9.0 Seamless knit and its application

Dr Kathryn Brownbridge

Manchester Metropolitan University

Dr Kathryn Brownbridge is a senior lecturer in fashion design at Manchester Metropolitan University. Her research is focused around body related matters within clothing product development. Recent publications have been concerned with the use of body measurement within complete garment knitting, the impact of the aspirational body within the design and development process and consumer issues around size and fit.

Table of Contents

9.1 Introduction

This chapter will focus on two different types of weft knit technologies that are associated with seamless garments; circular machinery and flat bed machinery.

Circular knitting traditionally produces a tube of fabric and is commonly used to produce hosiery. When used for garments the tubular structure is often cut down one side and opened out to create a flat length of fabric (Brackenbury 1999), which is cut into the component parts of a garment and sewn together. This technique is similar to the process used for woven garments and clearly creates a garment with seams. However a more recent application is to utilise the tubular structure to create partially formed garment parts, namely the tubular structure becomes the body and sleeves creating a garment with less seams.

Flat bed knitting machinery was originally only used to produce lengths of knitted fabrics. However the drive to decrease labour and costs and save cutting waste have driven the development of many machine improvements that have increased capabilities including the ability to construct garment panels. Perhaps the most innovative development has been the ability to construct tubular garments that can be constructed and assembled in one process, creating a garment that has a completely seamless structure.

9.1a Circular seamless knitting

Circular weft knitting machinery is traditionally used for hosiery. Developments came from the Italian machine builders Lonati in 1988, who were aiming to extend the capabilities of the machinery to knit seamless underwear. This led to the creation of a new company, Santoni who were promoted as specialist producers of machines with the capability to knit what was claimed to be seamless garments. It is however important to stress that although the body and sleeves can be knitted without seams, these component parts must be constructed once they have been knitted. Therefore it is perhaps a misnomer to call garments knitted on circular machinery ‘seamless’ (Semnani 209; Power 2012). Circular machinery is highly efficient and has a higher productivity rate than flat bed machinery (Broega et al. 2009). Santoni are still generally acknowledged to be leaders in seamless knitting, produced on circular knitting machinery.

Circular machinery is capable of producing fine gauge knitwear but it is difficult to create patterns and sophisticated garment shaping (Spencer 2001; Power 2008). It is also difficult to change the diameter of the seamless knitted tube (Semnani 209), a considerable limitation in terms of garment design and the ability to fit the complex shape of the body. Selective use of the circular needle bed can however enable the designer to knit garment shapes, other than a basic tubular construction.

Insert figure 9.1 Circular knitted garment

9.1b Complete garment knitting

Previous to the development that enabled complete garment knitting, fully fashioned garments were knitted on straight bar machines as shaped panel pieces, then constructed using a separate post-production process (Spencer 2001). Since the 1940s it had been the aim of many knitters to develop methods that enable complete garments to be produced on flat bed machinery. It is easy to understand why this capability would be beneficial, as it not only eradicates the need for time consuming post-production processes but it also minimises waste. A considerable number of different methods were patented but none were commercially viable until 1995 when Shima Seiki launched WholeGarment® technology at the International Textile Machinery Association (ITMA) (Gibbons 1995). The German company Stoll also made important developments that enhanced commercial viability (Gibbons 1996). Shima Seiki and Stoll are at the forefront of commercial application. Although Shima Seiki have patented their machinery as WholeGarment® and Stoll have coined the term ‘Knit and Wear’, Complete garment technology is a term commonly used to describe flat bed machinery with this capability.

9.2 Implications of knitted fabrics on garment fit; knit structures

The structure and properties of a knitted fabric influence the way a knitted garment fits the body. Weft knitted fabric is extensible across the width, the length and diagonally. Its extensible structure enables it to mould itself to a 3D shape through deformation (Power 2004). These fabric properties impact on the way a knitted garment relates to the shape of the body, allowing it to stretch and move on the body much more comfortably than a woven fabric would. Because of this it is possible to wear tight streamlined knitted garments without restricting comfort even when the fibres are non-elastic.

Having an understanding of different knit structures and their properties helps designers and product developers create garments that fit. It is possible to categorise three basic groups of knitted structures: Plain structure consisting of loops, which are all identical and intermeshed in the same direction. These structures are all face loops on one side and all reverse loops on the other. A rib structure is made of alternating face and reverse loops and the number of needles used to create a rib can vary. A two by two rib, for instance, is created by alternating two face and reverse loops at a time. Purl structures consists of alternate courses of back and face loops.

Insert Figure 9.2 (Face and back loops)

Each different knit structure has a range of differing properties which will impact on garment shape and ultimately on the way the garment fits the body. A knitted rib collapses across the width when relaxed, decreasing the dimensions of the width and increasing the thickness of the fabric. When tension is exerted across the rib courses the fabric is reported to extend up to 120% (Brackenbury 1992). Knitted ribs will therefore reduce the width of the garment if it is integrally incorporated into a plain knitted garment without compromising comfort. Ribs have traditionally been used to create shape within a garment, often to provide a snug fit on the cuffs and welt (bottom edge of the body panel). However designers can also insert bands of rib in other areas of the garment to create shape particularly effective at the waist where the body narrows. This practice exploits the rib structure's propensity to expand and contract. A plain knitted fabric extends more across the courses than the wales. It is therefore common practice for the courses to position the courses horizontally on the garment to exploit this increased extensibility where it is needed most. A purl knit which is less commonly used within commercial garments, contracts longitudinally. It therefore has more lengthwise elasticity than a rib or plain knitted structure (Raz 1993). Experienced knitwear designers will have a good understanding of how to use knit structures, evaluation of the properties of knit structures however, tends to be made by the technicians using their experience and judgement (Brownbridge 2010).

Insert figure 9.3 (Knit structures)

9.2a Application of body measurement

To create knitted garments that fit the body, it is important to have a method of applying body measurement within product development processes. For woven garments it is the pattern cutting process that translates body measurement from size charts into flat patterns and then through to flat fabric pieces. These are then constructed to make three dimensional garments. For knitted garments the pattern making process uses a calculation to translate key body dimensions such as chest, shoulder and waist into stitch numbers. This calculation is based on the stitch density, which is the number of loops in a given area of knitted cloth.

As knitted structures differ greatly from woven ones, the key body measurements used to achieve fit are also different. As a consequence of their extensible qualities, knitted garments tend to conform to simple flat shapes without darts, seams or other methods used when developing 3D shape for more stable woven garments. Commonly on women's knitwear, a bust girth measurement is not used and garments are unlikely to include bust shaping. The fit of these simple garment shapes clearly relies on the knitted fabric's ability to stretch and mould to the body. To achieve woven garments that allow for comfort and movement of the body, an extra allowance is added to body measurement, namely ease allowance. Extensible knitted garments do not always include ease allowance and garment dimension can conform to body measurement and still produce a comfortable fit. The degree of ease needed to achieve fit on knitted garments can vary from a negative amount to a positive amount at differing body regions and will depend on the style and type of fit that the designer is aiming to achieve. Historically it tends to be garment measurement rather than body measurement that is used to guide the process of defining garment dimension. Knitwear manufacturers therefore work from previously established garment measurements, often generated through trial and error.

9.2b Creating garment shape through stitch manipulation

When knitting on flat bed machinery, shape can be created through adding or reducing stitches, a technique known as fashioning. To increase the width the knitted loops are transferred onto a needle outside the selvedge edge, narrowing is done by transferring a loop to a needle inside the one that the loop was previously attached. This needle will then cease knitting. It is also possible to transfer a number of loops to create a loss or gain in fabric dimension within the body of the fabric. The smallest dimension that can be gained or reduced will only ever equal the stitch dimension. It is not possible to create the required dimensions with the same precision as it is when cutting garments to shape.

The angle created by the fashioning process can be controlled by the number of courses that are knitted between each fashioning course (fashioning frequency). It is also possible to transfer more than one loop at a time to create a more acute angle. There are methods of integrally shaping in order to create 3D contours within the garment which serve the same functions as a dart, used in woven construction (Black 2001). However this method has not been widely used in traditional industrial knitting. It has been argued that in order to develop knitted garments that have a more sophisticated approach to achieving fit it is necessary to use shaping in order to achieve 3D shapes that relate to the shape of the body (Guy 2001; Haffenden 2009; Brownbridge 2012).

9.3 Seamless garment fit

Machinery that has the ability to construct garments three dimensionally such as complete garment technology implies the possibility of creating a product that can conform to the three dimensional shape of the body. The process of shaping complete garments however relies on the capabilities of the machinery and its operator. There are difficulties associated with knitting tubular garments on flat bed technology. Shaping the garment is limited by the number of needles available on which to knit and transfer. The body and sleeve tubes must commence knitting on specific needles with an exact number of available needles between each tube. These needles are introduced to create underarm widening. The three tubes must meet at the correct location to merge. The sleeve tubes can then be gradually moved across and narrowed to eventually create the neck dimension. This is a complex operation and is not easy for technicians to master (Brownbridge 2012). There are, however knitwear teams who are successfully exploiting the ability to knit three dimensionally and create garments that have 3D shaping.

Figure 9.4 (Seamless draped top) shows an example of a garment where an integral shaping line has been incorporated on the back and the front of the garment which creates a 3D draped shape. Further shaping is created on the lower half of the body to enhance the 3D garment shape. Figure 9.5 (detail showing integral shaping) shows a close up of the widening technique where every three courses become one. The image reveals that it is only the courses on the left side of the shaping line that are lost. The courses on the right hand side remain constant. Figure 9.6 (detail showing integral shaping incorporated into pointelle panel) shows that more narrowing occurs running into the pointelle pattern. Insert images 9.4

(Seamless draped top), 9.5 (detail showing integral shaping) and 9.6 (Detail showing integral shaping incorporated into pointelle detail) here.

The process used to create circular knitted seamless garments is far more limited in terms of stitch manipulation as a method of shaping. It is therefore a more limited knitting technique and perhaps more difficult to create shape innovation.

The garment pressing process which, in the fully fashioned industry generally uses a wooden frame which is custom made to specific dimensions in order to maintain and set garment dimension (known as boarding) will also affect the stitch density. Fully fashioned practices are still used for complete garment production and this has been found to cause problems as the structure of the complete garments tend to be far less formulaic in shape than traditional fully fashioned styles. The seamless structure of complete garments also means they are less stable and more difficult to press flat. These differences have been found to render the use of frames obsolete. This makes the finishing of complete garments difficult.

11.5 Seamless knits and their application within sportswear

Seamless knitted garments have been available to the consumer for a number of years and some forward thinking knitwear manufacturers have embraced the opportunities this method of knitting offers in terms of technical sportswear development. The following sections outline how the use of seamless technology can create functional features that meet specific needs of the sportswear consumer in terms of comfort and sportswear aesthetics.

9.5a Garment comfort

Comfort is a garment attribute that the consumer seeks and is particularly important for sportswear as it can affect performance. The evaluation of comfort from a consumer’s perspective is subjective and complex as it takes into account a number of various factors. Studies relating to comfort tend to list these factors separately as follows.

Sensorial comfort in relation to garments includes the subjective evaluation that the wearer makes about how the garment feels against the skin. It has considerable bearing on the comfort properties of seamless garments because clearly the lack of seams eliminates any potential for seam abrasion caused by rubbing against sensitive areas of skin. This is clearly advantageous for sports garments, particularly those worn next to the skin, such as base layers and swimwear (Broega et al. 2009).

Ergonomic comfort relates to the ability of the wearer to move easily within a garment. In relation to seamless garments it has been noted that the customer should experience heightened ergonomic comfort as the seamless structure is claimed to be able to stretch and mould to the body more effectively then a knitted garment with seams (Brownbridge 2012).

Thermo-physiological comfort is when a person is satisfied with the thermal environment. To sustain thermal comfort the production and loss of heat from the body must balance. In addition to clothing, a number of factors can impact on the thermal environment including: humidity, air movement, air temperature and activity. Thermo-physiological encompasses heat and moisture that is transported through the body and impacts on a person's ability to regulate their body temperature. Wicking is a process that transports moisture away from the body. Knitted fabrics have a capacity to absorb water. This will vary depending on fibre content and knit structure. Knitted fabrics also have insulation properties because the knitted structure traps air which acts as an insulating layer and differing knit structures have different thermal insulation properties. Fibres vary in their ability to insulate and therefore can be used strategically within garments to target areas of the body that need more insulation than others. This is where the ability to use a variety of knit structures within one garment is advantageous (Abrue 209). Figure 9.7 (Circular knitted garment incorporating a variety of knit structures) shows a garment that incorporates a variety of knit structures mapping different areas of the body, 9.8 (Detail of differing knit structures on sleeve) shows a detail of the knit structures on the sleeve of the garment.

Insert figures 9.7 (Circular knitted garment incorporating a variety of knit structures) and 9.8 (Detail of differing knit structures on sleeve) here.

Psychological comfort relates much more to how someone feels in a garment and will be more influenced by factors such as styling, colour, fashion and aesthetics. When relating psychological comfort to sportswear, garments that are perceived to look and feel as if they will provide high performance may also provide the wearer with higher levels of psychological comfort. Psychological factors may also relate to how effectively the garment provides thermal, ergonomic and sensorial comfort to the wearer in order to create a sense of wellbeing and psychological comfort.

9.5b Garment aesthetics

Through the use of both circular and flat bed seamless machinery it is possible to use a number of different knit structures and patterning details within one garment. In addition it is possible to vary the types of yarn on specific areas of the garment. This enables designers to create patterns, textures, surface design and styling features. The use of elastomeric (stretch) yarn can reduce the diameter of the tubular structure, without the loss of comfort to the wearer. This can introduce body shaping, structure to the garment which will have an impact on the aesthetic and could be used by an informed designer to create aesthetically pleasing garment shaping (Broega et al. 2009).

The ability to map the body with the garment and create zoning areas that function differently creates a sports aesthetic, which suggests innovation and high performance. These garments draw attention to muscle groups and use body contour panels, a technique that not only has functional value but also is becoming accepted as signalling that this garment is designed as a high performance sports garment for a high preforming sports body. The performance aspects of seamless garments have therefore also created the aesthetic aspects. Not only does the garment aid performance but it looks like it aids performance and arguably this will increase psychological comfort for the wearer.

Complete garment technology has the ability to shape the garment three dimensionally and this can create an innovative aesthetic. Unbroken patterns, striping, and pointelle structures can be knitted around the whole circumference of the garment, particularly effective when used on a yoke. The stitch manipulation techniques (fashioning) used to shape complete garments form a visible patterning within the knitted fabric. This can be aesthetically pleasing and can draw attention to innovative shaping techniques and consequently in aesthetic terms makes the garment look like a product of sophisticated engineering.

9.6 Specific fit related opportunities

Body mapping can also be described, as comfort mapping and is a technique that is gaining popularity amongst sportswear developers. It is hoped that through in depth analysis of functional requirements of differing parts of the body, in relation to temperature, moisture control and the consideration of skin sensory needs, the need to wear multiple layers will no longer be necessary. Different knit structures and a variety of fibres with a range of abilities to insulate, ventilate, and control moisture are placed where they are needed on the body. The chest area, for instance, may be matched with a wind chill panel whereas the underarm will have wicking and breathable panels. In terms of fit this type of development creates opportunities to link anthropometric (the study of body measurement) research with technical garment development. Santoni have developed two methods that are claimed to help regulate temperature control by targeting specific areas of the body: firstly the use of mesh like knit structures to allow venting within regions of the garment such as the underarm, to help the body lose unwanted heat and the ability to create thermal pockets which are effectively double layers of fabric that are strategically placed to trap heat at areas of the body that are more vulnerable to heat loss.

If the specific areas of the garment must map to specific areas of the body, in order to achieve this end, it must be presumed that development should include a sophisticated understanding not just of the functions of the body but also body size, shape and proportion. In terms of the development of sizing systems for such garments, it would seem logical that this type of body mapping approach would demand a more sophisticated sizing system which would take into account the variety of heights, body shapes and sizes within a population in order for the mapping to function correctly.

The use of panels to compress specific muscle groups is another area of development, which creates opportunities for further study in relation to anthropometrics. These panels are knitted with extremely elastic yarns. They are said to have a number of benefits to the sportsman including reduction of muscle strain and the time it takes for muscles to repair themselves. There are also claims that compression panels can increase performance by improving oxygenation to working muscles. In terms of fit any compression panel incorporated within a sports garment must be located on the correct muscle group when being worn. Therefore for garments that are mass produced, the addition of compression panels that must conform to very specific regions of the body introduces additional fit complexities when creating sizing systems. The knitwear industry

It therefore may be difficult for some consumers to get the full benefit from these highly technical garments because they are not made for their body dimensions.

9.7 Current limitations within the industry

Currently the seamless technology (circular and flat bed) that is available to knitwear producers is expensive and requires a high level of design and technical skills in order to fully exploit its advantages. This is a relatively new type of manufacturing process and requires a considerable amount of research and development work. In the current economic climate, it is perhaps a more logical choice for knitwear producers to reduce both costs and risk taking decisions rather than in invest in the development of new and innovative products. Consequently although there are a growing number of sportswear companies who specialise in seamless knitted garments, it is perhaps a market that is yet to be fully exploited.

In terms of fit there is evidence to suggest that although knitwear is stretchy and therefore there is an assumption it will fit a wide variety of body shapes and sizes, there is still a need for fit improvements.

Complete garment development forces practitioners to consider all the component parts of a garment simultaneously which challenges traditionally trained personnel. Difficulties can occur when shaping the armhole for a set in sleeve and the desired effect is not always achieved. Various factors have been blamed for this including: fashioning restrictions, a lack of previous knowledge to draw on and no available garment templates or patterns on which to base methods (Troynikov 2008). The lack of templates is related to the fact that the technology is still relatively new. It is therefore likely that some of these restrictions will be alleviated as those who are driving development become more skilled and knowledgeable. The restrictions in shaping may also have originated from the fully fashioned industry where there have always been inconsistencies and inaccuracies in the methods used. There is also a lack of attention paid to the application of anthropometric data within the knitwear industry, which could well have a detrimental affect on the development of new methods for seamless garments.

There is however a further restriction that relates to the acquisition of appropriate skills and knowledge and that is the propensity within the knitwear industry to protect intellectual property with patents. The machine builders themselves have actively been developing new methods of knitting garments. In 2002 an interview with the president of Shima Seiki suggested that only one percent of machine capability was at the time being exploited (Mowbray 2002a). Whilst this statement is making claims for a vast, untapped potential, it also acknowledges a skills and knowledge gap within the industry. Shima's response to this need for new knitting techniques was to produce 2500 new sample garments a year. Through this approach, it is claimed that a whole new range of knitting techniques have been created and further potential for design innovation (Mowbray 2002b). However information is slow to be released and typically in formats that protect what is considered to be proprietorial information. This slows down creative innovation and contributes to an aura of exclusivity around seamless garments.

12 Summary

Two different types of seamless garments have been identified, those knitted on circular machinery and those knitted on flatbed machinery. Each of these methods of knitting create slightly different opportunities and limitations. Currently there are a number of specialist sportswear producers who are using both seamless circular garments to create highly technical sports garments using specific knit structures to map the body for warmth, comfort and performance. The ability to knit a number of different knit structures has been exploited by product developers to create highly specialised performance garments. Two innovative techniques have been discussed; the use of pressure panels and body mapping. Both of these techniques however demand a really sophisticated understanding of how to relate garment dimension to the human body. Currently there is little evidence to suggest the industry are producing sizing systems that can cater for a variety of sizes within a population. Therefore although innovative practice is evident there is still a skills and knowledge issue which limits the potential to innovate performance sportswear. In addition skills issues have been found to limit the ability of product development teams to achieve the fit results they desire in terms of shaping the garment and the protection of intellectual property limits the spread of knowledge. There is therefore a need for companies to invest in research and development in order to improve knowledge and understanding and truly exploit the potential capabilities of seamless knitting technologies.

13 References

Abreu, M. J. Catarino, A. Cardoso, C. Martin, E. (209) *Effects of Sportswear design on Thermal Comfort* Autec Proceedings for the Autec Conference, Mulhouse, France

Black, S. (2001) *Knitwear in Fashion*, London, Thames and Hudson Ltd.

Brownbridge, K. (2010a) 'Anthropometrics and the complete knitted garment' 86th *Textile Institute World Conference* Manchester November UK

Brownbridge, K. (2012) *The development of a conceptual model for anthropometric practices and applications regarding complete garment technologies for the UK women's knitwear industries* Thesis in partial fulfillment of a PhD Manchester Metropolitan University

Eckert, C. (2001) 'The Communication Bottleneck in Knitwear Design: Analysis and Computing Solutions'. *Computer Supported Cooperative Work*, Vol. **10**, pp. 29-74.

Gibbon, J. ed. (1995) 'Future Technology *towards 21st Century Manufacture*'. *Knitting International*, Vol. **102**, Issue 1222, pp. 60-61.

Gibbon, J., ed. (1996) 'Stoll in Dublin'. *Knitting International*, Vol. **103**, Issue 1232, p. 26.

Gill, S. (2009) *Determination of functional ease allowances using anthropometric measurement for application in pattern construction*, Thesis in partial fulfillment of a PhD Manchester Metropolitan University

Guy, K. (2001) *A design perspective on shaping possibilities with new technology V-bed knitting machines*, (part fulfillment of PhD), Nottingham Trent University.

Haffenden, V. (2009) Knit to fit: Applying technology to larger sized women's body shapes. *9th annual IFFTI conference. London College of Fashion 2nd-3rd April 2009 UK P 1- 122*

Magnus, E. Broega, A. C. and Catarino, A. (2009) *Interactions between Apparel design and seamless technology* Proceedings of first International Conference on Design, Engineering and Management for Innovation IDEM109 Porto, Portugal, September 14-15,

Mowbray, J. (2002a) 'The Quest for Ultimate Knitwear'. *Knitting International*, Vol. **109**, Issue 1289, pp. 22-23.

Mowbray, J. (2002b) 'A Quest for Ultimate Knitwear'. *Knitting International*, Vol. **109**, Issue 1289, pp. 22-23.

Power, J. (2004) 'Knitting Shells in the Third Dimension'. *Journal of Textile and Apparel Technology and Management*, Vol. **3**, Issue 4, pp. 1-13.

Power, J. (2008d) 'Developments in apparel knitting technology' in Fairhurst, C. ed *Advances in apparel production* Cambridge Woodhead Publishing Limited

Power, J. *Sustainable Development in Knitting* (2012) International Journal of Business and Globalisation 9 (1) pp 1-9

Raz (1993) *Flat Knitting Technology*, Westhausen, Universal Maschinenfabrik.

Semnani, D. (209) *Advances in Circular Knitting* in Au, K. F (ed). *Advances in Knitting technology* Woodhead Publishing, London

Spencer, D.J. (2001) *Knitting Technology a Comprehensive Handbook and Practical Guide*. (Third ed.), Cambridge, Woodhead Publishing Ltd.

Troynikov, O. (2008) 'Smart Body - Ergonomic Seamless Sprotswear Design and Development', *The Body - Connections with Fashion*, Melbourne, IFFTI, pp.1 -20.