

---

## **THE DEVELOPMENT OF UNIQUE RESIST DYED PATTERNING FOR SEAMLESS FASHION AND KNITTED FABRICS**

Wonseok Choi, Nancy B. Powell

### **ABSTRACT**

Wada (2002) defines resist as “technique or material that creates patterns on cloth by impeding dye from penetrating fabric” (p. 209). Resist dyeing techniques have been traditionally created in numerous ways worldwide, such as wax resist (batik), tied resist (shibori) and yarn resist (ikat). Most resist techniques have been created on woven fabrics and manipulated by hand. This research looks at the possibilities of resist (shibori) dyes created on knitted fabrics. The focus centers on exploring and developing diverse resist patterns on knitted fabrics created by computerized knit technology. Thus, the objective of this research is to give a new interpretation to the traditional resist-dyeing methods by incorporating seamless knitting technology.

Wada, Rice and Barton (1999) indicate that shibori designs, composed of binding, stitching, folding, and pole-wrapping, that appear on fabric are the result of the three-dimensional shape of the fabric even if the fabrics may be returned to a two-dimensional form after dyeing. This research examines a variety of three-dimensional knitted structures for resist designs duplicating traditional methods of stitching, binding, or folding to gather or pleat the fabric through electronic knitting systems. Different knit structure variables including float length, course distance, and placement of gathering threads have a significant relationship with the resist dyed image. In addition, the research studies different types of yarn applications to create knitted resist patterns. The authors also consider aesthetic and functional aspects in knitted resist-dyed structures. This research introduces the possibilities of an integrated process of knit design and knitwear design incorporated in the seamless knitting technology and the resulting design variations in seamless knitted shibori garments.

The research has implications for researchers, designers and industrial personnel, who require information in seamless knitting design, and resist-dyeing technique and its applications in the textile and apparel field.

### **1. INTRODUCTION**

Most knitted garments are colored to meet the demands of the customer’s preferences for the latest fashion trends. The coloration of knitted garments can be created through use of pre-dyed yarn or piece/garment dyeing. In order to make multi-colored patterns beyond stripes on knitted fabrics, several techniques can be used such as knitting with several different colored yarns, multi-colored printing on fabric or garments, or multi-colored piece/garment cross dyeing. However, the multi-colored patterning created on the knitting machinery has structural limitations including the number of colors and patterning. A printing or dyeing technique may be the solution to remove the knitted structural limitation. For example Shima Seiki has introduced their digital printing system for knitted fabrics and integral knitwear. It may not be preferable to invest in this

technology if existing technologies were available. In practice it would be a convenient method to dye on existing production garment dyeing equipment if a way to create multicolored patterned garments could be developed.

Resist dyeing, a special dyeing method, has been recognized as a unique design technique. Resist can be defined as a process of textile color patterning “by preventing the uptake or fixation of a dye in a subsequent operation” (McIntyre & Daniels, 1997, p. 276). Resist dyeing has been historically created in many ways throughout the world, such as wax resist, tied resist, pattern-dyed indigo and shibori (Bosence, 1985). Shibori is the Japanese term for varied methods of embellishing textiles by shaping a fabric and securing it before dyeing (Wada, Rice & Barton, 1999). Shibori may be utilized to create a variety of patterns on a fabric by means of a resist-dyed technique. However, most shibori techniques have been created on woven fabrics, and gathering yarns, required to pull up the fabric for resist dye, have been sewn or manipulated by hand. This research focuses on exploring the resist-dyed (shibori) patterns using structures in knitted fabrics created by computerized seamless-knitting technology.

“Seamless” garment knitting creates a complete garment by several different carriers (feeders) with minimal or no cutting and sewing processes. Hunter (2004) explains that yarn consumption can be reduced by seamless garment knitting as well as by effectively analyzing the yarn feed through the computerized system on the machine. Furthermore, seamless knitting has the capability for reduction in production time and cost-saving by removing post-knit processes such as the linking or sewing and cutting operation. It also minimizes yarn consumption by reducing the cutting waste and can attain higher total system productivity (Shima Seiki, 2006). Hence, the research into combining resist methods and seamless knitting technology is initiated by examining the traditional methods and looking at new possibilities of knit structures and yarn applications required for resist dyeing.

### **1.1. Objectives**

The objectives of this research are to:

1. explore current seamless knitting technology on flat V-bed machines and evaluate a new application for this advanced technology; and
2. review traditional resist dyeing methods and combine resist dyeing procedures with seamless knitting technology. These include:
  - a. evaluation of possibilities of appropriate knit structures for resist dyeing, and
  - b. examination of different types of yarn applications to create knitted resist dyed patterns, and
  - c. evaluation of aesthetic and functional aspects in resist dyed structures.
3. consider the possibility of shibori knitting in the integrated design process for complete garments.

## **2. RESIST DYEING**

## 2.1. Definition of Resist Dyeing

Although many researchers (Belfer, 1977; Bosence, 1985; Larsen, 1976; Wada, 2002) point out that most resist patterns have been created on woven fabrics, resist dyeing techniques can be divided into different groups including batik (wax resist), shibori or plangi (tied fabric resist) and ikat (yarn resist) according to the interpretation of the classification.

### 2.1.1. Batik (*Wax Resist*)

The word, batik, comes from Indonesia and means ‘wax writing’ (Singer & Spyrou, 2000). Dryden (1993) and Gittinger (2005) define batik as one of resist methods that include applying hot melted or liquid wax onto the surface of a fabric to protect the original colors on the fabric. After application, the wax quickly cools on the material and solidifies. As a cool dye liquid is then used, it cannot penetrate the wax and the area covered by the wax keeps its original color after dyeing (Spée, 1982). Researchers (Belfer, 1977; Krishna, 1977) indicate that Batik originated from Egypt approximately 2,000 years ago. Japan, China, India, Central and Southeast Asia, Europe and parts of Africa have also been known for areas of batik culture (Krishna, 1977). Batik throughout Asia has been historically created on silk and cotton, and been primarily used in garments (Belfer, 1977). Batik has several techniques, including hand-drawn wax resist created by a wax pen called tjanting (tulis batik) and wax resist by means of stamps (tjap batik), and provides a great variety of batik patterns (Larsen, 1977).

### 2.1.2. Ikat (*Yarn Resist*)

Larsen (1976) describes ikat, a Malay-Indonesian word, as the methods of wrapping-to-pattern, then dyeing, segments of yarn before the fabric is constructed. Ikat is different from batik or plangi (shibori) in that ikat binds and dyes yarns prior to weaving process, whereas batik or plangi uses resist techniques on an already woven fabric (Battenfield, 1978). The ikat process therefore requires meticulous sorting of yarns before and after dyeing, systematic wrapping and unwrapping of the areas for resisting or dyeing, and particular care in setting up of warps and wefts on the loom to guarantee that the pre-dyed parts emerge in the right place on the finished fabric (Crill, 1998). Ikat involves two main methods, which are ‘single ikat’ and ‘double ikat’. Nawawi (2003) states that in ‘single ikat’, either warp or weft threads are tied and dyed before weaving. In the method of ‘double ikat’, “both warp and weft threads are tied and dyed with such a precision, that when woven, threads from both axis mesh exactly at certain points to form a complete motif of pattern” (Nawawi, 2003). Battenfield (1978) indicates that cotton and silk have been the most widely utilized as ikat materials, linen and wool less frequently. This type of resist technique has been performed in numerous places around world including Indonesia, India, Japan, Persia, part of Africa and Latin America.

### 2.1.3. Shibori (*Tied Fabric Resist*)

Shibori is a process of dyeing to create unique patterns by tying fabric to restrict the penetration of dye before immersion dyeing (McIntyre et. al., 1997). Although tie-dye is described in different terms all over the world (for instance, it is called ‘bandhani’ in India, ‘plangi’ in Indonesia and ‘shibori’ in Japan), the techniques have also been shown in variety of countries such as India, Indonesia, Japan, China, Latin America and part of Africa. The techniques can be formed in numerous variations, including multiple color applications and diverse pattern repetition.

The word, shibori, comes from the Japanese verb root shiboru, “to wring, squeeze, press” (Wada, Rice & Barton, 1983, p. 7). It can be simply expressed as ‘shaped-resist dyeing’ or ‘tie-dye’. Shibori, as defined by Wada (2002), is a Japanese term that refers to many methods of embellishing textiles by shaping fabric and securing it prior to dyeing. Ellis (2005) defines shibori as “a term for shaped-resist dyeing, a process by which a flat piece of cloth is shaped by folding, stitching, tying, or wrapping and then secured before dyeing” (p. 3). During the dyeing process, the shaped resist areas can create various pattern designs. In order to achieve the shibori patterns, it is essential to create a three-dimensional form by folding, crumpling, plaiting, and twisting, rather than treating fabric as a two-dimensional surface (Wada, Rice & Barton, 1999).

Shibori has the potential to create a large number of shaped-and-resisted designs. The shibori shaped resist-dyeing techniques include “binding or tying the fabric in specific places to resist the dye; clamping the fabric; stitching the fabric to resist dye; and any number of variations on that theme” (Dryden, 1993, p. 97). Through the diverse texture of the fabric, dramatic, interesting, and complicated results can be accomplished. Wada, Rice and Barton (1999) explain that the particular characteristic of shibori is a soft-edge and blurry-edge pattern, which differs from the sharp-edged resist obtained with stencil, paste, and wax. Changing fabric structures may control the randomness or the repetitiveness of shibori patterns. This research will focus on tie-dye (shibori) among the three main resist dyeing techniques.

## **2.2. Techniques of Shibori**

The fundamental technique of shibori is based on fabric that is given a three dimensional form. After dyeing the fabric, it may return to its two dimensional shape. The resulting fabric delicately records both the shape and pressure of the bound fabric form, which are the essence of shibori.

### *2.2.1. Folding*

Fold resist dyeing is created by pleating or by folding fabric so compactly to resist absorption of the dye (Larsen, 1976). Dye reaches the uncompressed parts outside, but may not penetrate to the inside. According to folding positions and methods, diverse techniques are applied such as hand pleating, machine pleating, stitched pleating, double pleating, stripes and dyed band, triangles, tortoiseshell, and lattice (Wada et al., 1999), and numerous geometric patterns are accomplished.

### 2.2.2. *Stitching*

Stitching for shibori is usually accomplished by hand. This method depends on a needle technique of stitching on the fabric. The effects of stitched shibori are different according to the type of stitches and arrangement of stitches such as straight, curved, parallel and area enclosing. When the fabric is stitched as a form of resist, the threads are pulled up, and the fabric is gathered up along the stitched thread and secured by knotting. Stitched shibori requires a tight fabric in order that the fabric in the gathers will resist the dye (Brito, 2002). This is the reason why the gathering threads or cords utilized in the stitching process are required to be strong enough to endure the tension of the pulling up of fabric (Dryden, 1993). Finally, the gathered fabric is dyed. This technique includes wood grain shibori, which uses parallel lines of stitching, ori-nui shibori, which has undulating patterns, Japanese larch shibori and chevron stripes shibori (Wada et al., 1999).

### 2.2.3. *Binding*

According to Wada et al. (1999), the nature of the binding method restricts the type of pattern to circles and modified squares. They quote, “The shape of the cloth, the tension of thread, and the resisting action of the thread determine the configuration of each unit, while the placement, spacing, and amount of thread affect the way dye penetrates” (p. 55). A specific portion of fabric is drawn up by the fingers or a small hook and held while a thread is bound around it. Thus, bound sections of the fabric are undyed across the entire finished fabric (Larsen, 1977). This technique is comprised of ring shibori and dots, spiral and shell shibori, spiderweb shibori, looped binding shibori, and crisscross binding (Wada et al., 1999). It is also a common technique in traditional Indian bandhani, African resist dyeing, American tie-dye, and ancient Andean textiles (Brito, 2002)

### 2.2.4. *Pole-Wrapping*

Arashi, which means “storm” in Japan, was developed at the beginning of the nineteenth century in Japan (Möller, 2000). This technique is achieved by the process of wrapping a fabric around a pole, winding a thread around the wrapped fabric, compressing it into folds, and finally dyeing it (Wada et al., 1999). Through these techniques, various repeating patterns can be achieved in vertical, horizontal, and diagonal directions.

## 2.3. **Contemporary Shibori**

Recently, tied-fabric dyeing has become more advanced by incorporating modern technologies such as electronic jacquard weaving, heat-setting, steaming, chemical treatment and the latest fiber developments. The use of sophisticated colors and the preservation of the three-dimensionality of fabrics gives complex visual effects. Through the work of leading artists, shibori design has gradually become an important part of the development of high fashion and wearable art (Wada 2002). Current advanced computerized-knitting systems may permit diverse creation of three dimensionality including pleated or bound fabrics for shaped-resist dyeing. Therefore,

traditional shibori structures can be newly explored through advanced knitting technology. It is essential to maintain the desirable qualities of the hand processes such as three dimensional structures, random or irregular colorations and patterning while translating these attributes through electronic equipment.

### 2.3.1. Woven Shibori

Catherine Ellis (2005) has developed new approaches to shibori fabrics. Ellis has supplemented the weft and warp yarns in hand weaving to create shibori patterns, including numerous woven structures, such as monk's belt, overshot, twills, and laces. In achieving successful woven shibori, Ellis points out that two-end floats for gathering yarns are generally not enough to get distinct pleat images, but three- or four-end floats will obtain clear resist images. Ellis also mentions that when gathering yarns are removed, they leave small holes and spaces, which are characteristics of the process and not to be avoided in a fabric. In addition, longer floats are easier to pull up due to less resistance as well as result in bolder patterns. On the other hand, shorter floats bring less detail to the pattern (Ellis, 2005). Based on these woven structures a consideration of appropriate knit structures for gathering pleats was explored.

### 2.3.2. Knitted Shibori

Various possibilities of shibori knit design and knitwear design incorporated in seamless knitting technology were developed. For this experimental research, samples were developed on the Shima Seiki SES-124S machine and the SWG-V Wholegarment® machine and on the Fukahara Monarch® circular knit machine. Cotton and rayon were utilized to create sample fabrics, while locked-filament polyester, shrink polyester and Lycra® were used for gathering threads to create knit samples. The knitted samples were dyed with reactive dye stuffs. From the research, it is recognized that resist dye patterning can be successfully accomplished on either circular or flat knitting machines through the creation of gathering yarns composed of knit structures, which are utilized to make three dimensional forms required for resist dyeing. Different knit structure factors of float length, course distance, and placement of tuck and float of gathering threads were also found to have a significant relationship to the resist dyed image. In addition, resist patterns on knitted fabrics can be developed as various complex knitted structures affecting resist dye images by computerized flat V-bed knitting machines. The garment silhouette and size can be affected by the placement of the gathering threads. Variation in the type of yarn and its characteristics such as the amount of elongation in the yarn will determine whether the yarns will remain or be removed in the final garment. When the gathering threads are left in the garment they can be used as further surface enrichment or allow shaping of the garment.

With the ability to control patterning of color, three dimensionality and textures through knit structures and piece/garment dyeing, the development of unique seamless-knitted and resist-dyed garments *were* realized. The placement, scale, and character of the motifs on the specific seamless knitted garment or other product *can be* designed and managed.

### **3. FASHION DESIGN PROCESS**

Designers are generally expected to develop concepts and plans, and the styles that make up the product line. Fashion designers may begin by generating original ideas and sketches for the styles (Glock & Kunz, 2005) or following a leading trend in the market. Knit technical designers and surface or print designers may collaborate with the apparel designer on the textile designs for new fashions. In the production of seamless knitted and resist-dyed garments, designers can take an integrated role in a shortened time by the use of computerized seamless knitting machine systems. Through the digitized CAD system, designers may generate a creative concept and sketch, as well as develop a knit fabric or knitted garment, its style and surface design. After a knit pattern is designed on the CAD system, the machine ‘knit – ability’ of the design can be evaluated throughout the computerized-simulation system. After the process, the data for the design and marking for sizing can be directly transferred to the seamless knitting machine, and a complete garment with resist patterning structures can be created without or with minimal post-knitting operation including linking or cutting and sewing. Therefore, this new integrated process may not only minimize the labor and time to bring new products to market, but also create a different relationship between designer and technician (Black, 2002).

The realization of the designer’s vision or concept may be facilitated through this technological innovation that integrates the technical knit requirements. Furthermore, surface resist patterning can be created during the knitting. After the shibori knitting is complete, the garment can be dyed through a garment dyeing process, usually in a paddle or tub machine creating resist dyeing of the assembled garment. Finally, with additional finishing processes such as steaming or boarding, the seamless knitted and resist-dyed garment can be accomplished. Thus, the combination of advanced digital systems and traditional craftsmanship in knitted shibori may provide new inspiration and possibilities for fashion designers.

### **4. FUTURE RESEARCH**

Based on this research, more advanced knitted and resist patterns will be explored and studied as described in the following areas:

1. The color entropy (randomness), color contrast and color coverage in the different knitted-resist structures can be measured and analyzed.
2. More complicated resist textural patterns created on flat V-bed knitting machines can be explored.
3. The integrated process of knit design and knitwear design incorporated in seamless knitting technology can be expanded.

### **5. REFERENCES**

- Batternfield, J. (1978). *Ikat Technique*. New York: Van Nostrand Reinhold Company.
- Belfer, N. (1977). *Designing in Batik and Tie Dye*. New Jersey: Prentice-Hall, Inc.
- Black, S. (2002). *Knitwear in Fashion*. New York: Thames & Hudson.
- Bosence, S. (1985). *Hand Block Printing & Resist Dyeing*. New York: Arco Publishing Inc.
- Brito, K. K. (2002). *Shibori – Creating Color & Texture on Silk*. New York: Watson-Guptill Publications.
- Crill, R. (1988). *Indian Ikat Textiles*. New York: Weatherhill Inc.
- Dryden, D. M. (1993). *Fabric Painting and Dyeing for the Theatre*. New Hampshire: Heinemann.
- Ellis, C. (2005). *Woven Shibori*. Colorado: Interweave Press.
- Gittinger, M. (2005). *Textiles for This World and Beyond: Treasure from Insular Southeast Asia*. Washington, D.C.: Scala Publisher.
- Glock, R. E. & Kunz, G. I. (2005). *Apparel Manufacturing - Sewn Product Analysis* (4th ed.). New Jersey: Pearson Education Inc.
- Hunter, B. (2004). Technology Transfer. *Knitting International*, 111(1311), p.35-39.
- Krishna, C. (1977). *Batik and Tie-Dye*, Delhi: Hind Pocket Books Private Ltd.
- Larsen, J. L. (1976). *The Dyer's Art: Ikat, Batik, Plangi*. Bershire, England: Van Nostrand Reinhold Limited.
- McIntyre J. E. & Daniels, P. L. (1997). *Textile Terms and Definitions* (10th ed.). Manchester: The Textile Institute.
- Möller, E. (2000). *Shibori – The Art of Fabric Tying, Folding, Pleating and Dyeing*. Germany: Search Press.
- Nawawi, N. M. (2003). Ikat Limar: Investigation on Patterns, Motifs and Production Techniques. *International Textile Design and Engineering Conference*, Edinburgh, Scotland: Heriot-Watt University, Netherdale, Galashiels TD1 3HF.
- Shima Seiki Mfg. (2006). Retrieved May 15, 2006, from <http://www.shimaseiki.co.jp>

Singer, M. & Spyrou, M. (2000). *Textile Arts: Multicultural Traditions*, Massachusetts: Davis Publications, Inc.

Spée, M. (1982). *Traditional & Modern Batik*. Hong Kong: Kangaroo Press.

Wada, Y. I. (2002). *Memory on Cloth - Shibori Now*. New York: Kodansha America.

Wada, Y. I., Rice, M. K. & Barton, J. (1983). *Shibori – The Inventive Art of Japanese Shaped Resist Dyeing*. New York: Kodansha International LTD.

Wada, Y. I., Rice, M. K. & Barton, J. (1999). *Shibori – The Inventive Art of Japanese Shaped Resist Dyeing*. New York: Kodansha America.

### **ACKNOWLEDGEMENTS**

The authors express their sincere thanks to Catharine Ellis, Diana Razulis and Sandy Black.

### **RESPONDENCE ADDRESS**

College of Textiles  
Department of Textile and Apparel, Technology and Management  
Box 8301, NCSU  
Raleigh, NC 27695-8301, USA