditional hand surface design techniques of batik and discharge, investigating whether these could be achieved using graphics programs and digital printing technology. This was carried out prior to 2002 by Lawrence, C., and is reported in her thesis titled Digital Printing and Traditional Surface Design Techniques (www.worldcatlibraries.org) Selections of craft generated techniques were gathered from specialist textile craft practitioners of embroidery and weave as a basis for the work. The textile samples of varying sizes (some as little as only 50x80mm) were scanned in at high resolution (400dpi). Scanning in at this high resolution gives more flexibility for future resizing. All resizing should be considered before colour reduction for the highest quality of image to be achieved.

Colour Management and Software

Ink jet printing was developed from wide-bodied paper printers designed for posters and banners. These have long established methods of obtaining full colour reproduction from the secondary colours of CMYK, known as process colours. Textiles have used a spot colour method whereby the actual colour in the form of dyes issued. With the use of the various dyes there are some limitations to the printable colours that are achievable. Also, the full potential of these colour spaces is not visible until the fixation of the dyes, whereby the colours become a great deal brighter (Covered by Gordon, S., in his Color Management and RIP Software for Digital Textile Printing. Kimberley-Clark Corporation, 2001 www.techexchange.com). In this work, the textile specialist software 'Lectra U4ia' has been used. This software enabled an efficient work process to be developed with all the advantages it has to offer, particularly for printed textiles. Colour reduction can be achieved accurately, image clipboard can be used for building up a large data base of craft techniques and the 'repeats' function for the option of one-off craft techniques to be thrown quickly and effectively into repeat. In connection with the textile specialised software, a colour library was used as the method of colour management. This allowed for the correct colour to be chosen by eye. There is always some noticeable limitation with the printable colour using ink jet technology, due to the set of dye colours used in the printer, which can mean certain colours will lie outside the printer's colour ability. This was an important factor affecting this work.

ColourReduction

When producing digital representations of textile craft techniques, the image quality and colour standards must be accurate to the finished sample. High image quality can be obtained through scanning at an appropriate resolution, but colour must be examined in greater depth. When printing the true colour image with no colour alterations made, the printed outcome was unacceptable, with harsh and unsubtle colours. This demonstrated the importance of using a method of colour management: in doing so the reduction of colour is critical in this work. The colour-reduced file must be perfect to that of the original.

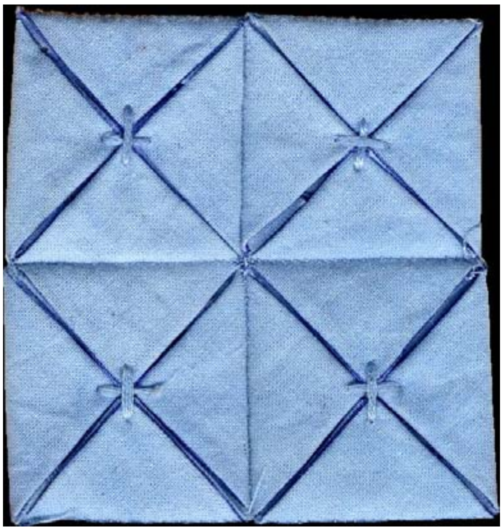

Figure 1: Original scanned embroidered sample

Figure 2: Reduced to 30 colours

Precise colour reduction can be obtained in many ways: it can be done automatically using most general CAD software by specifying the number of colours required to remain in the design (those that are most frequently used). More accurately, it can either be achieved by specifying the actual colours desired to remain in the design or by using 'Palette Builder' to select particular colours, for example, choosing a light and a dark tone, then specifying the additional number of tones between the two colours and finally allowing the software to automatically fill in these tones. This is then repeated to Craftily using Ink Jet gather all colours tones required in the design, which can be done by using textile specialised software only.

It was still important to keep large numbers of colours in each image to project a realistic version of the original crafted sample, to an almost photographic quality. Large numbers of colours in designs usually mean a great deal of time spent colour matching all colours. This work has looked at ways in which to limit the number of colours that require matching and still achieving excellent colour results.

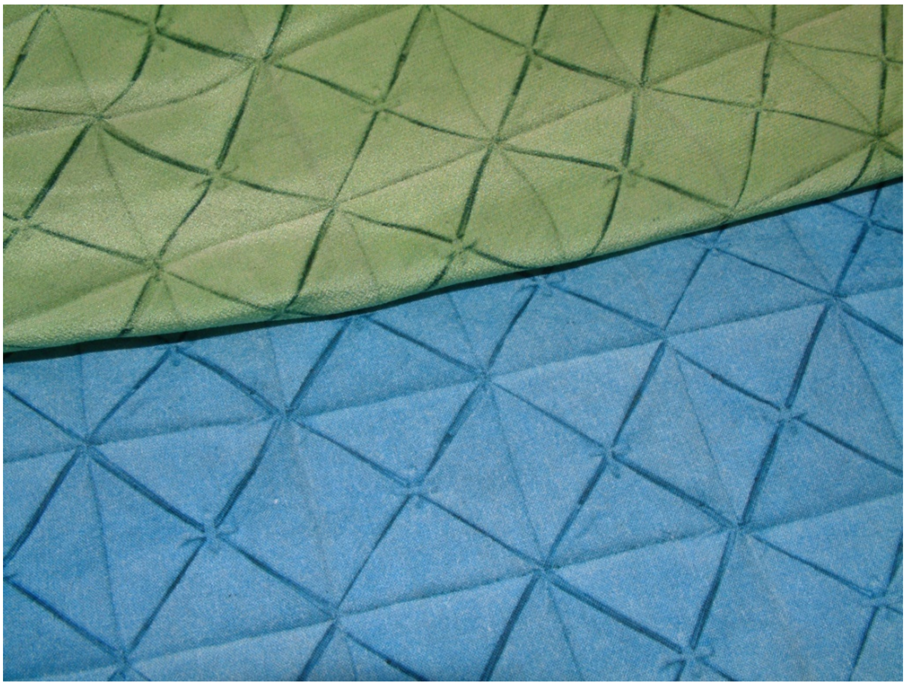

Figure 3: Finished repeated printed sample

Colour Reduction Method 1 -Most Common

This method works by selecting the number of colours that are desired to remain in the design/image, as described earlier. It is very quick to complete and sometimes achieves promising results; however, from experience this is rare. In these experiments, the images were reduced in colour to the maximum allowance in a reduced colour window (255). If at this stage the image was an accurate representation to the original, colour matching would be considered to ensure the required printed colour outcome. However, it was not feasible to colour match 255 colours. Therefore, the colour palette was re-organised to show the colours ranging from the most to the least frequently used, which allowed for the most commonly used colours (over1%) to be easily identified. However, it quickly became apparent that colour matching at the above 1% threshold would not achieve the desired standard, as many key colours would not be matched. Therefore logic would suggest lowering the threshold, ultimately increasing the number of colours required for matching, moving ever closer to the infeasible number of 255.

Colour Reduction Method 2-Tones

'Palette Builder' (LectraU4ia) can be found in textile specialist software. This proved to be the most successful process for colour reduction. It requires only 2 colours to be selected at any one time (typically a light and dark tone of the same colour). The software then builds up the palette based on the optional number of tones selected between the 2 tones/colours chosen initially. This method is time efficient and flexible as only a small number of colours need to be selected, each with a wide range of tones, and groups of colours can be added and deleted as necessary. With careful selection, an accurate representation can be achieved easily.

Two experiments in colour matching were undertaken. They examined ways in which the best colour results possible could be achieved and considered the time involved. Firstly, only the initial two tones/colours in each group were colour matched, which resulted in a smaller proportion of colours needing to be matched. For example, out of 125 colours only 50 colours were matched. Next, the reduced palette was re-organised into a range of the most to least frequently used colours (an automatic function available with textile specialist software). This made it clearly visible for matching all colours used over 1%.

Figure 7: Finished printed sample cotton jersey sample

Printed Results

The strongest results achieved were those colour matched using method2. By matching the initial two tones/colours in each group, a wider range of colours was matched. For example, if the most frequently used colours in a textile craft sample were the pale cream and grey tones with the occasional red, yellow, and blue, matching all colours used over 1%, would not reach enough of the latter colours. This suggests that more colours would need to be matched, thus extending the amount of time required or leaving unexpected colour results after printing. Achieving excellent colour outcome was felt essential to enable an accurate representation of the original. Colour matching is essential for this to occur; however, some colours are still unachievable. In this work, a Mimaki TX2 printer, using eight reactive dye colours (cyan, magenta, yellow, black, grey, light magenta, blue and golden yellow) was used. However, even with this number of dyes available, some colours are still unobtainable. A possibility of improving the colour outcome would be to change the dye colours as necessary. Image quality is also essential to achieving strong printed results. The printer was set to print at a resolution of 720dpi, which allowed for high quality prints to be produced.

The printed results are very strong, showing an accurate representation of a variety of textile craft techniques. Once each sample is recorded in a digital format and the above work has been applied, the crafted samples become very flexible as to their future uses. They can be custom made and commercially viable in small scale production using ink jet technology. For example, some images lend themselves to be thrown into a repeat, which gives the customer the option of the amount of printed fabric they require. Using CAD software, small areas can be simply extracted out of the original sample and dropped onto a plain background or even accurately positioned onto another design. The colours are inter-changeable to customer needs and alternative colour-ways are easily produced. Examples of these can be seen in the images throughout this article.

Figure 5: Original scanned embroidered sample

Figure 6: Finished printed sample onto a plain background

Conclusion

Custom-made bespoke fabrics can be produced utilising CAD, inkjet technology and traditional screen print techniques. However, this is only the beginning of combining these techniques. The advantages of linking CAD and ink jet technology and what they have to offer in developing custom-made fabrics, only just beginning to be explored. With the appropriate design skills, the relevant textile specialist software and experience of CAD/CAM, these can be combined creatively and can extend the boundaries of textile sampling and custom-made fabrics. They can also be used as a high quality production method of hand-developed creative textile crafts samples, which are usually very time consuming to make and are often 'one-off' pieces. This work is not trying to detract from the value of 'one-off' textile crafted samples, but aims to further develop and expand some of these qualities commercially.

There are many advantages of using CAD and ink jet printing for the development of complex textile craft techniques. The scale of the original textile sample can vary and small samples can be used with flexibility for future re-scaling. This means there is less time involved with the original development of the textile sample. Once the method of production is setup, each sample can be easily and quickly produced to a high standard. Once the samples are in a digital format, they are flexible to change, such as scale, re-colouring and repeats. The printed results are excellent using ink jet technology, with an almost photographic outcome. Digital printing is the most suitable method of production for this work due to its high quality, flexibility and its low cost for small scale productions.

Mass Customisation is becoming increasingly important and it unites the best traditions of the classical crafts era, when elite customers had products built to their, specifications, with those of mass production, when everybody can get the same product because it is affordable.

Appendix II

Research Costing

I. **Costing for pre-manipulated fabric (craft based)**

II. **Costing for reproducible craft techniques using ink jet technology**

Pricing for Pre-Manipulated Fabrics per metre

	price per hr	Simple	Medium	Complicated
Time involved (hrs)		8	15	22
Direct Labour costs (including embroidery/pleating techniques)	£5.80	£46.40	£87.00	£127.60
Time involved (hrs)		6	8	10
Design Labour costs fixed (single cost per design)	£12.82	£76.92	£102.56	£128.21

	Price per lm (1.4m width)	Simple	Medium	Complicated
Raw Materials (pre-treated fabric and dye)	£8.12	£8.12	£8.12	£8.12
Raw Materials (Lace and Tread) dependant on lace design	£20.00	£2.00	£10.00	£20.00
Post-treatment	£2.00	£2.00	£2.00	£2.00

Price Calculator				
		Simple	Medium	Complicated
Labour Costs price per metre		£46.40	£87.00	£127.60
Design Labour Costs single charge per design		£76.92	£102.56	£128.21
Raw Materials price per metre		£8.12	£8.12	£8.12
Raw Materials (Lace and Tread) dependant on lace design		£2.00	£10.00	£20.00
Post-treatment price per metre		£2.00	£2.00	£2.00
Fixed Cost per metre (Design cost)		£76.92	£102.56	£128.21
Variable Cost per metre		£58.52	£107.12	£157.72
Total Cost per metre		£135.44	£209.68	£285.93
Total Cost for work > 1 metre	**10m**	**£662.12**	**£1,173.76**	**£1,705.41**
Total Cost for work > 1 metre	**50m**	**£3,002.92**	**£5,458.56**	**£8,014.21**

* price per m/width of fabric (aprox 1.40m)*

*Excluding profit mark-ups, overheads and start up costs

Pricing for Reproducing Craft Techniques using Ink Jet Technology and CAD per metre

	price per hr	Simple	Medium	Complicated
Time involved (hrs)		0	0	0
Direct Labour costs (including embroidery/pleating techniques)	£5.80	£0.00	£0.00	£0.00
Time involved (hrs)		6	12	18
Design Labour costs fixed (single cost per design)	£12.82	£76.92	£153.85	£230.77

	Price per m	Simple	Medium	Complicated
Raw Materials (pre-treated fabric and dye)	£8.12	£8.12	£8.12	£8.12
Post-treatment	£2.00	£2.00	£2.00	£2.00

Price Calculator				
		Simple	Medium	Complicated
Labour Costs price per metre		£0.00	£0.00	£0.00
Design Labour Costs single charge per design		£104.00	£208.00	£312.00
Raw Materials price per metre		£8.12	£8.12	£8.12
Post-treatment price per metre		£2.00	£2.00	£2.00
Fixed Cost per metre (Design cost)		£104.00	£208.00	£312.00
Variable Cost per metre		£10.12	£10.12	£10.12
Total Cost permetre		£114.12	£218.12	£322.12
Total Cost per metre< 1	**10**	**£205.20**	**£309.20**	**£413.20**
	50	**£610.00**	**£714.00**	**£818.00**
	100	**£1,116.00**	**£1,220.00**	**£1,324.00**
	500	**£5,164.00**	**£5,268.00**	**£5,372.00**

* price per m/width of fabric (aprox 1.40m)*

*Excluding profit mark-ups, overheads and start up costs