Developments in apparel knitting technology

Chapter 9: Knitting Technology

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9.1 Introduction

The days of knitwear's association with harsh woollen structures has long past. In the twenty first century knitwear has become a contemporary fashion item, with many brands utilising the advanced properties knitted garments offer to their advantage. Perhaps knitwear owes some of its most recent success to the changes in lifestyle. Casual dress has become fashionable, resulting in many designers linking with sportswear brands to promote active ranges which benefit from the structural properties of knitted fabrics. Generally speaking knitwear can be classified in many ways, beginning with construction methods. Section 9.2 of this chapter discusses the various knitting construction methods, introducing the reader to the basic terminology used within the industry. Initially the principles of knitting are described outlining common structures used in fashion and clothing applications and their associated properties. Section 9.3 concentrates specifically on weft knitting technology and details are provided regarding the various production methods and recent technological advancements in this area. This leads into a full explanation in Section 9.4 of the shaping technologies commercially available in the weft-knitting sector, including the sophisticated 3-D complete knitted garment production method. To close the shaping section the various auxiliary processes involved in the garments make-up are outlined in Section 9.5, relating specific post knitting construction methods to shaping techniques. Section 9.6 outlines the notable successes in the history of weft knitting within fashion, beginning with the classic fully-fashioned twin-set and moving forward acknowledging the works of pioneers such as MacQueen and Pfäuti and their contribution to the development of complete garment production as we see it today. To conclude, Section 9.7 provides an outline of future knitwear trends. This chapter provides an essential read to fashion/clothing students and designers new to the knitting industry.

9.2 Principles of knitting

The term knitting is used to describe a textile structure composed of intermeshing loops of yarn. There are two types of knitted loop constructions currently utilised in fashion (weft and warp). The first method; weft knitting produces the type of structures commonly associated with hand pin knitting, however, for commercial applications weft knitting is conducted by a knitting machine. The fundamental difference between hand and machine knitting is that every knitted loop produced by a knitting machine has its own individual knitting needle rather than the two pins used in hand knitting (were all the stitches are progressively moved horizontally from one needle to another during the knitting process). Weft knitted structures are easily recognised by the length of yarn forming the knitted loop running continually in a horizontal direction (Figure 9.1). The types of knitted structure produced are most common in T-shirt fabrics and knitted outerwear. The second method of knitted fabric construction is warp; in contrast to weft knitting many individual ends of yarns are running in a vertical direction throughout the knitted structure. This method of construction generally creates a more stable textile and is largely associated with lace, sports and technical applications (Figure 9.1).

9.2.1 Knitting terminology

The intermeshing loop shapes that form the knitted structures are referred to technically as wales and courses (stitches and rows). The wales refer to the number of stitches in the knitted swatch, counting them consecutively across the horizontal axis. The courses refer to the number of wales along the vertical axis (beginning counting at

the bottom and working upwards to the end last knitted), the greater the amount of courses the longer the knitted swatch becomes. The example in Figure 9.1 shows four wales and five courses for both warp and weft knitting.

The knitted loop dimensions can be increased or decreased in size by adding or reducing the amount of yarn fed into the loop shape, this is termed altering the stitch length. There is a limit regarding the stitch dimensions, which is strongly related to the yarn diameter, needle size and the knitting machines needle spacing (the distance in-between each needle). In hand knitting the size of the yarn diameter leads to the selection of the correct needle size hence, thin yarns are knitted using knitting needles of a small diameter. In machine knitting a similar approach is adopted. The hook of the needle becomes larger and the spacing inbetween each needle increases for chunky gauge knitwear and reduces for fine gauge fabric. When referring to modern knitting machinery the needle spacing is represented by a number. This number corresponds to the number of needles per English inch (2.5 cm). Hence, a 2.5 gauge-knitting machine has two and a half needles in every inch (2.5 cm) and therefore produces a chunky knitted fabric, alternatively an 18 gauge machine has 18 needles per inch (2.5 cm) thus, producing a fine lightweight fabric.

9.2.2 Weft knitting - common structures

There are four base structures recognised within weft knitting (plain, rib, purl and interlock), each providing the knitted fabric with unique properties (Table 9.1 provides a quick reference guide for recognising the structures). The most common base structure within fashion applications is plain or single jersey (as it is often referred to).

It is strongly associated with T-shirt materials in fashion applications, and in heavier yarns for the classic knitwear market. The resultant fabric has good drape properties and therefore works well in silhouettes that skim the body. The structure is easy to recognise because it is visually different on the front and back, it has a correct side which should face outwards when worn, (the side which is normally visible during wear, is often referred to as the technical face), although some designers have made exception and used the reverse side of the structure for fashion applications, Table 15.1 provides further details. Usually when plain structures are used in garments they have welts, cuffs and collars made in a more stable structure to prevent the edges of the plain structure from curling (usually a rib structure or a plain structure folded to create a tube). In contrast the second base structure, purl (sometimes referred to by manufacturers as links-links) is very stable (no edge curling). This structure is quite decorative and is used frequently in the manufacture of babies' cardigans, like the plain structure it skims the body rather than clinging. The structure naturally collapses in the length once the knitting takedown tension (applied tension during knitting) has been removed, which results in a heavier fabric than in the plain structure, therefore, providing added stretch in the length and significantly improved thermal insulation properties. The third base structures are those described as ribs, traditionally this structure type is associated with the welts and cuffs of knitted garments. Generally all ribs are extendable structures, which contract to enable the knitted fabric to conform to the body contours. This structure type has become increasingly important in knitted fashion garments – where a tight-fitting silhouette is required and the garment must conform to the body's dimensions. The final base structure, interlock, is rarely used in fashion knitwear. It was originally utilised in underwear, however it has been

superseded by other structures and now finds uses in technical applications were stability is paramount.

9.2.3 Warp knitting - common structures

Prior to examining warp knitted structures it should be acknowledged that there are two general types of warp knitting machinery, which are largely associated with different structure types. The Tricot machines are associated with plain structures, whilst the Raschel machines are linked to open work lace, jacquards and fancy work. Warp knitted structures comprise of yarns that are intertwined in a zigzag formation as illustrated by the shaded wales in the warp structure (Figure 9.1). It is due to this knitting action that warp structures are more difficult than weft knitted structures to analyse, since they cannot be unroved course by course. This distinct feature provides warp knitted fabrics with the positive attribute of being ladder resistant.

Unlike weft knitting were shaping the selvedge is possible it is only possible to knit continuous widths in warp knitting. The simplest warp knitted structure is the basic tricot (half tricot) illustrated in Figure 9.1, however, it is not considered a stable structure and therefore unsuitable for uses in apparel. Once the tension applied during knitting has been released the knitted loops tend to incline. The solution to this problem is to produce a slightly more complex structure termed two bar tricot, which results in a stable fabric. The most popular warp knitted structure is locknit, finding extensive use in the lingerie market.

9.2.4 Warp knitting technology and fashion

Warp knitting can produce a variety of different structure types, providing a whole range of fabric properties; from stretch fabrics used extensively in lingerie and sportswear, to stable structures (and, in the extreme, spacer fabrics) used in technical and medical applications. Fashion applications for warp structures tends to be split into two categories those intended for functional wear which require specific fabric properties (lingerie, sportswear, outerwear) or those garments desiring aesthetical properties – laces, jacquards and nets. In recent years there have been significant advancements in warp lace producing machines resulting in some innovative fashion fabrics utilising lurex and spandex yarns. Despite these advancements the fastest growing users of warp knitted structures are by far the technical and medical industries. Applications find their way into car upholstery and mattress covers through to sophisticated medical implants.

9.3 Weft knitting technology

This technology has advanced significantly from its humble beginnings as a home craft. The development in 1589 of the first knitting machine by William Lee appears far removed from the advanced computer controlled electronic weft knitting machines that are at the forefront of today's technology. Generally weft knitting is more diverse and versatile than its sister technique of warp knitting. However, the weft structures produced during knitting have a tendency to be less stable than warp structures because yarn flows freely from one stitch to another. This factor is generally considered positive because it aids the stretch and recovery of garments, allowing the knitted structures to drape well on the human form and assists in the shaping process.

It is these attributes that attract designers year after year to utilise weft knitted structures in their collections and ranges.

Weft knitting technology can be classified into four general machine types (circular, fully-fashioned, flat-bed and complete garment production), which are discussed in detail in the paragraphs to follow. In terms of fashion and clothing applications knitted fabric can be produced as open width (a flat fabric which requires cutting to create shaped panels to produce a garment), shaped panels (panels that are shaped during the knitting process) or complete garments (garments that are produced with little or no final make-up), the shaping methods are discussed more fully in section 9.4. The machine type and related technology determines which type of knitted goods are produced. When shaping technologies are utilised during knitting the speed is reduced significantly because of the complexity of the transfer action thus, resulting in a more costly garment. Historically, shaped knitted panels (fully-fashioned) were only knitted when expensive yarns were used, the main benefit was the saving in yarn costs because this manufacturing technique eliminated or significantly reduced the requirement to cut. However, advancements in electronically controlled flat-bed machines are increasingly challenging the traditional fully fashioning technology by offering benefits of shaping whist simultaneously creating innovative structures.

9.3.1 Circular knitting

As the name implies circular knitting produces a continuous tube of weft knitted fabric. If the desired product is not tubular, the fabric is usually cut down one length and garment pattern pieces are cut from the open fabric (much the same as woven

garment production). Most single jersey T-shirt fabric is produced in this manner. Single jersey is by far the most popular structure manufactured on circular knitting machines (usually intended for the T-shirt and underwear markets) it can be produced using a variety of fibres form high tech micro fibres for active wear to standard and organic cottons aimed at the high fashion markets. Depending on the knitting cams and needle arrangement of the circular machine other structures and stitches can be produced including ribs, double jersey, purl structures, tuck stitches and miss stitches, which can add aesthetic or functional value to the product. The main advantage of circular knitting is the extremely high speeds in which it produces continuous lengths of fabric, thus, a cost effective production method for bulk products.

Advances in circular weft knitting technology during the 1990s include seamless garment technology. Underwear and intimate apparel have been the main market area for this technology. However, sportswear is predicted to be an area for significant growth in the future, with athletes striving to become more aerodynamic. Santoni is a major player in the development and production of circular seamless machinery. Currently their machines are producing weft seamless garments with the added benefits of jacquard patterning capability. More recently Santoni machines are involved with the manufacture of clothing and garments with integrated multi-sensory electronics to monitor a variety of body functions including electrocardiogram and respiration. It is envisaged that seamless garment technology will benefit from the fashion drive for an active lifestyle with a strong focus on well-being. The major concern with circular seamless production is that there are potentially a small number of seams in the gusset and shoulder seams, which may lead to some confusion in the market place with the use of the term seamless.

9.3.2 Fully-fashioned knitting (traditional)

This technology is traditionally associated with high quality knitwear produced using expensive raw materials (cashmere, merino wool and silk). The advantages of this knitting technique are firstly; the ability to knit shaped panels, thus saving significantly on raw materials in comparison to cutting the shape from a flat knitted panel were a high degree of waste is produced; and secondly a secure knitted selvedge, enabling flatter garment seams to be produced during manufacture. The success of the straight bar frame is accredited to William Cotton for producing a high-speed automatic fully fashioning knitting machine. Thus, explaining the reason why in industry the technology is commonly referred to as the Cotton's patent machine. Historically, this sector of the industry has seen dramatic change and has shown incredible resilience and determination. Its original market was the knitting of socks and the fully-fashioned half-hose. However, the introduction of circular knitting with the advantage of speed destroyed this market. The industry quickly diversified into underwear, only again to be challenged by cheaper manufacturing technologies. Finally the technology of knitting "to shape" took refuge in the outerwear sector. Nowadays the machines are still utilised by some traditional high quality outerwear knitters but are becoming increasingly challenged by the versatility of the modern electronic flat-bed knitting machines.

9.3.3 Flat-bed knitting

In the early days a variety of flat-bed knitting machines were available, capable of producing a vast array of different textured fabric in flat form only. Thus, occupying a completely different market sector than either circular knitting (were it could not compete with speed) or fully-fashioned knitting (producing high quality shaped panels). However, through significant technical and software advancements the modern world of flat-bed knitting machines (often referred to as V-bed knitting machines) has grabbed the attention of the fashion industry. The modern flat-bed knitting machines are of the type that have two needlebeds arranged in an inverted V-shape and cams which enable sophistication patterning (knit, miss, tuck and transfer) combined with advanced shaping to occur. This sector of weft knitting now provides the most versatility in terms of colour, pattern and shaping and is directly responsible for bringing fully shaped knitwear to the forefront of fashion. It is capable of producing highly intricate shaping whilst simultaneously producing complex patterning sequences through combinations of colour and texture. Recent technological advances over the last 20 years, such as the introduction of variable stroke (the ability to knit short strokes) have reduced the times required to knit a shaped garment significantly. Thus, opening up the once luxury sector of fully-fashioned garments to the fashion markets, and designers have not wasted any time in utilising this opportunity to introduce fully shaped acrylic, polyester and viscose garments into their seasonal ranges. During the 1990s knitwear manufacturers have learnt to exploit the advantages of computer controlled electronic flat-bed knitting to produce commercially viable integrally shaped features in the garments (integral shaping is discussed in Paragraph 9.4.3).

9.3.4 Complete knitted garment production

The concept of complete garment production during the knitting process has been traced back to the hand knitting techniques utilising four knitting needles. The famous painting of The Madonna knitting Christ's seamless garment (late 1300) has become widely associated with the idea of complete knitted garment production or 3-D seamless garments. However, the concept of machines knitting complete garments was not considered until much later. Two pioneers (MacQueen and Pfäuti) in the late 1950s both filed patents relating to methods of producing complete knitted garments. Unfortunately these ideas were regarded ambitious and condemned by the industry. During the mid 1960s Courtauld's research division began a study relating to complete garment manufacture, and found that in order to produce garments in this manner more control would be required during the knitting process. This has been a problem associated with seamless flat-bed knitting for many years. The technique of producing a complete knitted garment has been possible using conventional flat-bed knitting technology for some time, but there were problems regarding the complexity of programming, lack of patterning capabilities, takedown, and the poor quality of rib structures during the production.

The commercial launch of 3-D (complete garment) knitting is accredited to the International Textile Machinery Exhibition (ITMA) in 1995. This saw the first generation of machines capable of producing truly seamless knitted garments. A decade later the technology has moved forward to provide us with "Wholegarment" technology from Shima Seiki and "Knit and Wear" from Stoll. Machines capable of producing high quality knitwear, where the structures are engineered during knitting to produce a seamless garment. Today sophisticated clothing can be produced

combining both texture and colour with advanced 3-D garment shaping capacities. This technology is aimed at the western world to enable them to diversify into innovative knitwear markets and lead fashion knitwear forward into a new era. Sportswear and designer knitwear are the obvious choices when predicting areas of product growth for this technology, but there appears to be high interest in utilising this technology for cost cutting within mass production, which is a disappointing step backwards in terms of fashion and functional innovation.

9.4 Flat-bed shaping technologies

The versatility of modern weft knitting technology has paved the way for sophisticated garment shaping to occur. Through advancements in flat-bed technology new method of shaping knitwear have emerged which provide innovative opportunities for designers. Garments produced on flat-bed knitting machines can be classified into four shaping types (Cut and sew, fully-fashioned, integral knitted and complete 3-D garment), which relate directly to the technology type used during manufacture. Cut and sew and fully-fashioned production methods are largely concerned with producing 2-D panels that require auxiliary sewing procedures in order to produce a 3-D garment form (much the same technique as used in woven clothing manufacture); these technologies and manufacturing procedures are well documented by numerous authors including, Brackenbury (1992) and Spencer (2001). Integral knitting in contrast consists of 2-D panels with some evidence of sections taking a 3-D form, but not the garment in entirety. Quite often this is achieved through holding stitches and knitting short strokes (commonly referred to as the flechage technique). The most obvious examples of this technique include knitting collars, lapels, stoles, pockets, and

buttonholes as part of the panel. Integral knitting removes the requirement for some of the auxiliary sewing processes. The technology type used in the most advanced shaping method (3D complete garments) has the capability to remove all of the auxiliary sewing processes, hence, producing a knitted garment in its entirety. In addition to this level of shaping sophistication it retains the versatility to produce advanced patterning within the knitted structure and the ability to produce 2-D panels (cut and sew, fully-fashioned and integral knitting) if desired.

9.4.1 Cut and sew

As the name implies this manufacturing technique involves the production of continuous lengths of knitted fabric. The fabric is then removed from the machine laid flat and shaped panels are cut from paper/card templates. Once the panels have been cut to shape they are joined together using an overlocker machine (see Paragraph 9.5). Traditionally in cut and sew knitwear manufacture, ribs, welts and cuffs have been attached separately as part of the making up process. Hence, the knitted fabric may have been produced on a circular or flat-bed machine in a continuous length. During the 1970s skinny ribs were mass-produced for fashion application using this method of production. Later, the birth of the first fully electronic flat machine enabled jacquard to be combined with many stitch variations, which firmly placed flat-bed cut and sew knitwear at the forefront of the fashion arena. Knitwear dominated fashion in the late 1970s and early 1980s (Brackenbury, 1992) with highly patterned fabrics becoming the vogue.

The second method of cut and sew referred to by some experts as stitch shape cut (but often termed “knit to width and widen” by the industry), was again a result of innovation within flat-bed technology. During the late 1980s commercial flat-bed machines were introduced with a reversible motor (enabling variable stroke knitting to be conducted). This significantly reduced the time taken to knit a small width of fabric and enabled body panels to be knitted to the exact width and sleeve panels to be widened out from cuff to the widest point of the sleeve (sleeve widest); the requirement for the armhole, sleeve head and shoulder shapes to be cut still remained (Figure 9.2). Historically, cut and sew manufacturing methods have been associated with high fashion garments often produced with less expensive fibres. The advantages of producing cut and sew, are quick production times and easy style changes.

9.4.2 Fully-fashioning

Fully-fashioned knitted garments are knitted panels where the shaping process has been conducted during knitting. Individual garment panels are shaped through the re-positioning of wales (stitches) during the knitting sequence, hence, changing the number of active needles. To form the armhole shape, an action termed narrowing is employed; this is the movement of a single wale or groups of wales towards the centre of the garment (thus reducing the knitting width). In most cases two needles are reduced in each subsequent movement (Figure 9.3 illustrates a narrowing of 1 needle every 4 courses in the armhole area). If the width of the panel requires increasing, extra needles can become active gradually during the knitting sequence (this is termed widening). Fully-fashioned knitwear was historically associated with the luxury market sector, since the technique was used to save yarn during knitting (no or a very

small amount of cutting in the neck areas was required). However, modern flat-bed knitting technology, through electronics and advanced software has opened up the technique of fully fashioning to a wider sector of the industry. In addition to shaping, the modern flat-bed knitting machine has the added advantage of combining complex colour and pattern sequences. Much of the fashion knitwear on the high street is produced utilising this shaping technology and this is the biggest threat to the classic fully-fashioned manufacturing method.

9.4.3 Integral

The original drive for the development of integral knitting technology was to eliminate as many, post knitting operations (sewing - attaching trims and pockets etc.) as possible thus, producing savings in post knitting operations. However, advancement in programming software has lead to innovative style lines being produced with waist shaping and integral circular welts as buttonstands, not to mention the significant developments in technical textiles. With the improvements in takedown control during knitting, more controlled areas of integral shaping are now possible in garments resulting in styling innovation for fashion applications, which have not previously been commercially possible.

9.4.4 Complete garment

The concept of producing a complete garment that requires minimum or no sewing operations has been around for many years, Paragraph 9.3.4 outlined the notable areas of innovation, landmarks and pioneers. 1995 was a key date for the commercialisation

of this technology and since then there has been much development. The basic method of producing complete knitted garments is to knit the two sleeves and body independently on a tubular basis (sleeve–body section–sleeve). Hence, three separate tubes are manufactured; this in itself is easy to understand (Figure 9.4). The complexity occurs when the three tubes need to be joined together during knitting to form the shoulder part of the garment, Figure 9.4 illustrates the basic process. Since its launch commercially complete knitted garment manufacture has significantly improved in terms of patterning and shaping capabilities, through sophisticated programming software and advancement in takedown control. Many patents exist relating to various specific techniques involved in the shaping process and methods of production. Two flat-bed machine builders who are leaders in this area are Shima Seiki and Stoll both having dedicated flat-bed knitting machinery to produce complex 3-dimensional garment shaping whilst still retaining the versatility to knit pattern and texture.

9.5 – Post knitting - construction methods

The construction methods used to join the 2-D garment panels produced on a flat-bed machine differ depending on the shaping technology selected during manufacture. If the cut and sew method has been utilised it is important that the cut edge is secured completely. To ensure the seam is fully secure an overlocker type of machine must be used. It is most common to use the three-thread type to ensure the seam is secure and the raw (cut) edge is bound securely. The advantage of a three-thread overlocker is the extensibility it provides in the seam. Often the seaming thread is core-spun polyester

whilst the cover threads binding the raw selvedge edge are polyester bulked threads to provide maximum cover and flexibility.

9.5.1 – Alternative post knitting construction methods

The traditional construction method associated with fully-fashioned shaped panels involves a manufacturing technique termed “linking”. This is an expensive and time consuming process, which is heavily reliant on a highly skilled operator. It involves sliding individual knitted loops onto metal points from each of the two panels that are to be joined. Each linking point holds two loops; one from the front panel and the second from the back panel, once all the loops have been placed on the individual points a chain stitch secures them. The advantage of this method of construction is that when a course of wales are joined (producing a horizontal join) there is no visible seam inside the garment, the linking join lies perfectly flat to the body. Alternatively, if the selvedges of the shaped panel are joined using the linking technique (producing a vertical seam, it is often referred to as waleing in the industry) a visible seam is the result. This seam type is relatively flat if compared to an overlocked seam.

A less expensive method of joining fully-fashioned selvedges is a technique called cup seaming. This operation is much faster than linking and does not require the same level of operator skill. The machine derives its name from two large metal cups, which the selvedge of the garment is fed into. A continuous chain stitch and a small seam are formed (2-4 wales depending on the gauge), the resultant seam is not of the same precision as a linked seam, and may appear unstraight on some knitted structures. Cup seaming is not suitable for insecure knitted edges (most shoulder seams), so quite

often the resultant garment is a combination of shoulder areas that have been linked and cup seamed selvedges.

9.5.2 – Cost cutting construction methods

Outlined in the above paragraphs are examples of low, medium and high quality construction methods. Of course this list is not exclusive and other methods do exist. Brackenbury (1992) provides significant detail regarding various knitted garment construction methods, complete with fully illustrated diagrams for a more comprehensive read. Historically it was relatively simple to relate the shaping method used with the appropriate garment construction technology. However, with the fashion industry exploiting the versatility of flat-bed knitting machines these boundaries have blurred significantly. What looks like a high quality fully-fashioned shaped garment at first glance may not be constructed using the traditional high quality construction techniques. One popular combination in the high street fashion knitwear is to shape the armholes during knitting but cut the shoulder shape post knitting and overlock the seam. Hence, the armholes bear resemblance to high quality traditional fully-fashioned knitted garment (costly and highly skilled post knitting manufacture), whilst the shoulder seams use a lower quality construction method (less expensive and less skilled). Perhaps the shoulder seam is considered less important in fashion applications because of its position and the armhole is considered essential because it is a visible aesthetic styleline.

9.6 – Weft knitwear in fashion applications

Knitwear has been utilised in fashion for many years perhaps the first example of designer knitwear should be credited to the Elizabethans and their desire for the highly embellished finest knitted silk stockings. Historically knitwear has diversified from hosiery to underwear and finally outerwear. During the 1920s knitwear took two different directions, fashion knitwear found new uses for cut and sew jersey in outerwear applications (such as dresses), and the great leisurewear boom (Brackenbury, 1992) provided a market for the more expensive classic fully-fashioned shaped knitwear to thrive. By the 1930s classic British knitwear was recognised as the world leaders, Pringles had appointed its first knitwear designer in response to the growth in continental knitwear fashions (Gulvin, 1984). Designer knitwear in its true sense was born; the ladies twinset grew in popularity both in Britain and abroad. After the war years (late 1940s) fashion generally saw a dramatic change in styling. The glitz of Hollywood was the stage for fashion. The general population looked to the stars for inspiration. Classic knitwear styles became the vogue of women's style. With many celebrities adopting the classic fully-fashioned British twinset (Gulvin, 1984).

9.6.1 – The growth of flat-bed knitting in fashion

Flat-bed knitting machines historically were used to produce trims. This was due to the fact that they could not compete with the traditional fully-fashioned machines shaping capability, or the speed achieved by circular weft knitting. However, the first motor driven jacquard flat-bed machine in 1926 changed the role and contribution of this machine to fashion. It provided knitwear designers with patterning capabilities that had not previously been possible and thus established itself a unique place within fashion. Over the next few decades the flat-bed machine was transformed from a

mechanical mechanism to a highly sophisticated computer controlled machine that was capable of advanced shaping and patterning simultaneously. The next paragraph highlights the key developments in flat-bed knitting from the pioneering work in the late 1950s of MacQueen and Pfäuti and the effect these developments had on fashion.

The value of MacQueen and Pfäuti's works relating to complete garment production like so much innovation was not really valued until much later in history when the knitwear industry began to evolve naturally into 3-D knitted garment production. However, it prompted investigations into complete garment production by the Courtauld's team (although never commercialised), which lead to the development of the presser foot in the late 1960s. The introduction of the presser foot to commercial machinery at ITMA in 1975 brought about a new era for patterning capabilities in flat-bed knitwear. A second notable development in the early 1970s was the first flat-bed machine with electro/mechanical selection, this enabled jacquard patterning to be conducted easily (Hunter, 2004). Finally in 1975 the first fully electronic flat-bed machine was introduced by Stoll (Spencer, 2001). All these developments influenced fashion knitwear resulting in a boom in the 1970s and 1980s especially in the ladies fashion markets (refer to paragraph 9.4.1). This was assisted with design education catching up with the new technology (Brackenbury, 1992). The designer's of the time optimised bold patterning, assisted by the advancement in computer controlled knitting during the 1980s. However the most notable development flat-bed knitting has had on fashion is in the area of shaping. In 1987 a knitting machine was developed that was equipped with variable stroke, this caused a shift in fashion especially during the 1990s. Shaping now became cost effective in lower quality yarns and could be combined easily with colour and texture. Traditional British knitwear brands linked

with prominent designers and for the first time flat-bed knitting technology and its produce began challenging traditional classic manufacturing techniques. The 1990s were about exploring the new technological developments and its implication in terms of fit and style – the machine capabilities were pushed to assess the limits of the technology.

By the mid 1990s knitwear stylelines had become more tailored especially in rib structures and integral knitting opportunities were beginning to be exploited within shaped knitwear. 1995 saw knitwear technology mature with the introduction of the first generation of complete garment machines. It has taken time but slowly complete garment production has evolved, becoming increasingly commercialised, with some retailers choosing to acknowledge this method of production on the swing tags whilst others are simply retailing the knitwear (perhaps without the consumer ever realising the garment has no seams). Knitwear has become a key item of clothing in the fashion market, fashion authors such as Sue Jenkyn Jones (2005) acknowledge knitwear's significance in fashion, especially in the new sports and active wear collections. Today the flat-bed machines versatility cannot be superseded by the other knitting technologies. Flat-bed knitting technology is the driving force behind knitwear's innovation in fashion. Exploring and exploiting the opportunities require great technical expertise and competence, and often results in the designer and technician working as one.

9.7 – Trends in weft knitting

Knitwear has gained enormous popularity in fashion applications due to its unique comfort properties, which are derived from its structural configuration. Recent lifestyle trends have resulted in casual dress becoming more readily accepted in fashion generally, and as a result fashion outlets have been awash with knitted styles. Foreign imports from cheap labour countries are breaking into new markets by devising new garment construction methods to simulate quality knitwear techniques and as a result more shaped knitwear is available in value retail outlets. This has forced many luxury retailers to look towards new technological advancements in knitting machinery to provide inspiration in terms of quality and design capabilities.

Fully-fashioned shaped weft knitwear has and will remain popular for the foreseeable future in both the high street and the designer collections. New technologies and programming software in the weft-knitting sector have opened a window of opportunity for innovation in terms of combining patterning, texture, shaping with superior garment fit. There is still further development to be explored regarding the newest weft knitting technologies in the marketplace. However, it can be predicted that this will be exploited primarily in the luxury sector, elevating it to even greater heights for innovative knitwear styling.

9.7.1 – Exploiting complete garment knitting

Since the commercial birth of complete garment knitting in 1995 the needs and dynamics of the apparel industry have somewhat changed. Initially the industry was slow to adapt to the idea of complete garment production probably due to style shaping constraints. However, the new generation of complete garment weft knitting

machines have become easier to use and more reliable. The markets acceptance of the technology has fuelled an expansion in the development of product and manufacturing knowledge which has resulted in complete garment technology becoming more wide spread in fashion applications. Since the birth of the new Millennium there has been a steady stream of styles appearing in the commercial market place in both designer and high street collections. There are ample marketing opportunities to create customer awareness within the brands, some of the larger retailers are already beginning to exploit this by introducing swing tags on their merchandise, thus introducing customers to the value added benefits this technology offers. Complete garment knitting technology has evolved to be dynamic and is now accepted in the global community. Words such as “Wholegarment” and “Knit and Wear” link us to specific complete knitting technologies developed by global leaders, and it can be predicted that there is likely to be further significant growth in the clothing and fashion markets. Currently the world’s industries are still in the experimental stages regarding complete garment production and there are many avenues to be explored and developed, providing interesting innovation opportunities.

9.7.2 Complete garment technology providing competitive advantage

The technology in general appears to be advancing along three paths; firstly the companies utilising it to save production costs, some garments can be produced in entirety in as little as 30 minutes. This is increasingly important with the growth in fast fashion in the global fashion industry. The requirement for shorter lead times as a result of labour reduced production is becoming more popular, perhaps providing companies with the luxury of keeping a proportion of their production near to their

consumer markets rather than relying in entirety on low cost countries. Secondly the companies who are developing new styles and utilising the benefits of fit, in the luxury ends of the markets. Lightweight complete garment knitwear is now possible, making knitted styles available that are both fashionable and functional with beautiful silhouettes conforming to the bodies' dimensions. Finally the largest area of predicted growth lies in the active sportswear markets, were performance and functionality is paramount. Perhaps the biggest opportunity for complete weft knitted garments will be to challenge the circular machine's stronghold in sports apparel, producing garments that are both functional and fashionable.

9.8 – Additional Information

Many of the general textile publications cover some aspects of knitting technology. However, for more specific information David Spencer's (2001) 'Knitting Technology' (currently in its third edition) provides in-depth information regarding the fundamental principles of both weft and warp knitting and the complex aspects of knitting science. Various different knitting machines and related technologies are discussed in detail. The breath of this publication appeals to both scholars and professionals alike covering a wide range of applications in knitwear from clothing/fashion through to advanced technical applications. Further information relating to knitwear and knitted garment technology can be found in Brackenbury's (1992) publication. This provides a comprehensive read into issues relating to weft knitted shaping technologies (with the exception of complete garment) and post knitting construction methods. The reader will value the many illustrations to assist with the understanding of what otherwise may be considered complex processes.

In terms of innovation in knitwear design, 'Fashion Design' (Jenkyn Jones, 2005) predominantly focuses on the fashion industry and is intended for fashion scholars. However, it is interesting that this publication separates knitwear opportunities from mainstream womanswear thus demonstrating that specific skills are required for designers intending to pursue their career in this sector of the fashion industry. Throughout the book there are snippets of valuable information related specifically to knitwear, illustrating knitwear's growing significance in high fashion markets. A further publication entitled 'Knitwear in Fashion' (Black, 2002) also supports knitwear's place as an item of contemporary fashion. Black's publication encompasses knitwear as an art form including sculpture and many examples of contemporary designer knitwear are provided. Throughout the book there are beautiful illustrations and specific reference is given to new technologies that have impacted on fashion knitwear.

Despite the usefulness of specific publications relating to the knitting and knitwear industry, technology is advancing at such a pace that journal publications offer the most up-to-date comprehensive read. Information regarding trend innovation, technological advancements and marketing briefings are readily published to keep the industry abreast of the new developments. Knitting international provides an archive of information related to the knitting technology evolution, including reviews from machinery (ITMA) and trend exhibitions. In terms of marketing information Drapers provides a valuable source of knowledge and up-to-date information regarding current and predicted market trends in both fashion and knitwear markets.

Referencing

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