

From the Loom to Wear:
Shapeable Woven Textiles for Seamless Fashion

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ABSTRACT

There are various approaches in fashion and textile research which focus on how design processes could minimise environmental impact in order to make a more sustainable fashion and textile industry. One such approach is seamless or whole garment knitting technology, which results in much less fabric wastage than the 'cut and sew' method of garment manufacturing. However, seamless approaches in woven textile design have not been fully realised due to the characteristics of the woven fabrics. Moreover, research in seamless weaving has often focused on textile engineering and medical uses, and there has been little research into their use in fashion.

In this research, a design practice of shapeable seamless woven garments is proposed as an alternative way of combining shapeable woven textiles and tubular weaving construction that leads to creative seamless garments that are versatile. Based on the action research process, this practice-based research examines five stages (planning, exploring, prototyping, observing and reflecting) that are used to transform woven textiles from the loom into fashion garments. The research explores three-dimensional and textural surface effects and different degrees of shrinkage of shapeable woven textiles that show inherent stretchability. In the prototyping stage, a series of shapeable seamless woven garments were created through both hand-weaving and the Jacquard weaving process. At this stage, the research demonstrated how 2D woven textile designs can be transformed into 3D fashion forms, and how prototype garments can be fitted on the body and worn in many different ways. In the observing and reflecting stages of the research, a questionnaire and focus group were conducted in order to assess external perspectives on, and evaluation of, practical outcomes of the research, i.e. specifically shapeable woven textiles and the effectiveness of the prototype designs.

The research is capable of providing a creative way of designing seamless garments based on shapeable woven textiles by integrating key design considerations such as stretchability for adaptable fit, three-dimensional textural effects, versatility of prototype garments and material selection. By examining the above features, the research evaluates how the design process and practical outcomes enhance the product lifecycle and contribute to circular design and sustainability in fashion and textiles.

Dedication

I dedicate this PhD thesis to my family.

*An extraordinary feeling of gratitude to my parents who have encouraged and sacrificed
to bring my dream to fruition.*

I also dedicate this thesis to my friends who have supported me throughout this journey.

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I will never forget my cheerful, pleasant and delightful colleagues at the School of Textiles and Design.

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Chapter 2. Introduction

2.1 Background of Research

This research builds on the discovery that is derived from the researcher's Master's project; an investigation into sustainable textile design in the spirit of the eastern philosophy 'Taoism' as high-value textile products. As the basis of the philosophy which emphasises living in harmony may relates to sustainable thinking in fashion and textile design. The Master's project was based on a design practice in woven textiles addressing how sustainable textile design and a philosophical design concept could be fully integrated to improve product lifespan within complex weaving techniques. In this project, open-end double cloth scarves were produced as final outcomes, showing how a user could explore and wear them in different ways by means of the scarves being woven as three connected loops (see Figure 1).

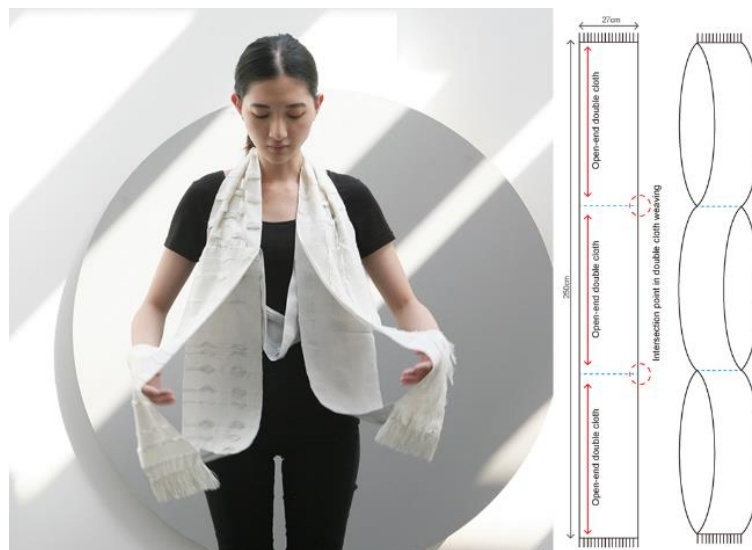


Figure 2.1. An (2014), Open-ended double cloth scarf.

Final outcomes of this master's project were inspired by existing textile designs which related to sustainability, especially multi-functional designs that have been shown to have a longer lifespan as a result of their adaptability (Koo, Dunne and Bye, 2013). The design concept examined in the Master's project focused on making small-scale fashion items using hand weaving technique such as scarves because the characteristics of the woven

fabric which often need either hems or seams at their edges to make larger fashion items such as garments, and the project had limits to explore more within the given time frame.

From the reflection of the Master's project, a number of points arose for further research: 1) how to create larger fashion items using integrated weaving techniques that could be worn in many different ways and may improve products longevity by wearing them often and keeping them longer, 2) how to minimise seams that may cause discomfort of wearing clothing but could prevent ravelling of woven fabrics, 3) what kind of materials could be used to meet the requirement of circular design perspective and to enhance both sustainability in fashion and textile design and physical properties of larger fashion items. Accordingly, developed design practice considering all these aspects related to seams, materials and products longevity based on circular design for sustainable fashion and textiles along with weaving techniques would be applied to create larger fashion items that could be worn on the whole body.

Traditionally, the 'cut and sew' method is the most common method of making garments with woven fabrics despite this method being often costly and complicated where multiple assembly processes are required in garment production. One of the attempts to eliminate or minimise the 'cut and sew' method is seamless textiles or fashion through the use of techniques that are mostly knitting, weaving, felting, knotting and braiding. Seamless knitting, technically, has been well developed because knitted fabrics enable the creation of various shapes 'via free transposition of loops' (Wang, 2010) without needing to use the 'cut and sew' method as opposed to woven fabrics (Yang, 2010).

As there is a growing interest in seamless weaving, parallel to knitting, a number of researches on seamless woven textiles have been introduced that are mainly focused on medical purpose seamless textiles and engineering purpose of partial three-dimensional weaving. Recently, several researches on seamless weaving for the fashion use have been introduced that are directed toward the use of various synthetic yarns to make the shape of seamless woven garments, or the use of additional chemical printing to prevent fraying of the garments. However, there are no notable achievements in the previous research of woven textile design for seamless fashion where the comprehensive design practice is considered and required in order to integrate the design, function, material and circular design perspective for sustainable fashion and textiles. This practice-based research thus

seeks to find opportunities in seamless fashion with woven structured textile design using a conventional loom in order to reduce fabric wastage and enhance sustainability in garment making by integrating natural material with inherent stretchability for adaptable fit, while improving product lifespan.

Woven textiles are consisting of a set of the warp and weft to create fabrics that are mostly two-dimensional sheets. This set of the warp and weft of woven textiles often shows a pattern that is primarily determined by colour, type and composition of yarns and weave structures. Since three-dimensionality of woven fabrics is an essential design element in order to transform woven fabrics into seamless garments, yarn types and weave structures are playing the most important role in the creation of shapeable woven fabrics.

The shapeable weaving is thought of as both a form of fabrics with three-dimensional surface effects and textures, and seamless garment. Both the three-dimensional form with surface effects and textures of fabric and the seamless garment, as a whole, are unique component of the shapeable seamless woven garment. The composition of ‘form (physical and aesthetic design of the shapeable seamless woven garments)’, ‘function (versatility)’, ‘material’ and ‘circular design perspectives for sustainability’ are as yet under researched and worthy of in-depth research.

The research therefore explores how 2D woven fabrics could be transformed into 3D fashion directly from the loom; especially using shapeable weaving technique to show how such garments and accessories fit on the body without seams as well as how they can be worn in multiple ways.

2.2 Aims and Objectives

The first aim of this research is to create shapeable woven textiles for seamless garments that are versatile (i.e. can be worn and used in many different ways) in order to:

- review the current shapeable textiles and seamless fashion sector
- explore ways in which woven fabrics can be shaped such as surface effects, textures, shrinkage and stretchability using wool fibre
- integrate shapeable woven fabrics into specific forms of seamless woven garments.

The second aim is to explore how shapeable seamless woven garments can improve the user engagement phase of the product lifecycle and contribute to sustainability in fashion and textiles. This is done by

- identifying the concept of versatility through shapeable seamless woven technique and test its application for fashion garments.
- evaluating user experiences and responses regarding the versatility of shapeable seamless woven garments produced as part of the project.
- assessing how the research and the garments contributes to circular design for sustainable fashion and textiles.

2.3 Thesis Outline

Chapter 1. Introduction

Chapter 1 presents the background of the research, aims and objectives, and detailed outlines of the thesis structure.

Chapter 2. Contextual Review

Chapter 2 provides the contextual framework for the research in relation to seamless and shapeable textiles within three-dimensional form and versatile fashion. The chapter also encompasses material choice and the field of circular design to improve sustainability in fashion and textiles, especially focusing on woven textile designs in the field of seamless fashion. The chapter helps an understanding of shapeable woven textiles in order to create shapeable seamless woven garments that are versatile.

Chapter 3. Methodology

Chapter 3 sets out the methodology and methods employed in the research. It starts by discussing the methodological framework with specific reference to fashion and textile designs. It moves on to explain the research methodology that is adopted, based on action research process consisting of five different stages in iterative cycles. Each stage is explained, showing what particular methods are chosen to achieve objectives outlined for this research.

Chapter 4. Practical Research Stage 1: Forming Shapeable Woven textiles

Chapter 4 explores the development of shapeable woven textiles in single-layer construction and using a tubular construction in order to identify which such shapeable woven fabrics could best support the creation of shapeable seamless woven garments. The chapter demonstrates and compares various three-dimensional surface effects and textures of shapeable woven textiles with different degrees of shrinkage that enable inherent stretchability. In order to find out how such three-dimensional surface effects with shrinkage can be applied to the prototype designs, the first part focuses on the changes of weave setts, structures and yarn types, and the second part concentrates on the differing arrangements of weave structures and yarn types.

Chapter 5. Practical Research Stage 2: Prototyping Shapeable Seamless Woven Garments

Chapter 5 introduces creation procedures of prototype designs of the shapeable seamless woven garment as research outcomes through hand-weaving and Jacquard weaving process. This chapter demonstrates how shapeable woven fabrics are deployed and integrated for the prototype designs, with selected yarns, weave setts and weave structures from the analysis and evaluation of Chapter 4. Creation by using the hand-weaving process provides four primary prototype designs in details whereas the Jacquard weaving process outlines two initial prototype designs.

Chapter 6. Evaluative Research: Questionnaire and a Focus group

Chapter 6 presents analyses of questionnaire and a focus group that are conducted as two phases to evaluate and reflect on the practical experiments along with the prototype designs of the research. The chapter demonstrates a process of questionnaire and its design and quantitative data analysis, and a process of a focus group with participant selection, its environment, limitation and qualitative data analysis.

Chapter 7. Conclusion

Chapter 7 summarises the practical works that are conducted, and concludes the research findings in relation to each aims and objectives. It presents a final reflection and foregrounds the key aspects in terms of their contribution to new knowledge. The chapter finally identifies areas for the future work.

Chapter 3. Literature Review

This chapter builds on the investigation into opportunities based on shapeable woven textiles in order to produce seamless garments, which is the design practice of this research (related to 2D woven textile design for 3D fashion). The literature review considers circular design perspective of the research for sustainable fashion and textiles. This literature review also introduces a comprehensive review of current practices and techniques that enable shapeability with three-dimensional surface effects and textures, as well as previous literature on seamless fashion and textiles, and versatility in fashion (see Figure 3.1). The review provides an in-depth analysis of the prior and current research context in order to identify research gaps.

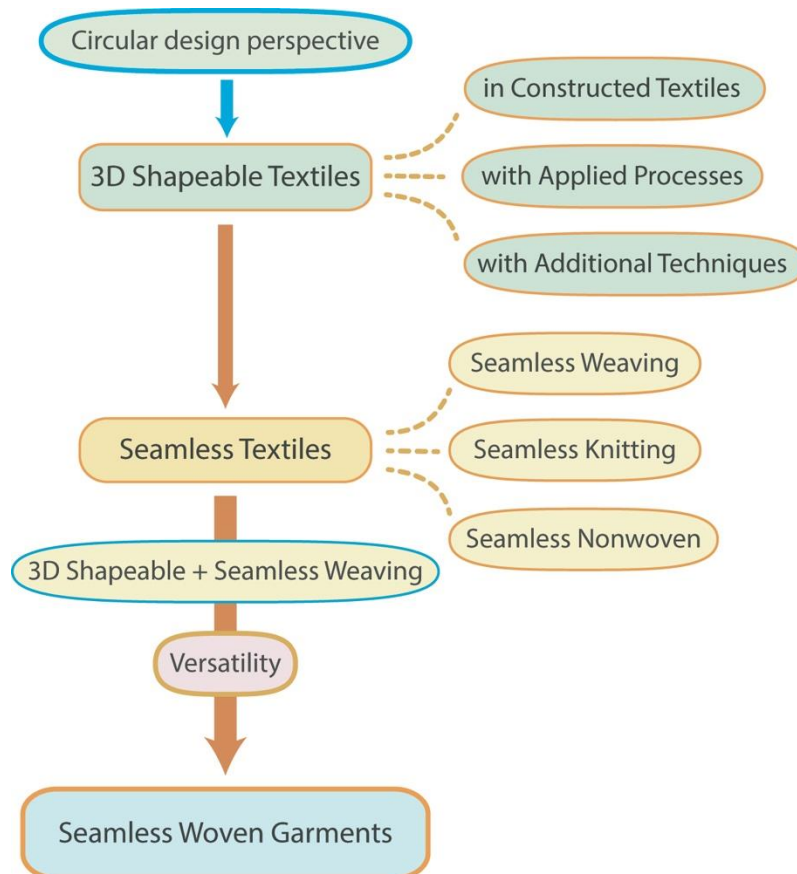


Figure 3.1. Overview and scope of literature review

3.1 Circular Design Perspective of the Research for Sustainable Fashion and Textiles

Currently, fashion in its fleeting nature, fuels an endless race for change, newness and variation. This constant cycle makes the fashion an energetic and attractive field (Chapman, 2014). According to Barnes and Lea-Greenwood (2010), styles from catwalk or celebrities in the media, foster a fast fashion cycle driving high levels of consumer demand. Such high consumption has resulted in consumers having a wardrobe that is full of unnecessary clothes. Fast fashion industries generally produce items for short-term use which can result in high levels of unwanted clothing waste and little consideration of sustainability. Moreover, due to the development of new technologies and production, textile and fashion industries have been able to use cheap materials and labour, and reduce the time cycles for new collections ever more (Joung, 2014). The increasingly fast turnover in trends and collections, consumers purchase fast-fashion products carelessly at low cost, without consideration, more than ever before (Joung, 2014) and fashion and textile products are often discarded before the products are worn out (Allwood *et al.*, 2006). As well as, the short lifespan of such fast-fashion products promotes consumers' needs and desires for products to be replaced and affects the environment in both the production and disposal stages (Klepp and Laitala, 2014). Such fast consumption and turnover in clothes mean that we have huge amounts of discarded garments, many of which are not recycled or reused and end up in a landfill. According to the Waste & Resources Action Programme (WRAP) report, 'An estimated 1.13 million tonnes of end-of-life clothing are no longer wanted by UK consumers and are either re-used (540,000 tonnes, around 7% of which goes overseas), recycled (160,000 tonnes), incinerated (80,000 tonnes) or go to landfill (350,000 tonnes)' (WRAP, 2012).

Clothing and textile waste piled up to 1.5 to 2 million tonnes annually, and it was the fastest growing waste sector between the years 2005 and 2010 in Britain (DEFRA, 2007). Additionally, Kerr and Landry (2017) state that between an estimated 55 and 92 million tons of waste is still generated from the fashion and textile industry, in reference to the consumption of 2015 (McQuillan, 2019). The influence of the fast fashion industry and the amount of clothing and textile waste are increasing enormously in the UK. On average, 30kg of clothing and textile waste are sent to landfill by UK consumers per capita each year (Allwood *et al.*, 2006). In the fast fashion sector alone in the UK, about 2 million tonnes of clothing are purchased annually, and it accounts for one-fifth of the market,

which has itself doubled in size over the last decade (DEFRA, 2010). According to (Ekstrom and Salomonson, 2014), clothing wastage is a significant problem for the environment, due to the considerable demand for natural resources as part of the textile production process. Each and every garment produced has a detrimental effect upon the environment due to resource scarcity, pollution and the waste produced by the entire industrial and sociocultural system - a system that is still at a significant growing larger rate (Ibid; Manonik, 2014).

Therefore, in the fashion and textile industry, sustainability, such as manufacturing with environmentally friendly materials using ethical methods of production has been a significant subject in recent years (Tobler-Rohr, 2011). Although, it is far from easy to understand and practice sustainability because it needs industry, society and the culture that surrounds fashion and textiles to develop a deeper understanding and make a concerted effort to improve the situation. When looked at in the abstract of sustainable fashion and textiles, sustainable design could also mean very different things to different stakeholders in fashion and textiles. Moreover, it is difficult to fulfil all the requirements of sustainable fashion and textile designs that all stakeholders involved in the process can agree upon (Earley, 2017). Despite such difficulties, the drive towards more practices in sustainable fashion and textiles has resulted in specific practical approaches being developed, such as C2C (cradle to cradle) (McDonough and Braungart, 2002), zero-waste design, seamless design and circular design.

Earley (2017: 427) states that the objectives of sustainable design differ from those of circular design in that the latter is “ultimately measurable – circular design closes the loop”. She also presents the case that ‘closing the loop’ in a circular design system through recycling and upcycling, returns its resources to the first stage of the product life cycle in perpetuity. It is also significant to maintain “the product, material and resources in the economy as long as possible, and minimising the generation of waste” (Virtanen, Manskinen and Eerola, 2017: 1611). Therefore, circular design aims to support fashion and textile designers to consider the choice of materials and the way of design that potentially enhance the longevity of products by the ‘close the loop’ (Earley and Goldsworthy, 2017). In order to ‘close the loop’ and enhance products life cycle, designers should be aware of sustainability issues from the circular design perspective and consider more flexible and intelligent design for longer lasting products. Consequently, a

conceptual framework for circular design by Moreno *et al.*(2016: 3) is introduced, and the study categorises three possible approaches; as “design for resource conservation”, “design for slowing resource loops” and “whole system design” in order to identify circular design practices for sustainability. Within three possible approaches, the classifications are subdivided into specific circular design practices in terms of their design strategy, focus and method/tool.

Based on the categorisation regarding “design for closing resource loops” (Ibid: 7), biodegradability is one of the solutions for closing the loop by using “safe and healthy materials” that are “biodegraded to start a new cycle” as they can be “biological nutrients” in a natural system of life cycle (Bocken *et al.*, 2016, p311). As it is also highlighted in section 2.1.1, biodegradability of materials is significant factor for preventing the environmental hazard because “an important sources of microplastic appears to be through sewage contaminated by fibres from washing clothes” (Browne *et al.*, 2011, p9175) Moreover, the use of biodegradable materials is the most efficient method to complete the cycle as it returns the resources to the first stage of their new life cycle without downcycling (McDonough and Braungart, 2002; Goldsworthy, 2012). Moreno *et al.*(2013) also state that the use of appropriate materials may enhance fashion products; more easily recyclable materials could facilitate re-use; biodegradable materials could reduce the load on landfill; more durable materials could extend lifespan.

The use of suitable for circular design is also highlighted with a view to close resource loops that “the purity of the raw material used in production process is an important factor” for recyclable design (Rathinamoorthy, 2019, p19). He claims that designing a product in a recyclable way would improve recyclability by offering better identification of products that can help to separate raw materials easily from embedded components and mixed materials. This recyclable design can lead to minimise downgrading of resources and reduce the cost of the recycling process as well as improve the quality of recycled products (Ibid; Vezzoli and Manzini, 2008). Thus, the positive impacts of such a way of design could enhance whole products life cycle and it is essential to consider creative ways of thinking, valuing and designing for completing ‘close the loops’ of the products’ life cycle. Moreover, McHattie and Ballie (2018, p4) claim that the use of “multiple cyclical iterations or loops” in such design processes could also “fully optimise lifecycles and reduce post-consumer waste”.

When considering design for longer lifetime of products within circular design strategies, functional aspects of products, such as ‘meaningfulness’, ‘flexibility’, ‘upgradability’ and ‘pleasurability’ (Moreno *et al.*, 2016, p7), are considered in order to enhance products longevity for slowing down the resource loops (Bocken *et al.*, 2016). (Vezzoli and Manzini, 2008, p142) also point out that if “design the products to be flexible, modular and with dynamical dimensions, performance and aesthetics, ... they could be used for longer periods”. As stated in section 2.3.2, designing garments with certain functions such as being multi-wearable, transformable and highly durable could encourage the wearer to use garments in specific ways and promote greater engagement between wearer and clothing (Fletcher, 2008; Gwilt, 2014). As (Chapman, 2005) indicates, products with such functions can generate a deeper emotional connection between consumer and product that can improve a products life cycle. Moreover, the versatile function of garments offers customers more chances to wear them in a number of ways that make a longer period of user engagement phase, and in doing so, it extends the life cycle of the garments (Dombek-Keith and Loker, 2011; Farrer, 2011; Koo, Dunne and Bye, 2013).

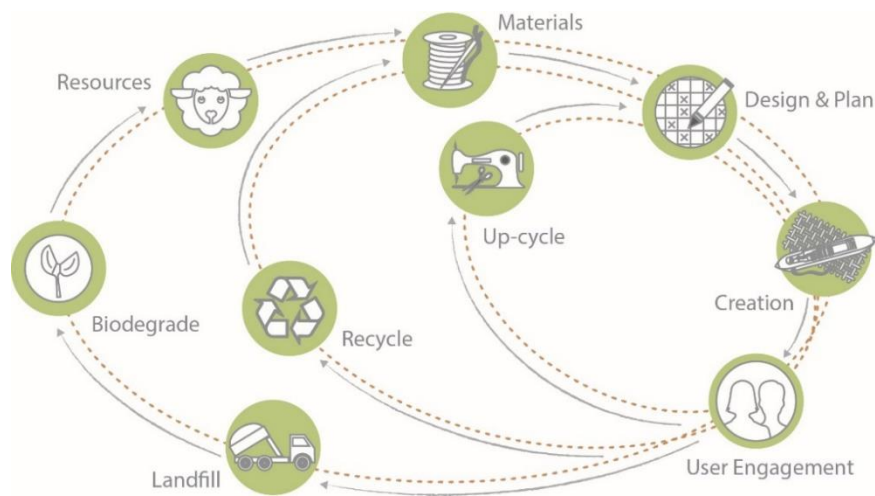


Figure 3.2. Circular design perspectives for sustainable fashion and textile design

Therefore, this research recognises abovementioned theoretical (close the loop of material life cycle as well as product life cycle and lengthening its use phase by an engagement with wearer) and practical methods (seamlessness and versatility in fashion and textile design and the use of material) of circular design for sustainable fashion and textiles, and focuses on the design practice that integrates such circular design considerations in order to bring multiple cycles of the products see details in Figure 3.2. Within the research, the

particular aspects of circular design for sustainability that this research addresses are following:

- design for closing resource loop,
- design for minimising waste,
- design for enhancing products life,
- design for slowing down resource loop.

In order to close the resource loop, the choice and use of material are taken into consideration, i.e. how material could promote biodegradability and recyclability as well as enables shapeable woven textiles. The seamless design is then taken into account for the purpose of minimising fabric waste during garment manufacturing as this is a part of circular design perspective. Moreover, for enhancing products life cycle and relatively slowing down the resource loop, utilising a versatility function in this design process is also taken into consideration, i.e. how this versatility function of garments could improve user engagement phase of the product life cycle. These considerations provide scope and clues in order to create shapeable seamless woven garments as part of this research and how it contributes to circular design for sustainable fashion and textiles.

3.1.1 The Use of Materials in Circular Design Perspective

There are a number of different materials that could be used to enable woven fabrics stretchable and elastic, such as Spandex, Lycra and elastane fibre. However, recent study reveals that emission of microfibers (qualified as the form of microplastic) from domestic laundry (1900 fibres per wash) of synthetic textiles and clothing significantly contributes environmental pollution (Browne *et al.*, 2011; Pirc *et al.*, 2016) as they are not biodegradable in nature.

Currently, Life Cycle Assessments (LCA) on clothing, as a tool, is often used to assess sustainability and environmental impacts of different types of textile fibres (Laitala, Klepp and Henry, 2017), based on the Higg Index tool developed by (Sustainable Apparel Coalition, 2019) and DEFRA's reports (Turley *et al.*, 2009). However, according to reports from International Wool Textile Organisation ((IWTO, 2016) and (IWTO, 2019, p1)), current rating tools and studies more focus on "environmental aspects of resource

use as well as depletion and emissions to land, water and air”, although it is significant to consider environmental impacts across products’ entire life cycle from raw material stage to disposal phase (i.e. C2C, cradle to cradle (McDonough and Braungart, 2002)). Thus, the use phase of products should be considered critically as it highly affects environmental impacts such as energy, water and detergent use of laundry. (Laitala, Klepp and Henry, 2018) state that wool products’ laundry is usually smaller than the average load of other fibre products and using less energy due to the fact that the laundry needs low temperature and gentle cycle than others. The study also shows that woollen products needs less washing because of their “natural ability to repel stains and odour” (Gullingsrud, 2017, p67) and they are more “likely to be used about twice as long between washes than cotton products” (Laitala, Klepp and Henry, 2018, p10).

According to the Campaign for Wool (2013) and (Gullingsrud, 2017), wool is a natural insulator, which controls humidity through absorbing and releasing water vapour. This wicking ability makes the wool breathable and helps it to feel dry next to the skin because the fibres are crimped and form millions of small air space (Gullingsrud, 2017). This hygroscopic ability makes wool fibre multi-climatic and trans-seasonal. (Rodie, 2012, p46) also claims that “wool is increasingly being touted as a performance fibre... [for all seasons due to its] inherently thermal-regulating, antimicrobial, insulating and water-repellent [functions]”. In accordance with (IWTO, 2019), people may feel skin irritations caused by garments due to diameter of coarse wool fibre from fabric, which is normally greater than 30 micron. The average diameter of merino wool fibre however lies between 18 to 21 micron (Simpson, 2002) that can support soft tactile impression to skin (Gullingsrud, 2017).

Moreover, in a documentary film called ‘Alex James: Slowing Down Fast Fashion (Akers, 2016)’, wool as a result of several experiments, is identified as sustainable fibre. The film compared the properties of synthetic fibres with those of wool fibres in terms of biodegradability and fire, stain and odour resistance. Other properties, such as being anti-static, low-lint and having flame resistance were also highlighted by the ‘Armadillo Merino’ company, which won a NASA competition for astronaut clothing (UK Trade & Investment, 2014). (Corcadden, Biggs and Stiles, 2014) also state that wool is a renewable resource (e.g. the weight of raw wool fleece sheared from each animal is between 2.3 and 3.6kg) requiring annual shearing from the body of sheep for the purpose

of the animals' health.

Circular design perspective for sustainable fashion and textiles is the main consideration of this practice-based research and therefore, the use of wool fibre is taken into consideration in order to facilitate biodegradability and recyclability.

3.2 Shapeable Textiles

This section explores how textiles can be constructed, applied and manipulated to have inherent shapes along with three-dimensional surface effects and textures. According to Tellier-Loumagne (2005), shapeable fabrics with three-dimensional forms and volumes could be divided into four different types of textiles that are woven, knitted, non-woven or employ multiple techniques. To explore a variety of three-dimensional shapeable textiles for flexibility, stretchability and the adaptable fit of seamless woven garments, it is essential to organise them into appropriate categories as part of the research. While Tellier classified them into four types, this section assigns current three-dimensional shapeable textiles into three main categories as constructed textiles, applied processes and additional techniques. The following sub-sections examine each of these shapeable textiles with three-dimensional effects in more detail.

3.2.1 Three-dimensional shapeable fabrics in constructed textiles

Knitted fabric structures are constructed from a series of loops of one continuous thread. Due to the loop construction, knitted fabrics are more flexible and stretchable than woven fabrics. As one continuous thread repeatedly loops to make knitted fabrics, such fabrics are capable of creating shapeable textiles in a three-dimensional form. For achieving shapeable knitted textiles, the composition of yarn types, stitch patterns and stitch tensions determines the three-dimensionality of knitted surfaces (Matthews, 2011). Tellier-Loumagne (2005) is a textile practitioner, introduced diverse stitches and structures to create knitted fabrics with various textures and volumes. The samples in Figure 3.3 combine advanced knit structures with hand-knit and jacquard techniques to create multiple flexible three-dimensional forms and textures in knitted fabrics.



Figure 3.3. Various shapeable knitted fabric samples by Tellier-Loumagne (2005)

In contrast to knitted fabrics, there is a variety of different ways to create woven fabrics that shape themselves along with three-dimensional surface effects and textures such as pleating, folding, crinkling and shrinking (Richards, 2012). The most common way to make three-dimensional shapeable fabrics in woven textiles is by using different characteristics of materials for maximising results on the surfaces (Lee, 2010). For example, using elastic yarns with different degree of elasticity in the warp or weft of woven fabrics can create pleats or wave effects on their surfaces. Diverse three-dimensional surface effects and textures can be made by using variations in weave sets, weave structures, tensions, types of materials and post-processing. Anne Field (2008) introduced ‘collapse weave’ which creates three-dimensional cloth. She presented a number of fabrics that are stretchable from two-dimensional clothes to form dynamic three-dimensional textures using a different twist of yarns with active and passive characteristics. One such example is a scarf woven by Sheila Reimann showing three-dimensional bumps created by the interaction of contrasting yarns used in the warp and weft, as shown in Figure 3.4.



Figure 3.4 ‘Bubble Wrap’ scarf woven and photographed by Sheila Reimann (Field, 2008)

Another practitioner, Ann Richards, demonstrated a distinctive practice to create various shapeable woven fabrics using advanced technologies in materials. In her book 'Weaving Textiles That Shape Themselves' (Richards, 2012), she described processes of making shapeable textiles from the yarn technology to post-processing to create dynamic three-dimensional textures and forms of fabrics. The neckpiece woven by Richards in Figure 3.5 combined silk and steel wire in one yarn and used this with a spun silk yarn in both plain and cord weave to create solid pleats in a spiral shape. Although the piece showed the potential ability to manipulate the shape of woven textiles, the use of such metallic material affects draping quality of fabrics, and that hard material may interrupt flexibility of garments when the fabrics are used to make garments.



Figure 3.5. 'Spiral' neckpiece by Richards (2012)

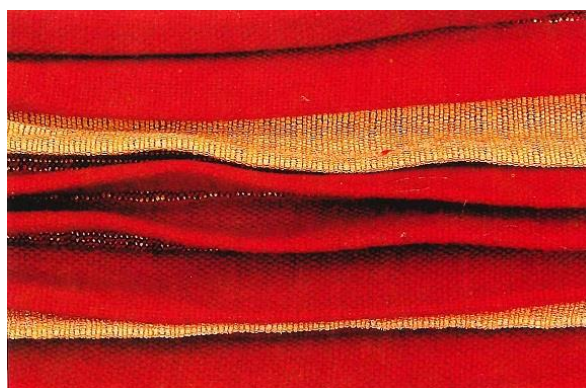


Figure 3.6. Carmen fabric woven by Selby (2012)

Contemporary woven textile designer Margo Selby (2012) outlined another way to create shapeable woven fabrics with a three-dimensional surface effects and textures which used two different tensions of warps in double-layered cloth to create pleats on the top layer.

First, the top layer is woven longer than the bottom layer, the tension of both the top and the bottom layer is then adjusted to form pleats in the top layer. Finally, both layers are beaten together with weft yarn to secure the pleats (see Figure 3.6). In this case, it is the different warp tensions that are produced in both the top and the bottom layer, by means of using diverse woven structures, create three-dimensional forms on the surface of the fabric, rather than using different yarns or technology. However, in this case of creating surface effects on the fabrics, it may result in producing heavy-weight fabrics because the fabrics need much more length of the warp to create those effects, which may also cause discomfort when the effects are attached to the shape of garments.

3.2.2 Three-dimensional shapeable fabrics created with applied processes

There are number of ways of manipulating techniques that create shapeable textiles using existing fabrics. Shibori, defined as “shaped-resist dyeing” (Wada, 2002, p13), is a traditional Japanese dyeing and manipulating technique using heat-setting that makes shapeable fabrics with three-dimensional surface effects and textures. Historically, shibori was normally used for making patterns on silk fabrics in a number of ways such as binding, stitching, folding, twisting or compressing cloth. Since the later decades of the twentieth century, shibori along with textile technology, has dramatically evolved from being used in traditional crafts to being used in creating contemporary art forms and fashion collections (Wada, Rice and Barton, 2011).

Hiroshi Murase, a shibori artisan and designer with 40 years of experience, incorporated traditional patterns of shibori into the production of modern materials by applying continuous running stitches in V-shaped lines on polyester fabric (see Figure 3.7). Yohji Yamamoto, a Japanese fashion designer, integrated this centuries-old shibori technique to produce unique outfits in his 1995 S/S Paris collection. However, the technique is often used for the purpose of decorating surface of fabrics utilising dyeing process (Wada, Rice and Barton, 2011). Moreover, shibori demands time-consuming as the technique requires hand binding, tying and stitching in order to make three-dimensional patterns on the fabric. Further, because of the manual process that depends on “the amount of force exerted on the binding thread, or in drawing up the stitching thread, or in compressing the cloth into folds on the pole”, the results are highly individual (Ibid, p54).



Figure 3.7. Hiroshi Murase, shibori on polyester (Wada, 2002)

Mariano Fortuny created the ‘Delphos dress’, inspired by ancient Greek garments, in 1907 (see in Figure 3.8). The dress is well known as a very finely pleated silk dress that was created using his patented pleating process in 1909 (Desveaux, 1998). The pleated silk fabrics he created are not similar to pleats in modern textiles; the shape of the pleats are irregular and uneven and show smooth, undulating, three-dimensional patterns. The dress was also designed to fit to all sizes of the body by means of a finely pleated fabric (Grossiord, 2019). He described his pleating process as ‘an evaporation system for vertically pleating and horizontally undulating silk with heated porcelain tubes’ (Desveaux, 1998, p11; Matthews, 2011, p42). However, although, the pleated silk fabrics are flexible to cover all sizes, the design needs extra features such as buttons and belt to wear the dress.



Figure 3.8. Delphos dress created by Mariano Fortuny (Grossiord, 2019)

Heat-moulding is another way of manipulating fabrics into a three-dimensional structural form, and was employed on the dress designed by Pierre Cardin in 1968 (Bolton, 2016). In Figure 3.9, it can be seen how heat-moulded brown polyester shows geometrical textures, shapes and patterns on the dress. The processes of heat-moulding, as well as heat-setting, have continued to evolve along with other techniques such as a laser technology (Goldsworthy, 2012) to create many more possibilities in design, and thus they have become widely used in interdisciplinary design projects (Morgan *et al.*, 2018). However, the technique is mostly applied to synthetic fabrics in order to set a three-dimensional structural form by using heat (Ibid).



Figure 3.9. Heat-moulded brown polyester dress by Pierre Cardin (Bolton, 2016)

Issey Miyake launched the revolutionary clothing line ‘Pleats Please’ in 1993. In this collection, he used shaping process such as “twist-and-crumple” (Wada, 2002: 77), which is a heat-set shibori technique to add irregular crinkled textures to the surface of the fabric as well as helping to create the shape of garments. Miyake and his director of women’s wear, Yoshiyuki Miyamae, have developed a new concept of woven fabric called ‘3D Steam Stretch fabric’, which uses yarn with different compositions of cotton and polyester that react to steam and turn into three-dimensional origami shapes (see Figure 3.10). This new concept of woven fabric was fully introduced for garments in Issey Miyake’s S/S 2015 women’s wear collection.



Figure 3.10. Steam Stretch (Issey Miyake, 2016)



Figure 3.11. Baked Stretch (Issey Miyake, 2016)

Miyamae also presented another new concept of shapeable textiles in Issey Miyake's S/S 2016 women's wear collection. In this collection, garments were made from 'Baked Stretch' fabric giving them three-dimensional textures. Heat reactive glue, which swells and expands at a particular oven temperature, was printed between lines of multi-coloured wavy patterns. Swollen and expanded lines protruded from the surface of the fabric and made it stretchable and springy (see Figure 3.11). However, although these new concepts of technologies could create three-dimensional shapeable fabrics, these processes heavily rely on the use of synthetic fibre such as polyester that significantly effects on the environment as stated in section 2.1.1.

3.2.3 Three-dimensional shapeable fabrics created with additional techniques (3D printing and laser-cutting)

Iris Van Herpen, a fashion designer in utilising 3D printing as a garment construction technique, designs innovative three-dimensional fabric forms, mainly nonwoven, using advanced technologies such as 3D printing and laser cutting. She introduced her first wearable 3D printed garment, inspired by shell structures, at the runway show at Amsterdam Fashion week 2010 (see in Figure 3.12). The garment was printed as a whole piece by using white polyamide. It was the most significant use of 3D printing for the fabrication of garments in contemporary fashion and showed the potential of integrating such cutting-edge technology into a new era of fashion design (Schleuning, Wilson and Zijpp, 2018). In her F/W 2017 collection, a garment was made from a feather-light silver lace cut into a three-dimensional wavy pattern form, showing a shimmering surface reminiscent of water. The laser-cut silver lace then shaped itself as a garment that simulated water falling around the body (see Figure 3.13). She introduces innovative

collections using advanced technologies, however, design of the garments focuses on exploration of “fusing technology with couture craftsmanship” into the runway show rather than creating ready-to-wear garments (Herpen, 2018).

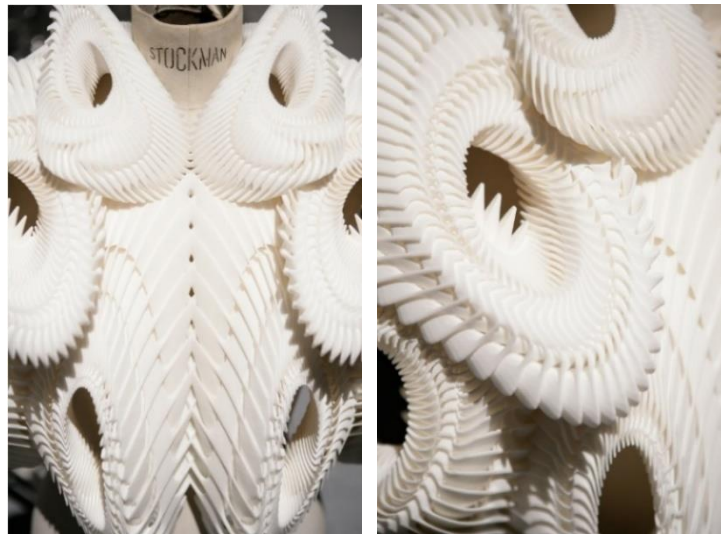


Figure 3.12. 3D printed ‘Crystallization’ top (Herpen, 2010)



Figure 3.13. Laser-cut Silver Lace (Herpen, 2017)

3.3 Seamless Textiles

Most garments are made from fabrics by means of ‘cut and sew’ method, which is a labour intensive process. Anderson (2004) and Seyam *et al.* (2014) identified a number of drawbacks of using the ‘cut and sew’ method in garment making.

- a) The ‘cut and sew’ method is the most labour intensive part of the garment formation process.

- b) Heddle hole-related fibre damage during the sewing process could affect the strength and performance of the fabric.
- c) The fact that stress concentration at the seams may result in product failure.
- d) The method creates the potential for human error, in that cutting and sewing are manual.
- e) Fabric waste (offcut) is produced by the ‘cut and sew’ method.
- f) The bulkiness of seams in a garment may cause user discomfort.

Considering such disadvantages has led some in the industry to seek alternatives to the ‘cut and sew’ method, mainly by avoiding the use of seams.

To date, significant attempts have been made in the creation of seamless textiles and fashion using various materials and techniques as technology advances (NG *et al.*, 2007; Wang, Ng and Hu, 2013). This section introduces a review and comparison of the current main technologies to create seamless textile products in the following categories: woven, knitted and nonwoven seamless textiles.

3.3.1 Seamless Woven Textiles

Currently, seamless fashion in woven textiles have not been fully developed because of such characteristics of woven fabrics, as unravelling and fraying of threads (Seyam *et al.*, 2014). Compared to knitting, weaving faces significant challenges when attempting to create a garment with minimal or no seams due to the use of two yarns sets (predetermined unchanging width of warp and weft), and thus seamless woven textiles are far less common than seamless knitted textiles (Piper and Townsend, 2016). To date, research in seamless weaving has generally focused on textile engineering and medical uses (see Bhattacharya and Koranne, 2012; Zheng *et al.*, 2013). Although some research has proposed the use of seamless woven textiles for industrial and medical applications (Anderson and Seyam, 2004), there has been little research into their use in fashion.

According to Ng (2004) and Wang (2010), tapestry, basketry, braiding and knotting as used in traditional crafts could be applied to create seamless woven products and deserve the same attention as modern technology. Basketry is one of the earliest traditional crafts

and probably predates pottery and weaving (Gill, 2012). The technique has evolved from use in the ancient craft to use in art forms, fashion and furniture. In Figure 3.14, Larsen and Freudenheim (1986) identified all kinds of traditional textile techniques from a single unit of knot to three-dimensional basketry that may have the potential to be used in making seamless woven products. The physical advantages of these elements, which are easy to be expanded and shaped, enable them to be combined in order to create a larger unit that may be a form of fashion garment.

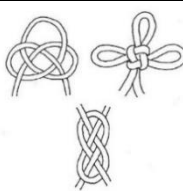
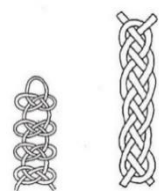
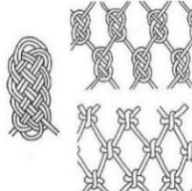
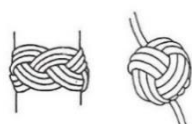

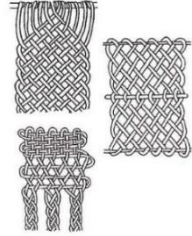
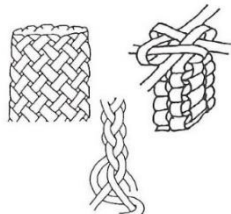

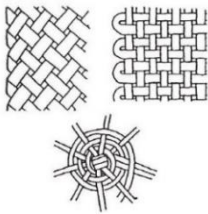

	Single Unit	Linear	Planar	3-D
1 and 2 elements	 <p>knots</p>	 <p>Macramé, knot</p>	 <p>mat knot, nets</p>	 <p>knots</p>
1 set of elements		 <p>braid</p>	 <p>Flat braid, sprang, bobbin lace</p>	 <p>3D braiding</p>
2 sets of elements		 <p>woven tape</p>	 <p>plaited mat, weave spiral/radial disc</p>	 <p>basketry</p>

Figure 3.14. Classification of interlacings by Larsen and Freudenheim (1986)

However, these techniques mainly require handiworks that demand time-consuming process. For instance, various braiding and knotting techniques are often seen in combination with other craft techniques in traditional craft making, and may also be used for decorating fabrics or trimmings in contemporary fashion designs as seen in Figure 3.15. Denisse M Vera is a women's wear brand based in Australia that uses traditional textile techniques such as braiding and knotting. The label aims to create unique pieces combining modern and traditional textiles. However, hand-knotted garments created by

Vera are all made-to-order and customised, so it normally requires unusual time-consuming (2-4 weeks) to make one that.



Figure 3.15. ‘Zephora’ top, braided and knotted by Vera (2018)

Anderson and Seyam (2004) introduced seamless shaped woven fabric for medical products using various shrinkable polyester yarns utilised in different segments. Anderson (2004) stated that shrunk and shaped three-dimensional tubes have the potential to be applied in fashion field such as a protective clothing. However, their weaving method could produce a limited sizes and shapes of tubes, and shrinkable synthetic yarns were required in order to create changes in the basic form of shapes produced.

Recently, there have been several studies focusing on the use of shapeable stretch textiles for seamless woven garments with simple and compound weaves using spandex yarn for shaping and fit (Wang *et al.*, 2009; Ng *et al.*, 2010). These studies examined successful attempts to produce seamless garments and introduced multiple samples of seamless garments. Further, the concept of ‘3D seamless woven fashion’ (Wang, Ng and Hu, 2013) and the study of ‘shaped seamless woven garments’ (Seyam *et al.*, 2014) introduced using Jacquard process to demonstrate their potential for the fashion industry. The studies, however, focused more on textile engineering aspects, such as composition of synthetic yarns and Jacquard structures involved in a functional element (elasticity using only spandex fibre), than on practical application for the use of the garments. Thus, although seamless woven garments were produced, the shape and design of the garments were excessive due to the emphasis on the applications of functional fabric.

In the series of works in the A-POC collection created by Issey Miyake and Dai Fujiwara, some examples of seamless woven garments were introduced among knitted-whole garments as seamless knitwear, but the seamless woven garments still needed to be sewn or stitched to be assembled as a garment (see Figure 3.16). The A-POC collection is widely known as seamless knitwear, and this will be detailed in the following section.



Figure 3.16. 'Frame work: woven' and 'Caravan' by Miyake and Fujiwara (2002)

Manonik is a studio focusing on fully-fashioned hand woven textiles from the fibre to final garments, developing “three-dimensional pattern weaving” (Manonik, 2014). This new hand weaving technique creates each part of a garment, such as a tapered tube for sleeves and torso with armholes, buttonholes and a neck hole, during the weaving process rather than cutting all parts of a garment out from a single layer of cloth (see Figure 3.17). This technique produces less waste than conventional pattern cutting, but it still requires hand sewing as an integral part of garment construction.



Figure 3.17. Woven bodice and a tapered tube for a sleeve by Manonik (2014)

Friends of Light is a weaving cooperative from New York City, developing and producing hand-woven jackets (Friends of Light, 2016). This project is based on shaped hand-weaving using pin looms for shaping each of the 2D patterns that are required to produce a garment using locally produced materials (see Figure 3.18). As such, the processes of making a hand woven jacket from fibre to garment are complex and require great care, taking up to 150 hours to complete. The project is the antithesis of industrialised garment manufacture and aims to re-establish craft with ‘innovation, sustainability and reconnection with material processes, celebrating imperfection’ (Klee, 2016).



Figure 3.18. Hand-woven 2D patterns by Friends of Light (2016)

Potential research and development of seamless woven garments have been introduced, showing, however, that whole seamless woven garments are not fully realised yet because of characteristics of the woven fabric. There have also not been any studies about

seamless woven garments since the last article in 2014. What current designs and creations of seamless woven textiles were found were restricted to handcraft techniques or academic research, (and it needs further development for commercialising).

3.3.2 Seamless Knitted Textiles

Technically, seamless fashion in knitted textiles has been well developed from handcraft because knitted, as opposed to woven, fabrics enable the creation of various shapes ‘via free transposition of loops’ (Wang, 2010) without needing to use the ‘cut and sew’ method (Yang, 2010). Yang (2010) stated that there are mainly two construction methods of knitting technologies widely utilised in knitted garments manufacturing, which are warp and weft-knitting. In general, weft knitted fabrics can be made either by hand or a machine that uses basic knitting stitches such as plain, purl or rib. However, warp-knitting structures can only be done on a machine that enables multiple loops of threads (Ibid).

Crochet is a handcraft technique that can be used to create seamless textiles using various sizes of crochet hook with a single strand of thread. According to (Matthews, 2011), crochet and knitting both consist of continuous interlocking loops however crochet differs from knitting because only one loop is active in crochet whereas an entire row of loops is active in knitting. For instance, the four-opening garment shown in Figure 3.19 is a seamless crocheted garment created by Landahl (2015), and is constructed by using one strand of the thread for each of the circular shapes which are then connected to form a seamless garment.



Figure 3.19. Nothingness: garment with four holes by Landahl (2015)

Sandra Backlund, a contemporary knitwear designer, works with “a three-dimensional collage method” (Udale, 2014) by using a combination of hand crochet, knit and machine knit to enable her design concept to be realised in three-dimensional form as a garment. The seamless hand crocheted pieces in Figure 3.20, created by Backlund, show how traditional handcraft techniques may be incorporated well into contemporary fashion designs.



Figure 3.20. Hand crocheted tops by Sandra Backlund (Udale, 2014)

Shima Seiki, a leading manufacturer of seamless knitting machine, introduced “ the world’s first commercially productive computerised seamless knitting machine” (Shima Seiki, 2018) at the 12th ITMA exhibition in Milan in 1995. The introduction of such ‘WholeGarment® technology’ into the knitwear industry has enabled companies to save

production time, and labour costs globally, as well as a significant saving in the cost of materials through minimising waste. Since the invention of the seamless knitting machine, ‘WholeGarment® technology’ has continued to develop within the fashion industry and has become capable of commercial viability (Yang, 2010), with potential creative uses of the technology moving beyond its conventional form. For instance, the ‘3D-Knit’ exhibition at the AXIS Gallery in Tokyo in 2005 presented three-dimensional seamless wearable sculptures designed by Yoshiki Hishinuma.



Figure 3.21. Seamless wearable sculptures designed by Hishinuma (2005)

The works in Figure 3.21 were designed in collaboration with the Shima Seiki company to develop seamless wearable sculptures in order to demonstrate the creative potential of seamless technology (Taylor and Townsend, 2014). The seamless knitting technology provided by Shima Seiki enabled wearable seamless knitwear to be realised from the creative drawings. However, although the technology that enables seamless knitted textiles has developed forward, its full potential has not yet been realised as far as making creative seamless fashion items is concerned (Yang, 2010; Taylor and Townsend, 2014). Moreover, innovative designs of current seamless knitting garments are hard to see perhaps due to the fact that there is skill gap between the technology and designers (Taylor and Townsend, 2014). Taylor and Townsend (2014) also claim that although the digital process of up-to-date technology enables creative forms of seamless knitted garments, the process is “not [only] a total solution or an end in itself and that it could be influenced by knowledge of the hand-knitting [craft] discipline vice versa (Ibid: 167)”.

The A-POC (A-Piece Of Cloth) collection created by Issey Miyake, launched in 1998, is an example of seamless fashion, and it was developed with weft-knit technologies which

could make whole-garment knitwear commercially viable (Lin, 2001; Piper and Townsend, 2016). Miyake presented the cutting-edge design concept of ‘Tube Knit’, which entails joining pieces of the knitted tube using a computerised seamless knitting machine. The resulting work was worn by a number of models together. It was a customisable machine-knitted tube which could be altered by customers to change the shape of the garment. The collection was patented by Miyake and it has not yet been revealed how the collection was created.

‘The Endless Garment: the new craft of machine knitting’ an exhibition at the RMIT Gallery in Melbourne, also presented a creative collection of knitwear that had been produced by combining up-to-date computerised industrial knitting machines and innovative fashion design (RMIT Gallery, 2010). The exhibition aimed to suggest “future directions of new craft of machine knitting which is changing the way fashion is designed and made” (Ibid). Seamless garments in creative art forms from the exhibition in Figure 3.22 blur the line between art and fashion design. In the case of such projects mentioned above could realise the complex forms of seamless knitted garments because of temporary technical supports between technology and artists or designers. Moreover, the technology is still mainly used to produce conventional or simple shapes of garments (Taylor and Townsend, 2014).



Figure 3.22. ‘The Perfect’ designed by Freddie Robins (left) and ‘Skin King’ (right) designed by Walter Van Beirendonck (RMIT Gallery, 2010)

3.3.3 *Seamless Nonwoven Textiles*

Nonwoven textiles are another type of seamless textile and are formed from sheets consisting of fibres that are continuous or staple filaments and yarns (whether natural or synthetic). The sheets are created through a process that can use water, heat or chemicals without any structured construction such as weaving and knitting (Fangueiro and Soutinho, 2011; Gong, 2011; Matthews, 2011). Nonwoven textiles are generally used in applications such as fashion accessories, home furnishing and engineering as well as for industrial purposes and medical products. In contemporary art and design, nonwoven textiles such as felt and heddle felt are widely used to create small scales of three-dimensional art forms and products (Mullins, 2009).

Felt fabric is basically composed of animal fibres, such as wool, often mixed with synthetic fibres. The compositions of felt fabric may vary depending on intended end uses. Some felt fabrics are made entirely from synthetic fibres for industrial purposes. Felt hat making is a traditional craft and an example of seamless nonwoven textiles used in the fashion industry. Traditionally, felt fabric, generally using animal fibres, is treated by wet and steam processes to make fibres shrink, interlock and mat. This tightens and integrates fibres within the fabric, and helps guard against fraying and ravelling. The fabric is then shaped using various sizes of perforated moulds with heat, steam and pressure in order to set the shape of the hat. Christys' London (2018), the largest hat making company in the U.K is one of the examples, has made felt hats in diverse shapes and sizes. Felt making techniques may also be used to create larger seamless fashion items. An example is a Nuno felt technique developed by Polly Stirling in the early 1990s in Australia (Schofield and Kilfoyle, 2014). It uses fine silk organza fabric along with wool fibres felted in between strands of silk. The silk then distorts into three-dimensional seamless shapes when the wool fibre shrinks. The technique is widely used in making fashion accessories as well as fibre or textile art forms and has the potential for creating seamless nonwoven garments. Cho is a Korean textile artist who uses Nuno felt to make a series of seamless garments (Design press, 2018). However, the technique itself is hard to standardise and varies each garment in physical properties such as forms, shapes, colours and textures because the technique requires only hand making process. The felt garments' range is also limited to simple shapes such as a poncho or a shawl wrap due to the lack of stretchable properties of felted fabrics to create wearable garments without seams.

Another way of producing felt is ‘heddle felting’, in which barbed heddles are used to create three-dimensional forms. The heddles take fibres from the surface of the fabric or object and drag them through the fabric or object by punching. The fibres then become tangled and may be joined many pieces together without sewing or bonding. This technique is also used in manufacturing synthetic suede and leather by machine heddle felting (Matthews, 2011). Although seamless felt making has evolved and been integrated with other techniques to create fabrics or objects, the use of felt has largely remained focused on industrial or architectural purposes rather than fashion and textiles. For within fashion and textiles, felt is generally used to create small pieces of fashion and interior accessories, however, it has the potential for creating seamless fashion items, and is becoming popular with many contemporary artisans and designers (Tellier-Loumagne, 2008).

3.4 Versatility in Fashion

3.4.1 The Use of Term

This research is focused on creating shapeable woven textiles forming into seamless garments. When looking at current academic literature and fashion and textile industry about the use of terms for such garments, which can be worn in many different ways. Three different terms could be found such as ‘transformable garments’, ‘convertible garments’ and ‘versatile garments’. However, there were no clear definitions of those terms for describing such garments in current academic literature. Moreover, they may have different meanings in some contexts and are often used interchangeably in academic literature as well as fashion and textile industry. In this section, definitions need to be explored in broader contexts in order to clarify the use of terms for garments, which can be worn in many different ways. Thus, Worth Global Style Network (WGSN), which is one of the leading resources for fashion and textile trends, Oxford English Dictionary and academic articles are used to define those terms for such garments in this research.

Terms related to this section:

Transformable *adj* A thing is transformable if it is possible to make a marked change in its form, nature, or appearance. (after (Oxford English Dictionary, 2018b) definition of ‘transform’)

Regarding using a word ‘transformable’ in the fashion industry, it often refers to an object, a garment or an item “which allows the wearer more than one-use” (Paget, 2017). According to a report of Paget (2017) on Worth Global Style Network (WGSN), he described transformable garments as “practical application or pieces which convert once zipped, snapped, Velcroed or tied together (or apart)” from Paris catwalk A/W 2017/18.

There is also an explanation of ‘transformable garment’ used in an academic article saying that,

“A ‘transformable garment’ has changeable design functions. The candidate elements for changeable design functions are colour/pattern, size/fit, silhouette, garment type, and design details.” (Koo, Dunne and Bye, 2013: 12)

Convertible *adj* Able to be changed in form, function, or character. (Oxford English Dictionary, 2018a)

Anna Ross from Worth Global Style Network (WGSN) reported a style of convertible garments for S/S 2019 as being “with a firm focus on multifunctionality” (Ross, 2018). In her report, the convertible garment is described as a “revamp ... using zips, tie-closures or buttons at the seams of sleeves, hoods and hems to encourage adaptable styling” and “inserting a zip ... [enables on to convert] the coat into a jacket ... providing an item with versatility and style in one.”

Versatile *adj* Able to adapt or be adapted to many different functions or activities (Oxford English Dictionary, 2018c).

Maggioni and Muston (2018) highlighted the versatility of garments in a report of the Buyers’ Briefing on Worth Global Style Network (WGSN). According to the report Maggioni and Muston (2018), versatility is illustrated in the report as “... offering

multiple ways of wearing a garment.” Moreover, “the versatility of the multi-way crossover is appealing ...”.

After reviewing the definitions and terms addressed above, there are no clear differences between ‘transformable’, ‘convertible’ and ‘versatile’. These are often used in similar ways, and or even interchangeably to describe a garment which can be worn in many different ways. However, as Paget (2017) explained transformable garments transform into other garments through physical attachment or detachment by means of zips, snaps or Velcro. Moreover, convertible garments need additional installations to be able to convert to other forms in similar ways as transformable garments. Although the term ‘versatile’ covers not only types of objects but also colours, shapes, textures and other physical features, the term ‘versatile’ has a more restricted meaning on the ways of wearing a garment, and refers to a garment that is wearable in multiple ways. Therefore, the research is based on the term of ‘versatile garments’ and concentrated on a new design practice of seamless garments that may not require additional features (zips, snaps or Velcro, or extra installation) to wear them in many different ways. Further, versatile garments provide a simple way and more scope for changing shape and function from its own design.

3.4.2 Practical Applications of Versatile garments

Designing garments with functions, which are versatile, or changeable, or transformable (convertible), or highly durable could encourage users to wear the garments in particular ways that they were designed for and it could improve engagement between user and clothing (Fletcher, 2008; Gwilt, 2014). According to Farrer (2011) and Koo, Dunne and Bye (2013), Garments that are designed to be versatile have more chance of being worn and used, thus having a direct effect on the sustainability of such items. Dombek-Keith and Loker (2011) also state that the versatility of versatile garments encourages the consumer to use such garments in many different ways, making the garments more useful for consumers and thus more likely to be used over a longer period, extending the lifespan of such garment.

As stated in section 2.3.2, the A-POC series is also one of the example of versatile garments that started from a piece of fabric cut into garments without sewing or mending.

The knitting technique used in the A-POC series enables the consumer to switch permanently from long sleeve T-shirt to short sleeve T-shirt or even sleeveless through by cutting, and as such it could play a part in creating user-oriented or customised versatile design that enables longer lasting products.



Figure 3.23. A-POC Series by Issey Miyake (Miyake *et al.*, 2002)

Refinity®, “an inspiration blog on textile product design for a circular economy” (Refinity, 2009), and Berber Soepboer, Dutch fashion designer, developed a garment called ‘Fragment Textiles’ shown in Figure 3.24, that is a modular versatile garment and is able to change its shape, type, colours and textures. The garment is made of C2C certified wool flannel with a ‘click/fold modular system’ that users can create various shapes of a garment by joining pieces of wool panels. Such modular textiles can be used to create versatility in a range of products, from small accessories to larger fashion items.



Figure 3.24. Fragment Textiles (Refinity, 2009)

Hussein Chalayan, innovative fashion designer, introduced versatile garments and wearable sculpture inspired by war refugees, and it referred to his own past in his show

at London Fashion Week A/W 2000. The stage was set up as a 1950s living room with four chairs and a table as part of the show. Models removed the chair covers and wore them as garments that each had a distinctive individual look (see Figure 3.25). At the end of the show, the last model stepped onto the middle of the table and lifted the table up around her, turning it into a wooden skirt (see Figure 3.26). Lau (2011) states that these garments were inspirational and impressive, and they are now well-known examples regarding versatile function of the garments.



Figure 3.25. Afterwords, A/W 2000. (Violette, 2011)



Figure 3.26. Afterwords, A/W 2000. (Violette, 2011)

Recently, Ma and Koo (2016b) introduced versatile garments with various features created by many designers such as the Untagging dress by Chalayan and the square module dress by Baldooi. Guo (2014) also proposed a versatile garment, this 'Boditecture Dress', which is a three-way dress, as a bubble dress, a full-length dress, or a mini dress

(see Figure 3.27). Boditecture is an award-winning clothing label inspired by architecture, and it aims to design a garment that has multiple styles for various occasions. These examples of versatile garments need additional features, such as zips, buttons or snaps, to be changed into another forms of garment.



Figure 3.27. Boditecture Dress, F/W 2012 by Guo (2014)

3.5 Summary

This chapter has presented the contextual and technical framework in which this research is positioned, and has outlined relevant literature of circular design perspective for sustainable fashion and textiles and related design practices in the fields of shapeable textile design, seamless textiles, and versatile fashion and textiles.

In light of the review, it is highlighted how the design practice in this research could consider a number of ways to improve circular design for sustainable fashion and textile design practice. It reviewed that the design practice of the research could be effective in integrating circular design considerations in order to bring multiple cycles by designing garments for closing resource loop, minimising waste, enhancing products life, and slowing down resource loop. The review also highlighted various technical approaches to seamless textiles along with shapeability that forms three-dimensional textures and surface effects in order to create shapeable seamless garments. It revealed that seamless knitting technology has been developed to enable advanced seamlessness in textiles and fashion, however the full potential of the seamless design has not yet been realised. Thus, the active relationship between technology (machinery) and designers is required in order to produce more creative shapes of garments or innovative functional fashion items rather

than produce basic garments. It also showed that previous design practices for seamless woven textile and fashion were only focused on the technology itself, or the use of synthetic fibres, or the way of design. In that case, it recognised that woven textiles in this research have the potential for creating innovative seamless fashion garments using both hand and Jacquard weaving within the consideration of circular design perspective for sustainable fashion and textiles. Therefore, it reviewed how this research can be unique from existing researches and practices with the new design practice that integrates key design considerations, such as seamlessness, shapeability with inherent stretchability, three-dimensional textures and surface effects, versatility, material choice and circular design perspectives for sustainable fashion and textiles.

The methodological approach for the research, and practical explorations will be discussed in following chapters.

Chapter 4. Methodology

This chapter describes the methodology used in this research. The research is practice-based and situated in the textile design discipline. The current discussion about the integration of practice with research is highlighted. The chapter concludes with an explanation of the methodological approach and the chosen methodology along with selected research methods.

4.1 Building a Methodology

The methodological approach in this research is essentially practice-based, one builds new knowledge through design practice (Candy and Edmonds, 2017). Within practice-based research, Candy and Edmonds (2017) highlight that claims of originality and of making a contribution to knowledge can be demonstrated through creative outcomes (designs or exhibitions) with an accompanying written thesis.

As the research is set within the context of textile design practice, the aim and objectives addressed within this design practice concern the nature of designing and specifically creating shapeable woven textiles for seamless fashion. Thus, the methodology for this research is developed from existing methodological approaches for creative design research in order to enable textile design practice to be the central element of the research design process.

The framework for practice-based research in textile and fashion design is ‘research through design’ (see the framework in Figure 4.1) (Bye, 2010). The process of the framework is similar to action research process (Uğur, 2013) in the iterative stages that include four-stages such as plan, action, observation and reflective stage. Through an iterative and reflective process, this research has however developed a five-stage action research process based upon ‘research through design’ framework that broadly fits within the action research methodology.



Figure 4.1. ‘Research through practice (design)’ framework for clothing (fashion) and textile design scholarship (Bye, 2010, p.214)

The section below describes research aims and objectives, followed by a methodological approach and specific research methods.

4.2 Methodological Approach

Practice-based research in design disciplines is a relatively young field of study compared to the field of science as “there was considerable thinking and writing which had an enormous impact on the concept to the method and practice of design” from the 1960s to 1970s (Swann, 2002, p50). By the end of the 1990s, significant clarification about practice-based research has appeared through broad debate “about the nature of research in Art and Design” (Gray and Malins, 2004, p3). Gray (1996) and Gray and Malins (2004) note that practice-based research as the way of raising researchable problems in practice, responding researchable questions through aspects of practice, and generating knowledge through practice. ‘Research through design/practice’ has been widely used as a distinct term to describe practice-based research that generates transferable knowledge (Durrant *et al.*, 2017). There is however still an ongoing debate about appropriate approaches and

methods to generate new knowledge in the field of design research. Durling (2002, p 81) argues that “research and [design] practice [should] coexist as different categories of creative endeavour, and should not be confused with being identical categories”. He also highlights that design practice could form a PhD study “either through being structured as a method for collecting data systematically or as a means to allow structured reflection upon (design) practice” (Ibid, p82). In this research process, textile design practice is also central to the aim of the research, thus textile design practice is structured both as a method and a reflection through an iterative process of action research process.

Although ‘research through design’ is not a formal methodological approach, it is a fundamental means of inquiry into design practices (Durrant *et al.*, 2017). Both Frayling (1993) and Archer (1995) describe action research within ‘research *through* design/practice’. For example, Archer states that action research is a “... systematic enquiry conducted through the medium of practical action; calculated to devise or test new, or newly imported, information, idea, forms or procedures and generate communicable knowledge” (Archer, 1995, p11). Although Archer mentioned that action research is a systematic enquiry, this research also pays attention to the fact that design “has its own intellectual culture” (Cross, 2007, p48). Taking into consideration this researcher’s background as a textile designer, and using a ‘research through design’ framework, the researcher plays an active role by participating in the design process which he has situated himself within Jonas (2015). Here, the practitioner as the observer takes a subjective position at the centre of the design practice where reflective practice generates and communicates knowledge. In this process, the researcher is careful to integrate and carry out design research as “purposive, inquisitive, informed, methodical and communicable” (Cross, 2007, p48), because it should differ from ordinary everyday design work (Bye, 2010), as it also needs to contribute to the development of academic or professional practice (Friedman, 2002).

This design research process is not only “a systematic enquiry” (Archer, 1995, p11), but also follows what Cross (2007, p49) describes as “designerly ways of knowing, thinking and acting” where the researcher combines his practitioner background to form a comprehensive methodology while integrating an action research approach with the framework of ‘research through design’. For a similar research strategy, Uğur (2013) uses a combined strategy of a ‘research through design’ framework and action research based

on practice-based design research to create wearable technology. Vuletich (2015) uses action research based on the framework of ‘research through design’ to explore new sustainable practices for fashion and textile designers.

Action research is a practical research methodology, and it arises from a problem or an ambiguity in the situation that is clarified through a spiral of cycles of planning, acting, observing and reflecting (Swann, 2002; Kemmis, McTaggart and Nixon, 2014). Through these iterative cycles, action research aims to integrate research and practical development (see Figure 4.2) “to gain a better understanding of the change (action) and development of processes (research)” (Kemmis, 2009, p.463; Zuber-Skerritt, 2011, p.6).

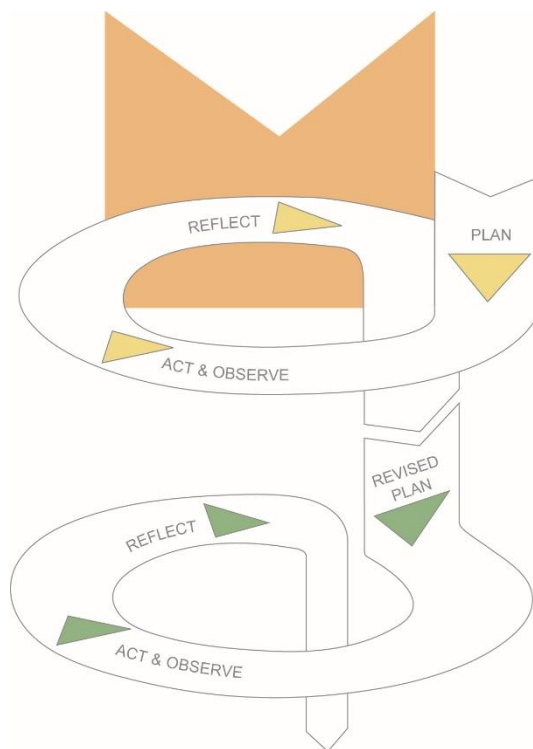


Figure 4.2. The action research spiral (Kemmis and McTaggart, 2005, p.278)

As action research “emphasises knowledge produced in the context of application” (Eden and Ackermann, 2018, p.1147), this research attempts to generate new knowledge of seamless woven textiles for fashion, while simultaneously trying to re-think, improve and develop such knowledge in order to create unique ways of applying it.

Here, the practitioner as a researcher “identifies researchable problems raised in practice”, “responds through aspects of practice”, continuously learns from “creative process”

(action), tries to understand the process (research) and critically thinks and reflects throughout each iteration of the research practice (Gray and Malins, 2004, p.20-21).

4.3 The Action Research Cycle of The Research

The action research process was the basis for combining the practitioner-researchers background to form a comprehensive methodology with the ‘research through design’ framework for fashion and textile design discipline. Based on the basic four-stages (plan, act, observe and reflect) of action research cycle, the action research process in this research was developed and expanded to five stages (see Figure 4.3). The ‘act stage’ was divided into ‘exploring and prototyping stage’ in order to conduct technical experiments (material selection, testing, application with weave structure and construction) in ‘exploring stage’ and to implement the result of technical experiments into prototype designs in ‘prototyping stage’.

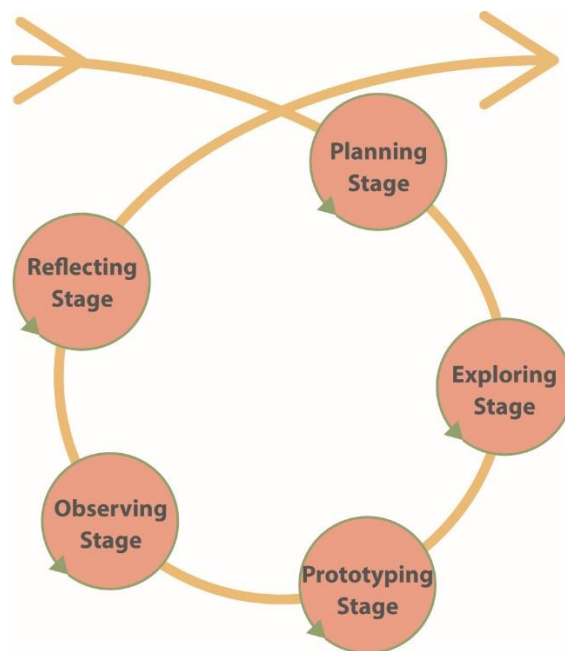


Figure 4.3. Five stages of action research cycle in this research

- i. The planning stage explores critical contextual review, identifies research aims and objectives concerning the creation of shapeable seamless woven garments and their impact on circular design for sustainable fashion and textile design.

- ii. The exploring stage investigates practical explorations on shapeable woven textiles including material experiments, technical developments, and evaluations.
- iii. The prototyping stage examines the practical integration of previous explorations into shapeable seamless woven garments that are prototype design outcomes, followed by evaluations.
- iv. The observing stage analyses and evaluates the outcomes of both exploring and prototyping stages where the practical or visual data and the information is gathered. As a part of observing stage, questionnaire and a focus group are conducted in order to have diverse perspectives from the public.
- v. The reflective stage shares and gets feedback from other perspectives on the design outcomes and findings. It discusses the results of the practical experiments along with questionnaire and a focus group, their evaluation and research processes, which could lead to a new cycle.

The five-stage action research process provides an effective basis for this research project, and the specific methods used in the process have to be developed for each stage of action research cycle. Moreover, although action research cycle is iterative and simultaneous process of taking action and doing action (Lewin, 1946), one cycle of the five-stage action research is conducted in this research project. In the following section, the particular methods used in action research approach will be summarised.

4.4 Methods

4.4.1 Methods in Action Research Cycle for the Research

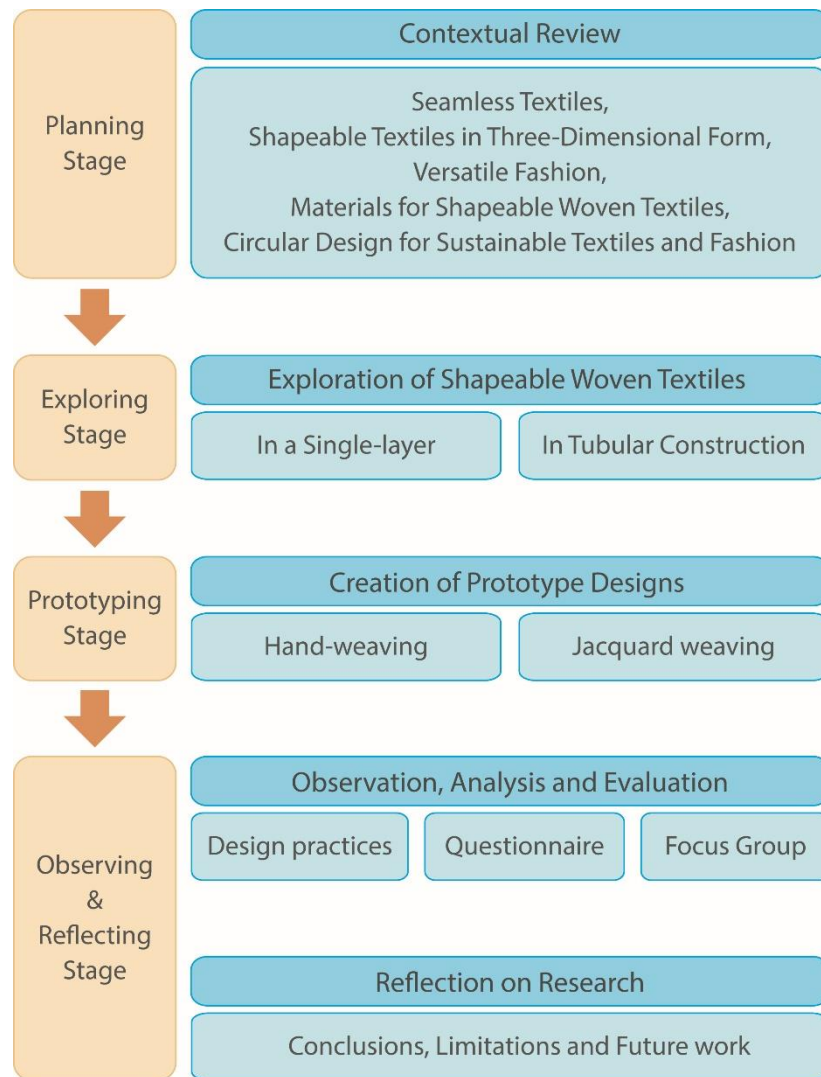


Figure 4.4. Overview of action research process in this research

4.4.1.1 Planning

The process of identifying the research aims and objectives involves broadly exploring the literature, media, exhibits and artefacts. In this initial stage, a contextual review is conducted to establish the area of research. The contextual review explores five areas that may indicate a gap in the research – seamless textiles, shapeable textiles in three-dimensional form, versatile fashion, materials for shapeable woven textiles and circular design for sustainable textiles and fashion. This planning stage, which includes research background, aims and objectives, is addressed in Chapters 1 and 2.

4.4.1.2 Exploring

This stage involves the practical exploration of materials and weave structures through two stages of weaving trials; ‘shapeable weaving trials in a single-layer’ and ‘shapeable weaving trials in tubular construction’, in which key aesthetical and physical properties of shapeable woven textiles are investigated. Each practical investigation within these two stages of weaving trials is based upon technical plans that reflect the previous stage and follow a systematic approach. The result of experiments is critically analysed and evaluated to identify relevant technical information concerning shapeable woven fabrics. The data collection tools used in this stage are:

- sampling preparation sheets/sampling schematizations
- weaving sample charts/analysing and evaluation charts
- fabric realisation
- photography
- written summaries

This exploratory stage is addressed in Chapter 4.

4.4.1.3 Prototyping

This second stage of action, the prototyping stage, focuses on the creation of prototype designs that are based on the result derived from the exploratory stage. Both aesthetic features and physical properties such as three-dimensional textures and surface effects, stretchability and shrinkage are systematically investigated and selected for the creation of shapeable seamless woven garments. These findings from the previous stage are integrated and developed in order to create prototype designs. Based on the findings, initial prototypes of garments are outlined and visualised as part of design preparation. Such visualisation provides advantages when making prototypes and modifications during the prototyping stage. A total of six practical trials are conducted in this stage of creating prototype designs. In order to generate communicable practical knowledge, the following data collection tools are used:

- design preparation sheets/design visualisation

- prototype designs creation
- photography
- written summaries

This prototyping stage is discussed in Chapter 5.

4.4.1.4 Observing

As a central element of analysis and evaluation of the research, the observing stage obtains both qualitative and quantitative data that are collected, analysed and evaluated through design practices, questionnaire and a focus group.

The researcher mainly observes qualitative data of design outcomes during practical experiments such as exploring and prototyping stages of action research process. The researcher, as a practitioner at the centre of the design practices, captures significant information using photography, technical data and structured documentation sheets.

A questionnaire, an example of quantitative data collection, is carried out during the exhibition of design outcomes of this research in order to acquire various perspectives regarding the research and prototype designs.

A focus group discussion, another means of qualitative data collection, is adopted as a form of the peer review process in order to acquire other perspectives on this research, evaluating prototype designs and generating new idea. The observation is made by the researcher participating in the discussion as a moderator, and using photography and video/audio recording during the discussion. Using the observation, transcription and visual data, the interactions between participants and prototype designs are analysed and evaluated.

The first data collection of practical outcomes is outlined in Chapters 4, and the creation of prototype designs are illustrated in Chapter5. Data analysis and evaluation of questionnaire and a focus group are discussed in Chapter 6.

4.4.1.5 Reflecting

The final stage of the action research cycle requires that the researcher adopts a more objective position than in the previous stages, in order to reflect on the outcomes and findings, and at the same time to develop relevant questions for the new cycle. Each stage of the action research cycle has its own reflection stage, involving analysis and evaluation in preparation for the next stage. Through the integrated reflecting stage, the researcher may clarify what he planned, explored, discovered and achieved in this design practice. This reflective stage of the research along with conclusions, limitations and potential further developmental work, are identified in Chapter 7.

4.4.2 Questionnaire and a Focus Group

According to Milton and Rodgers (2013), one of the effective ways of extracting information from a group of people is asking them directly by using tools and techniques such as questionnaires and focus groups, both of which help designers and researchers get a better understanding of the complex relationship that can exist between users and designed products.

The questionnaire used in this research, is a “way of getting information from people, usually by posing (a set of questions with constructed scales)” (Gillham, 2008, p.2), and is a self-administered questionnaire. In order to refine “theories about interactions with designed objects through validation of exploratory research findings”, design discipline often use questionnaires as quantitative methods (Ireland, 2003, p.63).

Focus groups have been used in market research for many years and are widely associated and implemented with practical research (Bryman, 2016). Kawamura (2011) also claims that focus groups have become an essential element of qualitative data collection for research in fashion and textiles. The use of a focus group is generally “a carefully planned discussion designed to obtain perceptions in a defined area of interest in a permissive, nonthreatening environment” (Krueger, 1994, p.6).

Within this research, a questionnaire and focus group are employed to enable analysis and evaluation of the design practice of shapeable seamless woven garments, and to establish it as a new design attempt of the research that could assist in circular design practice for

sustainable fashion and textiles. Moreover, in order to obtain diverse perspectives of potential users regarding the prototype designs and further developments, they are carried out after the prototyping stage as part of the observing and reflecting stages of the research process:

- phase 1: questionnaire during the exhibition to the public
- phase 2: a focus group with fashion and textile design academics and professionals

Each of these methods is discussed in detail in Chapter 6.

4.4.2.1 Data Triangulation

As discussion and issues around practice-based research have identified the complexity of design research, it is clear that appropriate research methods, ones that are robust and rigorous, need to be used in practice-based research in order to enable accessible and disciplined inquiry (Gray and Malins, 2004). In order to generate diverse perspectives on research problems and outcomes for the validity and reliability of research, the advantage of employing a combination of methods for data collection has been highlighted by many research projects (Crouch and Pearce, 2012). The use of more than one method or data source for collecting information relating to a research problem or issue is referred to as ‘triangulation’ (Gray and Malins, 2004; Bryman, 2016). Through the use of different methods, the researcher can “obtain a better, more substantive picture of reality, a richer and more complete array of symbols and concepts” (Kawamura, 2011, p111). Triangulation could increase validity and reliability, which can strengthen research by enabling a comparison and contrasting of the data that has been gathered using both qualitative and quantitative approaches.

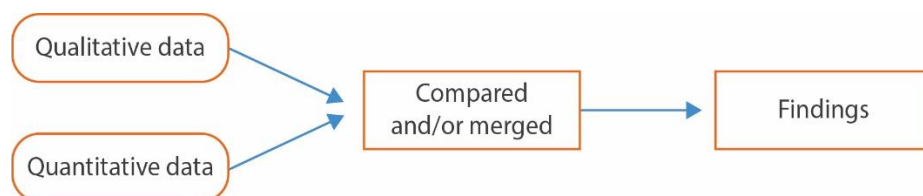


Figure 4.5. Convergent parallel design

Qualitative and quantitative methods are often combined (Silverman, 2013), which is one form of triangulation approach (Crouch and Pearce, 2012). A combination of qualitative and quantitative methods in such research may present “deeper and more penetrating insights” and “information about the general representativeness of that understanding” (Wilson, 2006, p.105). Within the framework of ‘research through design’ used in the research, the triangulation supports corroboration of the design process and outcomes, and also rigorousness and robustness of the research. Bryman (2016, p.638) suggests the convergent parallel design of mixed methods (see Figure 4.5) for a triangulation approach “whereby the researcher aims to compare two sets of findings”. The convergent parallel design encompasses qualitative and quantitative data collection, and the analysed data are compared and/or merged to have integrated findings.

In light of such considerations, a combination of qualitative and quantitative methods is used in this research in order to identify in what ways the design process of achieving greater versatility of the prototype designs through the use of shapeable woven textile is perceived by the public and fashion and textile design experts. In addition to perceptions, this combined method is also useful for identifying the suitability of applying shapeable woven textile to seamless garments, as well as evaluating user experiences and responses regarding the versatility of prototype designs produced as part of the research and how the technique supports circular design perspective for sustainable fashion and textiles.

4.5 Summary

This chapter outlines the methodological approach and the methods used in this research. It describes a useful framework, ‘research through design’, for the study of fashion and textile design. Within this framework, one cycle of the five-stage action research methodology is adopted and developed to meet the research aims and objectives. For each stage of the research that has specific approaches, the chapter establishes that the method is mainly qualitative and comprises reflective design practices through the action research process along with a focus group discussion and questionnaire.

The following chapters document design processes of this research in detail and outline a comprehensive textile design practice with analysis and evaluation of shapeable woven textiles for seamless fashion.

Chapter 5. Exploring Stage: Shapeable Woven Textiles

This chapter, the exploring stage of action research process, aims to explore various three-dimensional surface effects and textures of shapeable woven textiles with different degrees of shrinkage that enable inherent stretchability. The work here compares the opportunities and challenges presented by weaving trials to the research and identifies which outcomes of trials could best support the development of shapeable seamless woven garments. In order to find out how such three-dimensional surface effects and textures with shrinkage could be applied to the garments, the exploring stage consisted of two types of weaving trials: shapeable weaving in a) a single-layer and b) tubular construction (see Figure 5.1).

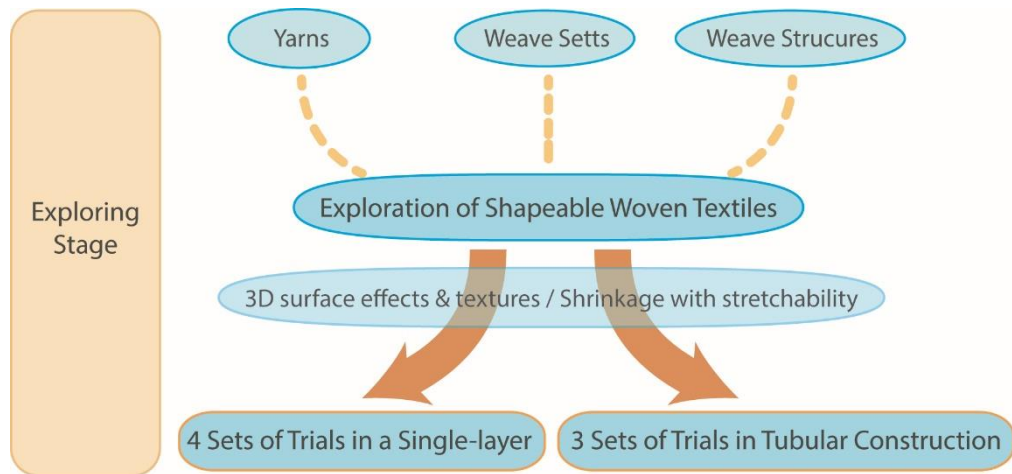


Figure 5.1. The exploring stage of the research

The first part, shapeable weaving trials in a single-layer, focused on the changes of weave setts, structures and yarn types required to identify different degrees of fabric shrinkage, which is the essential design element allowing inherent stretchability that enables seamlessness in woven garments. The emphasis of these trials was also to create three-dimensional surface effects and textures by means of the degree of shrinkages. In order to analyse various degrees of fabric shrinkages from possible combinations of weave designs (weave setts, structures and yarn types), a total of four sets of shapeable weaving trials in a single-layer were conducted under the supervision.

The second part, shapeable weaving trials in tubular construction, concentrated on the differing arrangements of weave structures and yarn types on the tubular weaving samples to identify how these varying arrangements of weave designs influenced degrees of

shrinkage of shapeable tubular weaving samples (the basis of seamless woven garments). The significance of these trials was also to create diverse shapes using woven tubes in order to see how these diverse shapes can be applied to the prototype designs. Based on the chosen combinations of weave designs from the supervision, a total of three sets of shapeable weaving trials in tubular construction were conducted.

In these practical trials, a 24-shaft dobby floor loom was utilised to produce a variety of shapeable woven samples in both single-layered and tubular construction. The specification for woven samples of each part will be detailed in the following sections.

5.1 The First Experiment on Shapeable Weaving Trials in a single-layer

In this experiment, a number of single-layered woven samples were produced to analyse various three-dimensional surface effects that correlated with the degree of shrinkage. To achieve the goal, a total of four sets of shapeable weaving trials were undertaken to produce 45 samples in diverse combinations of warp and weft. The purpose was to create stretchable fabrics with decorative three-dimensional surface effects and textures due to shrinkages such as pleating, curling and shaping by using high-twist wool yarns, which results in fabrics shrinking vertically and horizontally.

5.1.1 Materials

In this research, the inherent elasticity and stretchability of woven fabrics are necessary design elements in order to create shapeable woven textiles for seamless garments. Moreover, for the key feature of creating three-dimensional and textural surface effects (such as pleats, curls, ripple, wave and crinkle patterns) of shapeable woven textiles, the use of high twist wool yarn is important factor to enable those effects (Acar, Meriç and Kurtuldu, 2019). According to Richards (2012, p.21), twist factor of yarn has “a powerful influence on the appearance, handle and functional properties of fabrics” and it is a vital element in textile design. Field (2008, p.6) also claims that high twist yarn is one of the factors that make fabrics “flexible and fluid in movement” and it often uses to make collapse fabric that “bends, distorts and deviates from the usual linear movement of most other cloth”. Thus, high twist wool yarns were selected for the use of making shapeable woven fabrics that were elastic and stretchable, instead of using synthetic fibre yarns such

as Spandex, Lycra and elastane fibre. Moreover, merino wool yarn was selected for the basis of shapeable woven fabrics that gives comfort feeling next skin and also supports to maximise three-dimensional and textural surface effects of high twist wool yarns as mentioned in section 2.1.1 (the material selection with regard to circular design for sustainable fashion and textiles).

Therefore, For the shapeable weaving trial using a single-layer, three different yarns in the colour ‘ecru’ were utilised for both the warp and weft, specifically a 2/30Nm merino wool, 1/30Nm high twist wool yarns in S twist and Z twist.

The basis of cloth setting is based on the yarn count and has a significant role in estimating the diameter of yarn required for an appropriate sett for the weave (Richards, 2012). The number of threads of the yarn that would fill one inch or a centimetre needs to be determined in order to weave with particular yarns, such as high twist wool yarns, for textured fabrics. The diameters per inch are also important for the identification of the twist factor of high twist wool yarns. This calculation can often be done by simply wrapping the yarn around a ruler to check the number of threads that wrapped in an inch or a centimetre. The calculation is however done by using the Ashenhurst formula (Ashenhurst, 1884) as follows:

$$\text{Yarn diameter per cm} = 0.236(\text{for woollen yarns}) \sqrt{\text{Yarn length(m)}/\text{Yarn weight(kg)}}$$

$2/30\text{Nm merino wool} = \frac{30,000}{2} = 15,000\text{m/kg}$	$1/30\text{Nm high twist wool} = \frac{30,000}{1} = 30,000\text{m/kg}$
$\text{Yarn diameters(cm)} = 0.236\sqrt{15,000}$ $= 0.236 \times 122.5$ $= 28.9(\text{cm})(73.4(\text{inch}))$	$\text{Yarn diameters(cm)} = 0.236\sqrt{30,000}$ $= 0.236 \times 173.2$ $= 40.8(\text{cm})(103.6(\text{inch}))$

Such high twist wool yarns have generally been manufactured and used for industry to produce crepe fabrics rather than aimed at the hand-craft sector, however some of the high twist wool yarns have recently become available to handweavers and designers (Richards, 2012). For the purpose of forming inherent stretchability along with three-dimensional surface effects and textures of the fabrics, the twist factor is the key feature of high twist yarns (Ibid), and it has been often described in turns per inch, centimetre or metre (tpi,

tpcm, tpm) along with the angle of twist. In Figure 5.2, in order to ascertain the angle of twist, the picture was taken by scanning electron microscope (SEM) showing a 50 times magnified high twist wool yarn in Z twist. Magnified high twist wool yarn showed approximately 32° of twist angle on average.

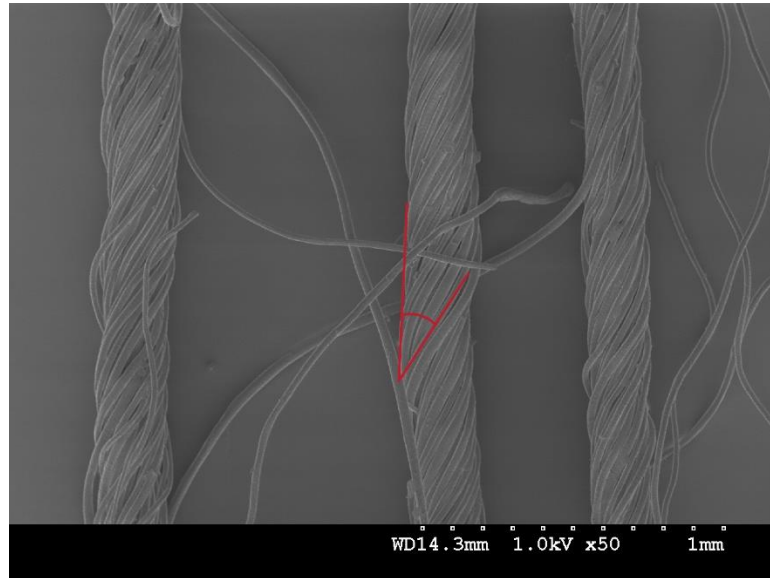


Figure 5.2. SEM picture of high twist wool yarn in Z twist

To identify the number of twists per inch (tpi) of the high twist yarns used in the research, the following formula was used. The formula was derived from Richards (2012), as were the values for ‘the tangent of the twist angle’.

$$\text{tpi} = \frac{\text{the tangent of the twist angle} \times \text{diameters per inch}}{\pi (\pi = 3.1416)}$$

$$\text{tpi} = \frac{\tan 32^\circ \times 104}{3.1416} = \frac{0.625 \times 104}{3.1416} = \frac{65}{3.1416} = 20.7 \approx 21\text{tpi}$$

As a result, the high twist wool yarns used in the research had 32° of hard twist that was approximately 21 twists per inch. The trials were conducted to look at how the yarns with different twists and characteristics react to each other as well as respond to the degree of shrinkage when they intersected within various weave settings and structures.

5.1.2 Weave Designs

In an effort to make shapeable woven fabrics, four sets of variations were examined, specifically different yarns in the warp and weft combinations and weave designs for diverse fabric formations in a single-layered construction. The basic simple weave structures were chosen to compare the degree of shrinkage of woven samples with three-dimensional textures on the surface, namely a plain, 2/2 twill, 1/3 twill, 2/2 basket and 2/3 basket. These basic weave structures are detailed in Figure 5.3.

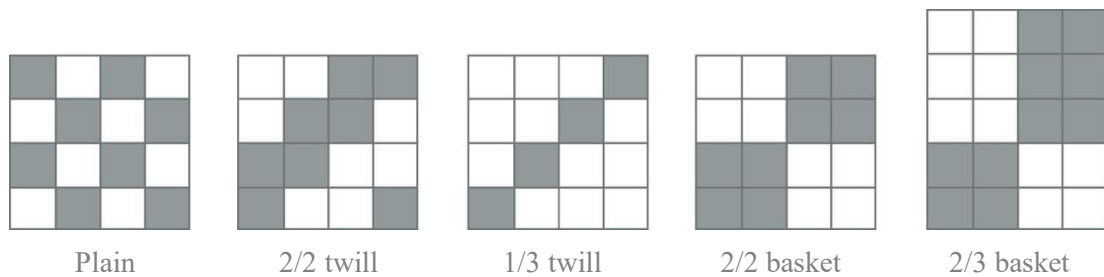


Figure 5.3. Basic weave structures

5.1.2.1 Weave Setts

The weave sett of cloth refers to the number of threads (ends and picks) within a specified unit of measurement (Dixon, 2007; Kearley, 2014). The unit of measurement is generally based on a centimetre or an inch, and the weave sett is described as ends per centimetre or inch (epcm or epi) and picks per centimetre or inch (ppcm or ppi). For all the practical experiments involved in this research, the epi (ends per inch) was used for the weave sett measurement. A total of three weave setts were applied to four different sets of shapeable weaving trials in a single-layer.

In the first set, 2/30Nm merino wool was mainly used for the warp of 15 samples. The dpi (diameters per inch) of 2/30Nm merino wool was calculated by using Ashenhurst's formula in section 4.1.1. Based on the plain weave structure, each warp end is intersected by a weft pick (see Figure 5.4), therefore the number of warp ends would be half the number of diameters per unit for a plain weave structure due to the fact that each warp end needs a space for each weft pick (Dixon, 2007; Field, 2008).



Figure 5.4. Weave sett for a plain weave structure

For the 2/2, 1/3 twill and 2/2 basket weave structures (except for 2/3 basket), all shows the repetition of every four warp ends with two intersections by weft pick (see Figure 5.5). It is therefore recommended that the number of warp ends would be two-thirds the number of diameters per unit because every four warp ends need a space for every two weft picks (Dixon, 2007; Field, 2008).

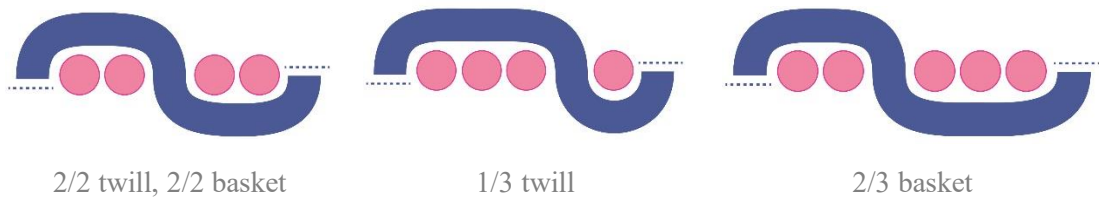


Figure 5.5. Weave sett for 2/2, 1/3 twill and 2/2, 2/3 basket weave structures

These formulas are usual guidelines for basic weave structures to give any maximum sett cloth the properties of a degree of stiffness and the best possible durability (Gilligan, 2004). However, there are other fabrics which need not be constructed at their maximum sett level. Weave sett can be varied and diverse in many cases for the end use of fabrics in order to create differences in such properties as draping and texture. Thus, the end use of fabric is the main consideration when deciding the sett to be used. Gilligan states that there are percentage reductions from the maximum sett for different fabric types depending on the drape, stiffness and handling requirements in worsted and woollen fabrics. For example, it is suggested that 20% - 30% reductions from the maximum sett should be used for ladies dress fabrics and drapes.

Therefore, the preferred number of epi (warp ends per inch) for 2/30Nm merino wool yarn was calculated, based on a plain weave structure, as follows:

$$\text{ends per inch (2/30Nm merino wool yarn)} = \text{approximately } 73/\text{inch}$$

$$\text{Maximum sett of a plain weave structure} = \text{epi} \times \frac{1}{2}$$

$$36.5 = 73 \times \frac{1}{2}$$

25% reduction for ladies dress fabrics and drapes,

$$28\text{epi} \approx 27.3 = 36.5 \times \frac{75}{100}$$

As a result, a 28epi weave sett of 2/30 merino wool yarn was applied for the warp of the first weaving trial with a total width of 8 inches.

For the second and the third set of shapeable weaving trials, 1/30Nm high twist wool yarn in S twist and Z twist were mainly used for the warp. However, as the weave sett of 2/30 merino wool yarn was nearly maximum in the first set of weaving trials, yarn movement was relatively restricted, and this limited the formation of textures. Thus, weaving trials in the second and third set were in contrast to close sett where the yarn need more space to move, and the patterns of textures appear. According to (Field, 2008) and (Richards, 2012), weave sett is an important factor in using high twist yarns for shapeable woven fabrics, and variations in weave sett would affect the shape, texture and shrinkage. It was therefore advised to use an open sett in order to create clearly emerged three-dimensional textures.

The weave sett for the second and third weaving trials was calculated based on the plain weave structure as follows:

ends per inch (1/30Nm high twist wool yarn) = approximately 103/inch

$$\text{Maximum sett of a plain weave structure} = \text{epi} \times \frac{1}{2}$$

$$51.5 = 103 \times \frac{1}{2}$$

25% reduction for ladies dress fabrics and drapes,

15% additional reduction for open sett,

$$32\text{epi} \approx 32.8 = \left(51.5 \times \frac{75}{100} \right) \times \frac{15}{100}$$

As a result, 32epi of 1/30Nm high twist wool in S twist was applied for the warp of the second weaving trial and S and Z twist of 1/30Nm high twist wool with 32epi were used for the warp of the third weaving trial.

For the last set, 2/30Nm merino wool, and both S and Z twist of 1/30Nm high twist wool yarns were used together for the warp in different sections. In this case, the weave sett, 32epi, of 1/30Nm high twist wool was applied as the basis to investigate three-dimensional, textural surface effects and shrinkage occurring from different sections of three different warps. Because of the difference in thickness between warp threads, the weave sett, 16epi (half the number of the basis weave sett), was set for 2/30Nm merino wool in order to produce even-sett cloth. More technical information on each set of shapeable weaving trials in a single-layer will be detailed in the following sections.

5.1.2.2 Fabric Formations

After specifying the weave sett of yarns, the technical preparations for each set of shapeable weaving trials were planned. The basic steps were listed below:

- a) Set the draft. This determines the effect of woven patterns, along with a lifting plan.
- b) Set the total number of warp ends ($\text{epi} \times \text{warp width} = \text{total number of warp ends}$)
- c) Calculate the number of heddles for each shaft.
- d) Choose the reed size (in the Scottish weaving system, $\text{reed \#} = \frac{\text{epi} \times 1.875}{\text{epd (ends per dent)}}$).
- e) Calculate the total length of the warp (including loom waste).

The technical preparation was detailed on the design sheet for each weaving trials (see example in Figure 5.6). The design sheet showed the basic technical information about woven samples from the first set of shapeable weaving trials.


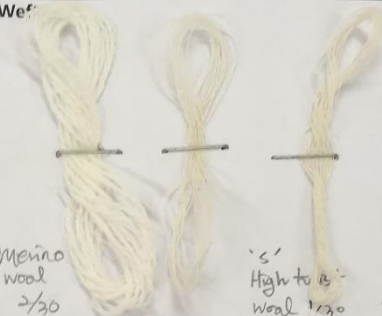
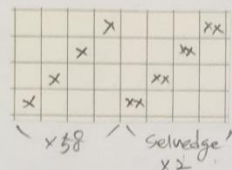
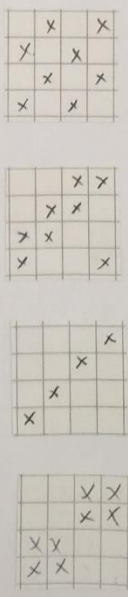
<p>Selected Warp Yarn</p>  <p>Merino Wool 2/30</p>	<p>Weft</p>  <p>Merino wool 2/30 '1's' High to 1/3 Wool 1/30 '2's' high twist Wool 1/30</p>
<p>Threading Plan & Shaft</p>  <p>4 shafts</p> <p>x 60 needles for each shaft</p>	
<p>Warp EPI - 28 epi</p>	<p>Weft PPI - Depends on structure,</p>
<p>Total Width - 8 inches (about 20cm)</p> <p>Total Ends - 240 ends inc 16 selvedges</p>	<p>Peg Plan</p>  <p>plain Twill 2/2 Twill 1/3 Basket 2/2, 2/3 x floating Selvedge</p>
<p>Bundles - Total 18 ea each bundles - 14 ends selvedges - 8 ends x 2.</p>	
<p>Reed Allocation * 26 reed, 2 EPD 4 EPD for selvedge</p>	
<p>Beam requirement 1 Beam</p>	
<p>Total Length 1 sample is 8 inches Total 15 samples - 120 inches + waste = 160 inches</p>	

Figure 5.6. Technical preparation sheet for the first set of shapeable weaving trials.

With a 28epi weave sett, using 2/30Nm merino wool yarn, the total ends of each sample were 240, including 16 ends for selvedges. The warp ends were threaded through each shaft in a straight draw configuration, and each shaft needed 60 heddles. The reed number was #26 in the Scottish weaving system, which had 14 dents per inch, and two ends were

threaded through each dent. The total length of the warp with loom waste was calculated as 160 inches to produce 15 samples of 8-by-8 inches.

In all, 15 samples were created, divided into three types, A, B and C, each of which was composed of five samples representing the five basic weave structures (see Table 5.1). In type A, woven samples were intersected with the weft of 2/30Nm merino wool while samples in type B were woven with the weft of 1/30Nm high twist wool in Z twist. Samples in type C were constructed by using the weft of both 1/30Nm high twist wool in S and Z twist respectively in every two inch section of sample (see examples in Figure 5.7). A total of 15 samples were produced to determine the amount of shrinkage that could be achieved by utilising five variables in weave structures, different weft densities and different weft yarns.



Figure 5.7. Off-loom samples from single-layer shapeable weaving trial no. 1.

Table 5.1. The first shapeable weaving trial in a single-layer.

No.	Weave Structure	Warp yarn	Weft yarns	epi
1 A	Plain	2/30Nm merino wool	2/30Nm merino wool	28
2 B			1/30Nm high twist wool Z	
3 C			1/30Nm high twist wool S & Z	
4 A	2/2 Twill		2/30Nm merino wool	
5 B			1/30Nm high twist wool Z	
6 C			1/30Nm high twist wool S & Z	
7 A	1/3 Twill		2/30Nm merino wool	
8 B			1/30Nm high twist wool Z	
9 C			1/30Nm high twist wool S & Z	
10 A	2/2 Basket		2/30Nm merino wool	
11 B			1/30Nm high twist wool Z	
12 C			1/30Nm high twist wool S & Z	
13 A	2/3 Basket		2/30Nm merino wool	
14 B			1/30Nm high twist wool Z	
15 C			1/30Nm high twist wool S & Z	

For the second set of shapeable weaving trials, 1/30Nm high twist wool yarn in S twist was mainly used for the warp. Including 32 ends for selvages, total ends were 288 ends with the weave sett, 32epi, of 1/30Nm high twist wool yarn. A straight draw configuration of the draft plan with four shafts was applied, and each shaft needed 64 heddles for the warp ends. For the weave sett, 32epi, of 1/30Nm high twist wool yarn, the reed number #30 was utilised, and every two ends of the warp and four ends of the selvages were threaded through each dent. In order to produce 15 samples of 8-by-8 inches, the total length of the warp was calculated as 160 inches including loom waste.

Three further types of fabric (D, E and F) with different weft yarns, were woven to create another set of 15 samples (see Table 5.2). Samples in type D and E were produced by using the weft of 1/30Nm high twist wool in S and Z twist respectively. In type F, samples were woven with the weft of 2/30Nm merino wool and both 1/30Nm high twist wool in S and Z twist, and those two weft types were alternated for every inch of sample (see examples in Figure 5.8).



Figure 5.8. Off-loom samples from single-layer shapeable weaving trial no. 2.

Table 5.2. The second shapeable weaving trial in a single-layer.

No.	Weave Structure	Warp yarn	Weft yarn	epi
16 D	Plain	1/30Nm high twist wool S	1/30Nm high twist wool S	32
17 E			1/30Nm high twist wool Z	
18 F			2/30Nm merino wool & 1/30Nm high twist wool S & Z	
19 D	2/2 Twill		1/30Nm high twist wool S	
20 E			1/30Nm high twist wool Z	
21 F			2/30Nm merino wool & 1/30Nm high twist wool S & Z	
22 D	1/3 Twill		1/30Nm high twist wool S	
23 E			1/30Nm high twist wool Z	
24 F			2/30Nm merino wool & 1/30Nm high twist wool S & Z	
25 D	2/2 Basket		1/30Nm high twist wool S	
26 E			1/30Nm high twist wool Z	
27 F			2/30Nm merino wool & 1/30Nm high twist wool S & Z	
28 D	2/3 Basket		1/30Nm high twist wool S	
29 E			1/30Nm high twist wool Z	
30 F			2/30Nm merino wool & 1/30Nm high twist wool S & Z	

In the third set of shapeable weaving trials, both 1/30Nm high twist wool yarn in S and Z twist were utilised for the warp by changing from S to Z, and vice versa, after every inch of sectional warp configuration of the samples (see Table 5.3 and examples in Figure 5.9).

In common with the second set, the same specifications of technical information were applied to the third set of shapeable weaving trials. The total length of warp requires for ten 8-by-8 inch samples was around 120 inches, including loom waste.

Two additional types of weft yarn order (G and H) were used to produce another ten samples (see Table 5.3). Samples in type G were woven with both 1/30Nm high twist wool yarn in S and Z twist, and each of them was filled in every inch, respectively. For the samples in type H, 2/30Nm merino wool and both 1/30Nm high twist wool in S and Z twist yarns were used for the weft yarns, and each weft was used alternately for every inch of the samples (see examples in Figure 5.9).

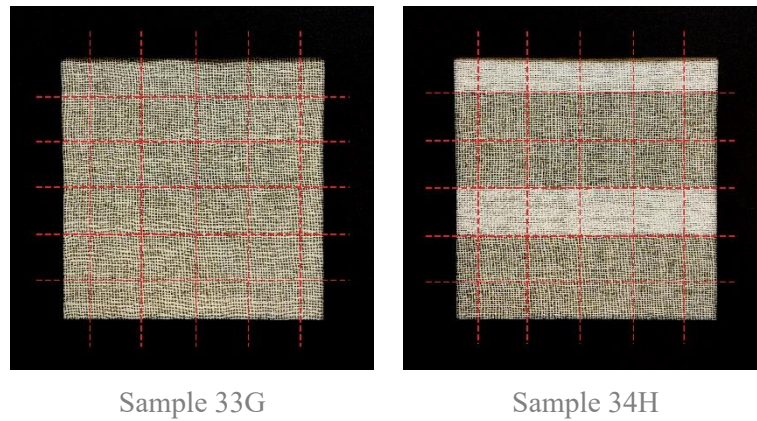


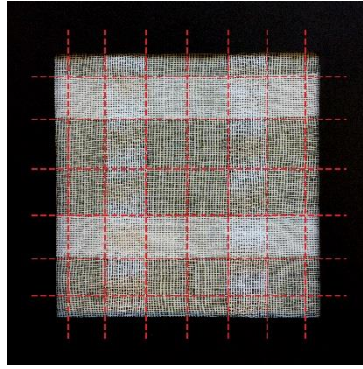
Figure 5.9. Off-loom samples from single-layer shapeable weaving trial no. 3.

Table 5.3. The third shapeable weaving trial in a single-layer.

No.	Weave Structure	Warp yarn	Weft yarn	epi
31 G	Plain	1/30Nm high twist wool S & Z	1/30Nm high twist wool S & Z	32
32 H			2/30Nm merino wool & 1/30Nm high twist wool S & Z	
33 G	2/2 Twill		1/30Nm high twist wool S & Z	
34 H			2/30Nm merino wool & 1/30Nm high twist wool S & Z	
35 G	1/3 Twill		1/30Nm high twist wool S & Z	
36 H			2/30Nm merino wool & 1/30Nm high twist wool S & Z	
37 G	2/2 Basket		1/30Nm high twist wool S & Z	
38 H			2/30Nm merino wool & 1/30Nm high twist wool S & Z	
39 G	2/3 Basket		1/30Nm high twist wool S & Z	
40 H			2/30Nm merino wool & 1/30Nm high twist wool S & Z	

For the last set of shapeable weaving trials, 2/30Nm merino wool and both 1/30Nm high twist wool in S and Z twist were used together for the warp and the weft (see Table 5.4). Using an inch of sectional warping, a total of five 9-by-9 inch samples were produced. In the use of the weft, all samples were filled with each weft, alternating every inch within the samples (see Figure 5.10).

The weave sett of 2/30Nm merino wool was calculated in section 4.1.2.1 as 16 epi, which was half the number of the weave sett of 1/30Nm high twist wool, in order to use a reed of the same number, #30, and so produce cloths with an even-sett. Thus, with a weave sett of 16/32epi, there were a total of 272 ends including 32 ends for selvages. The reed number #30 was utilised, and every single end of 2/30Nm merino wool, two ends of 1/30Nm high twist wool and four ends of the selvages were threaded through each dent. In order to produce five samples, the total length of the warp was calculated as 85 inches including loom waste.



Sample 41I

Figure 5.10. Off-loom samples from single-layer shapeable weaving trial no.4.

Table 5.4. The final Shapeable weaving trial in a single-layer.

No.	Weave Structure	Warp yarn	Weft yarn	epi
41I	Plain	2/30Nm merino wool	2/30Nm merino wool & 1/30Nm high twist wool S & Z	16 / 32
42I	2/2 Twill	&	2/30Nm merino wool & 1/30Nm high twist wool S & Z	
43I	1/3 Twill	1/30Nm	2/30Nm merino wool & 1/30Nm high twist wool S & Z	
44I	2/2 Basket	high twist wool	2/30Nm merino wool & 1/30Nm high twist wool S & Z	
45I	2/3 Basket	S & Z	2/30Nm merino wool & 1/30Nm high twist wool S & Z	

5.1.3 Finishing Process

During the weaving process, fabric on the loom is stretched by the tension caused by beams on each side of the loom. The fabric generally shows a reduction in length and width when it is taken off the loom. According to Behera and Hari (2010), the reduction is due to the yarns of ends and wefts returning to their ‘relaxed state’ after the release of tension. After each set of shapeable weaving trials, the dimensions of each sample in a relaxed condition were measured and documented (see examples in Table 5.5). It was also necessary to record the size before a wet finishing process to investigate three-dimensional surface effects, textures and the amount of shrinkage.

Table 5.5. Dimension measurement after wet finishing (sample #1A, #2B and #3C).

No.	Weave Structure	Warp yarn	Weft yarns	Width/Length Off-loom inch(cm)
1A	Plain	2/30Nm	2/30Nm merino wool	8.3 × 7.8 (21 × 19.8)
2B		merino wool	1/30Nm high twist wool Z	8.7 × 8.2 (20.5 × 20.8)
3C		wool	1/30Nm high twist wool S & Z	8.1 × 8.6 (20.5 × 21.8)

During the wet finishing process, fabric samples were submerged in a 60°C water using a soft detergent solution in order to maximise texture effects. A hand-wash was preferred to using a washing machine because the necessary manipulation of the fabric was easier during the wet finishing process. After the washing process, fabrics were air dried by laying them on a drying rack without tension to maximise three-dimensional textures and shrinkage. Each sample was then cut off from the fabric, and sewn by using an overlocking sewing machine to prevent fraying. Each sample was tagged with a number and technical information (see examples in Figure 5.11).



Figure 5.11. Wet finished samples from single-layer shapeable weaving trial no.2.

5.1.4 Analysis of Outcomes

The results of the first experiment and subsequent discussion demonstrated the effects of materials and weave designs in regard to three-dimensional surface effects with textures and the degree of shrinkage of shapeable fabrics in a single-layer. A number of samples in the experiment provided the necessary aesthetic characteristics and exhibited appropriate empirical data on shrinkage for shapeable fabrics. For the purpose of

experimental analysis, specific measurements of the sizes of samples were recorded before and after the wet finishing process. As a result of the finishing process, each sample showed a distinctive pattern of three-dimensional surface effects and textures with various degrees of shrinkages depending on the combinations of weave structures and the warp and the weft yarns used. (see examples in Figure 5.12).



Figure 5.12. Comparison of sample #23E before and after the wet finishing process

The samples were then compared and evaluated to determine overall changes. This analysis was useful in that it obtained from set of reference points by which future samples could be compared as it can be seen in the following sections. As such, the patterns of three-dimensional surface effects and textures of each sample were discussed in section 4.1.4.1. Moreover, a comparison of sizes and an evaluation of the shrinkage of samples are detailed in section 4.1.4.2.

5.1.4.1 Three-dimensional surface effects and textures

The diverse combinations of weave structures, warp and weft yarns, created various unique three-dimensional surface effects and textures on the sample fabrics. In the first set of shapeable weaving trials, samples generally showed two types of pleat effects, which were exhibited as wavy pleats in running vertical direction from sample type B and vertical pleats with horizontal flattened lines that were situated at the points where the weft yarn changed in sample type C (see examples in Figure 5.13).

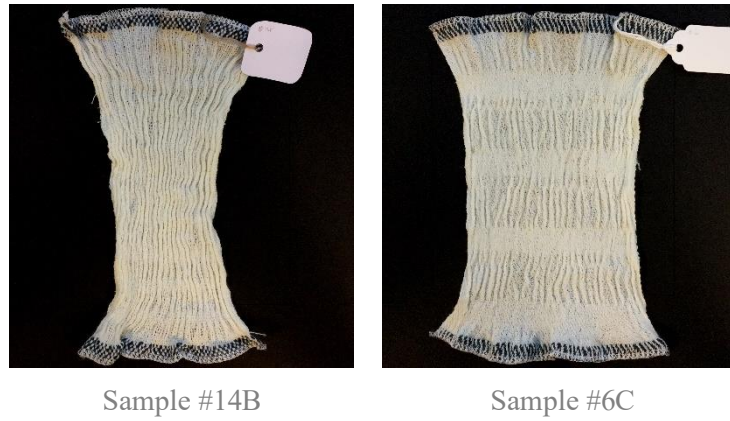


Figure 5.13. Examples of samples of type B and C.

In the second set of shapeable weaving trials, surface effects and textures were more lively and dynamic than samples from the first set. Samples were mainly woven in three different ways to produce three different sample types; D, E and F. Each type displayed a distinctive pattern. Samples of type D generally showed both horizontal and vertical crooked lines on the surface. Samples of type E had dramatic textures on the surface, which were very fine vertical pleats forming in vertical wavy patterns that resulted in having horizontal wavy patterns. Samples of type F showed three distinctive areas that were filled with different weft yarns on the surface. The first area using 2/30 merino wool weft showed slight horizontal curly lines. The second and third area had similar effects and textures that were from sample type D and E, which was an irregularly distorted pattern, and a strong vertical curly pattern, respectively. Examples of samples are detailed in Figure 5.14.



Figure 5.14. Examples of samples in type D, E and F.

Samples of type G and H from the third set of shapeable weaving trials had more variation in the effects resulting from changes to the yarn used for warp and weft. In Figure 5.15, samples of type G generally had protruding square shapes in between vertical curly wave patterns and the sizes of square shapes depend on the weave structures. The effects and textures that appeared in sample type G showed that a definite pattern with high shrinkage was created when different twists of yarns were encountered such as S and Z twist of 1/30 high twist wool. Samples of type H had similar effects and textures as the sample type F, however more dynamic curly wave pleats appeared in areas filled with 2/30 merino wool weft in the sample type H due to having a warp of 1/30 high twist wool in Z twist.



Sample #31G

Sample #34H

Figure 5.15. Examples of samples in type G and H.

Samples from the last set of shapeable weaving trials showed every distinctive effect and texture from all combinations of the warp and the weft yarns. In Figure 5.16, samples had similar three-dimensional surface effects and textures, which varied slightly according to the weave structures used and the amount of shrinkage obtained.









Figure 5.16. Examples of samples from the final set of shapeable weaving trials.

It was shown that although variables in the weave sett and weave structures also affected the construction of shapeable woven samples, diverse combinations of the warp and the weft yarns were mainly involved in creating three-dimensional surface effects and textures in the samples. Of the forty-five samples created in the shapeable weaving trials using fabrics in a single layer, a total of six characteristic patterns, involving combinations of surface effect and texture, were identified as having potential for use in creating shapeable woven fabrics as detailed in Table 5.6.

The samples displayed in Table 5.6 were woven using every possible combination of warp and weft. Each combination of the warp and the weft created its own distinctive pattern in the samples. In types I and II, 2/30Nm merino wool was used as the warp, but samples showed different effects and textures depending on the weft yarns. Type I showed an irregular curly wave pattern in the vertical direction while type II showed vertical pleats of a moderate ripple pattern. When 1/30 high twist wool yarns in the same twist were intercrossed, a pattern of irregular distortion was mainly seen, which was shown in types III and V. The difference was that the pattern of irregular distortion in type III was formed in the horizontal direction while type V showed a vertical pattern. In type IV, effects and textures had fine curly pleats in the vertical direction with a horizontal coarse wave pattern on the surface. In the case of type VI, it is expected to find a similar pattern as in type IV because of using the same combination of yarns in different directions, however, the pattern in type VI showed that the formation of pattern was affected by which combinations of the warp and the weft in areas were bordering pattern. Therefore, the pattern in type VI showed much thicker and wider pleat effects and textures than the pattern in type IV.

Table 5.6. Six types of patterns of three-dimensional surface effects and textures from shapeable weaving trials in a single-layer.

I.	II.	III.
		
M warp + H·T·S weft	M warp + H·T·Z weft	H·T·S warp + H·T·S weft
IV.	V.	VI.
		
H·T·S warp + H·T·Z weft	H·T·Z warp + H·T·Z weft	H·T·Z warp + H·T·S weft

* Note – M = 2/30Nm merino wool,

H·T·S = 1/30Nm high twist in S twist,

H·T·Z = 1/30Nm high twist in Z twist.

An analysis of three-dimensional surface effects and textures of each fabric sample is documented in Appendix A.

5.1.4.2 Shrinkage evaluation

As mentioned earlier in section 4.1.1, the inherent elasticity and stretchability of woven fabrics were necessary elements for the research in order to achieve seamlessness and the versatility of the prototype designs. Thus, high twist wool yarns were suitable for attempting to create shapeable woven textiles for seamless garment that have three-dimensional surface effects and textures. A number of samples from shapeable weaving

trials were evaluated in order to assess to what extent they were successful in achieving the desired result of shrinkage.

The percentage of width, length and overall shrinkage of the samples were calculated by using the following formula:

$$\text{Shrinkage (\%)} = \frac{\text{Original measurement} - \text{Final measurement}}{\text{Original measurement}} \times 100$$

The results reflected the fact that the use of different types of weave designs and yarns could affect shrinkage in shapeable woven fabrics both lengthwise and widthwise. Four sets of experiments were conducted to analyse the degree of shrinkage of each possible combination of yarns and structures of shapeable woven fabrics. The measurements of dimensions and the amount of shrinkage that occurred in the first set of shapeable weaving trials were detailed in Table 5.7. In the first set, 2/30Nm merino wool was used as a warp. All samples in type A were woven with a weft of 2/30 merino wool. The result showed the amount of shrinkage caused by the finishing process, which was generally in the range of 10-15%.

Table 5.7. Dimension and shrinkage measurements of samples from the first set of shapeable weaving trials.

No.	Weave Structure	Width/Length Off-loom (cm)	Width/Length After Finishing (cm)	Shrinkage (%) W-wise/L-wise
1A	P	21×19.8	20.7×18.4	1% / 7%
4A	2/2 T	20×20.5	19.2×19.3	4% / 6%
7A	1/3 T	20×19.8	19.2×18.6	4% / 6%
10A	2/2 B	20×20.3	18.9×19.2	6% / 5%
13A	2/3 B	20×19.5	18.5×18.3	6% / 6%
2B	P	20.5×20.8	10.1×19	51% / 9%
5B	2/2 T	20×19.7	11.8×19	41% / 4%
8B	1/3 T	20×20.4	10.9×19.5	45% / 4%
11B	2/2 B	20×20.5	9.3×19.4	53% / 5%
14B	2/3 B	20.5×21	8.3×20.1	60% / 4%
3C	P	20.5×21.8	10.8×20	47% / 8%
6C	2/2 T	20×20	12×19	40% / 5%
9C	1/3 T	20×21.3	11.1×20.3	45% / 5%
12C	2/2 B	20×20	9.8×19	51% / 5%
15C	2/3 B	20.3×21.5	8.5×20.2	58% / 6%

* Note – P = Plain, T = Twill, B = Basket

In samples of type B and C, the lowest shrinkage was expected with the plain weave because the structure made a high number of intersections with fewer spaces that allow yarns to move. However, overall shrinkage of samples with the plain weave showed as much shrinkage as samples with basket weave structures due to significant shrinkage in the vertical direction. Although there were a few percentage points of difference in shrinkage depending on the structures and the weft yarns, the shrinkage of samples in type B and C was similar. Here, the amount of overall shrinkage resulting from the use of 2/2 twill to 2/3 basket weave structures, other than the plain weave, progressively increased. Moreover, the overall result showed remarkable shrinkage in the horizontal direction, which was much more than in the vertical direction. Thus, it could be seen that 1/30Nm high twist wool had a great impact on shrinkage when used as weft yarns.

Table 5.8. Dimension and shrinkage measurement of samples from the second set of shapeable weaving trials.

No.	Weave Structure	Width/Length Off-loom (cm)	Width/Length After Finishing (cm)	Shrinkage (%) W-wise/L-wise
16D	P	20.3×22.5	13.4×12.3	34% / 45%
19D	2/2 T	20.3×21	13.1×16.4	35% / 22%
22D	1/3 T	20.3×21.5	11.5×15.8	43% / 27%
25D	2/2 B	20.3×20.5	8.2×17.8	60% / 13%
28D	2/3 B	20.3×19.5	8.1×16.8	60% / 14%
17E	P	20.3×21	6.5×14.2	68% / 32%
20E	2/2 T	20.3×21.5	6.4×18.6	68% / 13%
23E	1/3 T	20.3×20.5	6.8×14.1	67% / 31%
26E	2/2 B	20.3×20	6.1×14.2	70% / 26%
29E	2/3 B	20.3×20	5.9×13.8	71% / 31%
18F	P	20.3×23.5	8.7×17.3	57% / 26%
21F	2/2 T	20.3×19.5	9.4×15.3	54% / 22%
24F	1/3 T	20.3×20.5	9×15.4	56% / 25%
27F	2/2 B	20.3×21	7.5×15.6	63% / 32%
30F	2/3 B	20.3×22	7.2×14.8	65% / 33%

Table 5.8 details the dimensions and amount of shrinkage of samples from the second set of weaving trials. In general, the overall shrinkage obtained was similar to that of samples of type B and C, i.e., the percentage of shrinkage gradually increased in samples from using 2/2 twill to 2/3 basket weave except for the plain weave structure. In sample type D, the result in the vertical direction of samples with plain weave showed a degree of shrinkage that was more than twice that of the samples using other structures. Here, the samples of the basket weave structure showed the lowest shrinkage in the vertical direction but showed the highest shrinkage overall, due to the high shrinkage in the horizontal direction.

Table 5.9. Dimension and shrinkage measurement of samples from the third and the last set of shapeable weaving trials.

No.	Weave Structure	Width/Length Off-loom (cm)	Width/Length After Finishing (cm)	Shrinkage (%) W-wise/L-wise
31G	P	20.3×23.5	9×13	56% / 45%
33G	2/2 T	20.3×19	8.2×13.7	60% / 28%
35G	1/3 T	20.3×20.8	8×14.2	61% / 32%
37G	2/2 B	20.3×20	7.3×15.2	64% / 24%
39G	2/3 B	20.3×22	7×15.8	66% / 28%
32H	P	20.3×25	10.4×12.4	49% / 50%
34H	2/2 T	20.3×24	8.4×16.6	59% / 31%
36H	1/3 T	20.3×22	8.8×14.8	57% / 33%
38H	2/2 B	20.3×22.5	7.6×15.8	63% / 30%
40H	2/3 B	20.3×23.5	8.1×14.5	60% / 38%
41I	P	22.9×24	10.4×17.1	55% / 29%
42I	2/2 T	22.9×24.5	9.4×20.3	59% / 17%
43I	1/3 T	22.9×24.5	9.4×19.8	59% / 19%
44I	2/2 B	22.9×24	9.2×19.5	60% / 19%
45I	2/3 B	22.9×24.5	10.3×17.5	55% / 29%

Table 5.9 showed the results of the third and last set of shapeable weaving trials. In type G and H, 1/30 high twist wool yarns in both S and Z twist were used for the warp and weft. The overall shrinkage was generally similar to that seen in the previous sets. In the same way, the samples of the plain weave structure have significantly higher shrinkage in the vertical direction than samples of other structures. In type I, it was also noticed that the sample with the plain weave has more shrinkage in the vertical direction than samples of other structures, but the difference in percentage points is not greater than type G and H due to the warp variation in type I. The detailed data of shapeable woven textiles in a single layer are shown in Appendix A.

5.2 The Second Experiment on Shapeable Weaving Trials in Tubular Construction

This experiment was conducted to examine how the shrinkage results of the first experiment could be applied to create various forms using tubular construction. In order to examine various shapes, a total of 15 samples from three sets of shapeable tubular weaving trials were produced. Each sample had three parts using different wefts and weave structures to see how different degrees of shrinkage may interact with each other, and how this interaction influenced the surface effects and shapes that may be obtained through the use of tubular weave construction.

5.2.1 Materials

As described in section 4.1.1, 2/30Nm merino wool, 1/30Nm high twist wool yarns in S twist and Z twist are utilised for the experiment. In shapeable tubular weaving trials, the number of areas using different combinations of yarns and structures in each sample were increased from the first experiment. Therefore, two colours (black for high twist wool in S twist and red for high twist wool in Z twist) were added to more easily see the effects of the use of different warp and weft yarns in combination with various weave structures.

5.2.2 Weave Designs

In an effort to create shapeable tubular fabrics, four basic double-cloth weave structures were selected from the previous experiment, namely a plain, 2/2 twill, 1/3 twill, 2/2 basket weave structures. The first experiment showed that samples using 2/3 basket weave structure had greater shrinkage than samples using other weave structures. However, when comparing surface effects and textures of the fabric, unrecognisable collapsed effects and textures were shown due to a high degree of shrinkage in samples with 2/3 basket weave structures. Accordingly, in this second experiment, four basic double-cloth weave structures were applied except for 2/3 basket weave (see details in Figure 5.17).

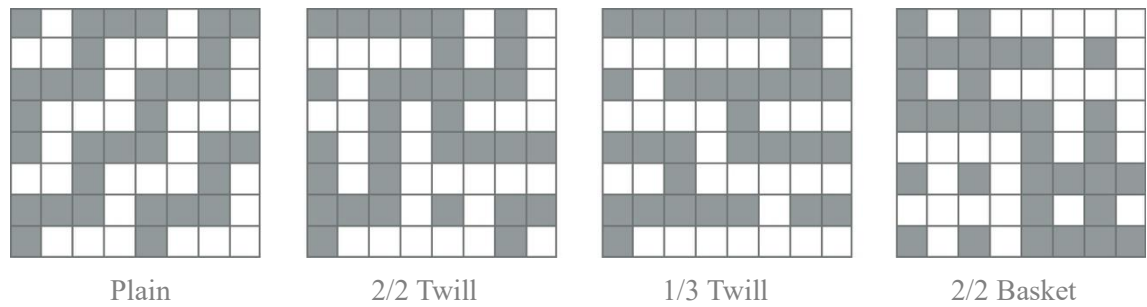


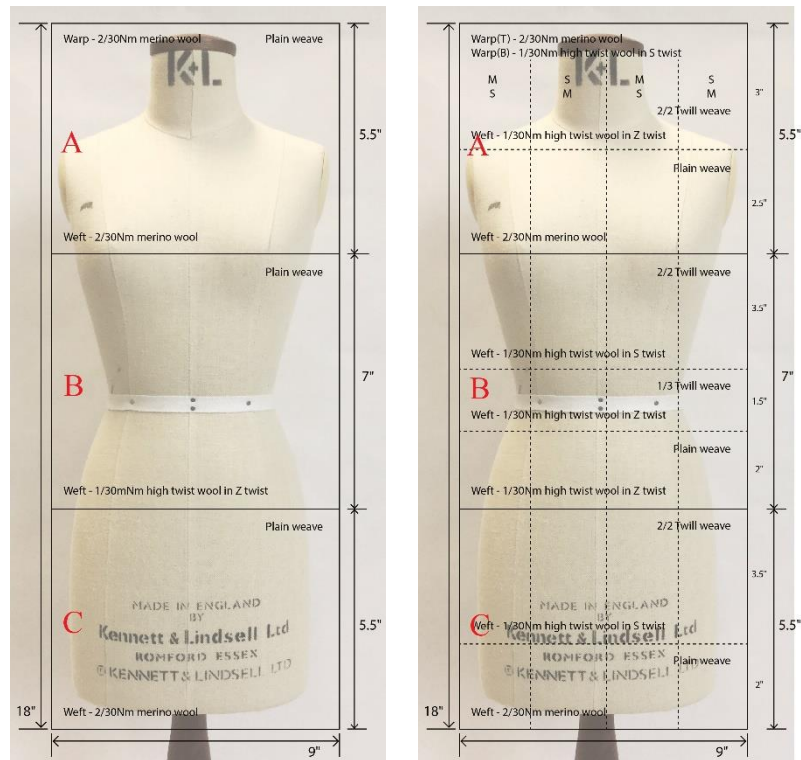
Figure 5.17. Basic double-cloth weave structures

5.2.2.1 Weave Setts

In this second experiment, shapeable tubular weaving requires double-cloth construction, which required double the number of weave sett for creating both the top and bottom layer. In accordance with the weave sett calculation was highlighted in section 4.1.2.1, 32epi, a weave sett for the warp of 2/30Nm merino wool and 1/30Nm high twist wool was applied in all three sets of this tubular weaving trial. When 2/30Nm merino wool and 1/30Nm high twist wool were used together in the last set of the first experiment, weave sett at 16epi was used for the warp of 2/30Nm merino wool. However, the result of the first experiment showed that a weave sett at 16epi of 2/30Nm merino wool was overly opened, and thus the yarn was not able to control the movement of high twist yarns. Therefore, 32epi, the minimum weave sett of 1/30Nm high twist wool, was applied to 2/30Nm merino wool to produce even-sett tubular fabrics.

5.2.2.2 Fabric Formations

This second experiment consisted of three sets of tubular weaving trials. Each set produced five tubular samples, resulting in a total of 15 samples from all sets. The tubular samples were designed to have three parts (A, B and C) based on a miniature mannequin for examination of various shapes of tubular samples (see Figure 5.18). The middle part of the samples was designed with various combinations of yarns and structures, in an attempt to find a combination that maximising shrinkage.



Sample #46

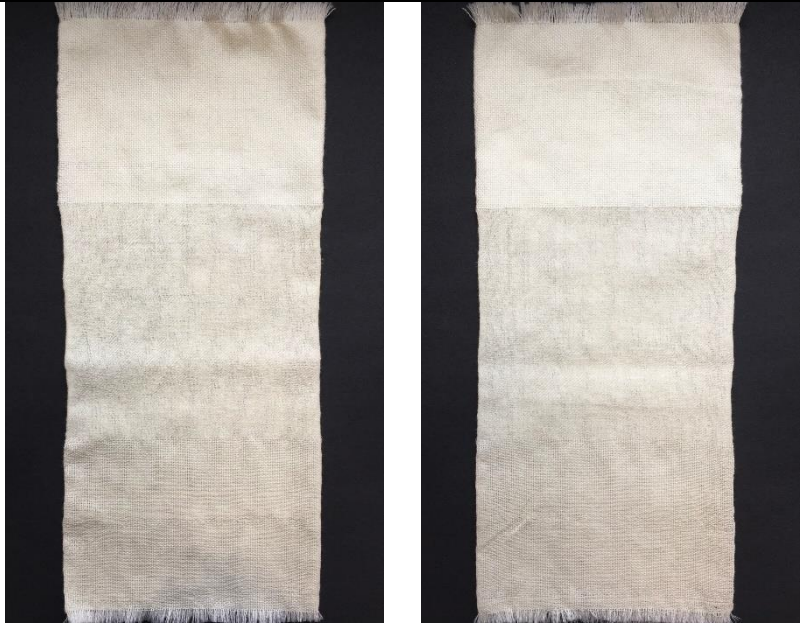
Sample #57

Figure 5.18. Examples of design preparation on a miniature mannequin.

With weave sett at 32epi of 2/30 merino wool and 1/30 high twist wool, total ends of each sample were 575 ends. The warp ends consisted of the top and bottom layer, each of which had 288 ends each. In order to create tubular fabrics, it was essential to have an odd number of warp ends on the bottom layer, thus there were 287 ends in the bottom layer in total. For double-cloth construction of tubular samples, eight shafts were utilised. The warp ends were threaded through each shaft in a straight draw configuration. Each shaft required 72 heddles except for shaft #8, which needed 71 heddles because of an odd number of warp ends. The reed number was #30, which had 16 dents per inch, and threading four ends per dent. The total length of the warp, including loom waste, was 130 inches for each set for five samples of 9-by-18 inches.

In the first shapeable tubular weaving trial, 2/30Nm merino wool was used as the warp of both the top and bottom layer. Each sample was planned to have identical parts (A, B and C) as mentioned above. Diverse combinations of the weft yarns and weave structures were applied to each part of samples to explore various shapes that may result from different levels of shrinkage (see examples in Table 5.10).

Table 5.10. Shapeable tubular weaving trial 1 (sample #49).

					
		Top layer		Bottom layer	
No.	Weave Structure	Warp yarn	Part	Weft yarn	
49	2/2 Basket	Top & Bottom M	A	M	
	1/3 Twill		B	H·T·Z	
	2/2 Basket		C	H·T·S	

* Note – M = 2/30Nm merino wool,

H·T·S = 1/30Nm high twist in S twist,

H·T·Z = 1/30Nm high twist in Z twist.

In the second trial, 2/30Nm merino wool and 1/30Nm high twist wool in Z twist were used as the warp for the top and bottom layer respectively. Black and red colours were added to the weft yarns to verify the change of yarns in different areas. Table 5.11 details combinations of weft yarns and weave structures of each part of sample #52. In order to see the diversity of forms of samples, variations of weft yarns were applied to subsections within the three different parts (A, B and C). Within the three parts, the proportion of variations of weft yarns and weave structures varied between each sample (the detailed preparations are illustrated in Appendix B).

Table 5.11. Shapeable tubular weaving trial 2 (sample #52).

A				
-B-				
-C-				
Top layer		Bottom layer		
No.	Weave Structure	Warp yarn	Part	Weft yarn
52	2/2 Twill	Top - M Bottom - H·T·Z	A	H·T·S
	Plain		B	H·T·Z + M
			C	H·T·S + H·T·Z

In the last weaving trial, 2/30Nm merino wool and 1/30Nm high twist wool in S twist were used as the warp. Unlike in the case of previous trials where different yarns were used as the warp for the top and bottom layer, two yarns were used together, crossing from the top and to the bottom layer every three inches (see details in Table 5.12). Each part of the samples was subdivided in accordance with the outer curve of the miniature mannequin as can be seen in Figure 5.18. The purpose was to apply different degrees of shrinkage to the body silhouette, with the degree of shrinkage varying with the combination of yarns and weave structures used (see example in Figure 5.18).

Table 5.12. Shapeable tubular weaving trial 3 (sample #56).

---- A ---- - - - - B ---- ---- - - - - C ---- ----				
	Top layer	Bottom layer		
No.	Weave Structure	Warp yarn	Part	Weft yarn
56	Plain	Top – M + H·T·S Bottom - H·T·S + M	A	H·T·Z
	2/2 Basket			M
	2/2 Twill		B	H·T·S
	2/2 Basket			H·T·Z
	2/2 Twill			H·T·Z
	1/3 Twill		C	M
	2/2 Basket			H·T·S

5.2.3 Finishing Process

The dimensions of off-loom samples from each set of shapeable tubular weaving trials were measured and recorded in a relaxed condition. Stitches were then applied to each side of the samples to prevent them from fraying. During the wet finishing process, tubular samples were submerged in water at 60°C containing soft detergent. A manual wash was preferred to a machine wash to ensure more effective fabric manipulation while the samples reacted with the hot water. Tubular samples were air dried by laying on a drying rack without tension in order to obtain maximum shrinkage and surface effects.

5.2.4 Analysis of Outcomes

After the wet finishing process, a number of distinctive shapeable tubular samples were completed. The combinations of yarns and weave structures produced a variety of interesting shapes with varying degrees of shrinkage. Precise measurements of tubular samples were taken before and after the finishing process to compare the overall shapes of tubular samples with the surface effects, textures and shrinkage obtained. The three sets of the experiment indicate that changes to the weave designs and variations in the weft yarn used in different areas of the samples all influenced the effects, textures and shapes of the tubular fabrics to a certain extent. The following section 4.2.4.1 describes the surface effects and textures of tubular samples derived from particular combinations of yarns and weave structures. Section 4.2.4.2 evaluates the overall shapes of seamless tubular samples.










5.2.4.1 Three-dimensional surface effects and textures

In this second experiment, the result from the first experiments were applied to tubular samples. The outcome showed that three-dimensional surface effects and textures were similar to or different from those seen in the first experiment, depending on the width of the applied area and surrounding area, which had different combinations of yarns and weave structures. The Table 5.13 below illustrates three-dimensional surface effects and textures of selected shapeable tubular samples with each weave structure.

In general, the effects and textures in tubular samples were similar to those in the first experiment. However, as seen in sample I, ripples and pleats were weakened and decreased due to the slightly higher weave sett when compared to the samples from the first experiment. The most interesting effects and textures could be seen in samples II and III, which had clearer tracking lines of patterns than the first experiment. Both vertical and horizontal ripples with an irregular crumpled wave pattern appeared in sample II. Sample III showed bold vertical pleats with a combined horizontal wave and ripple pattern. Moreover, it could be seen in all the samples from IV to IX inclusive that samples using the same combinations of warp and weft had slightly different effects when different weave structures were applied. Samples VI and VII woven in 1/3 twill weave showed finer pleats and ripple pattern than those woven in 2/2 twill when comparing the thickness of the effects and textures. Samples VIII and IX woven in 2/2 basket weave also showed

fine vertical pleats, but the shape of pleats was disconnected and interrupted in places due to the influence of the structure.

Table 5.13. Surface effects and textures of shapeable tubular samples.

I.	II.	III.
		
M warp + H·T·Z weft in plain weave	H·T·Z warp + H·T·S weft in plain weave	H·T·Z warp + H·T·Z weft in plain weave
IV.	V.	VI.
		
H·T·Z warp + H·T·S weft in 2/2 twill weave	H·T·Z warp + H·T·Z weft in 2/2 twill weave	H·T·Z warp + H·T·S weft in 1/3 twill weave
VII	VIII	IX
		
H·T·Z warp + H·T·Z weft in 1/3 twill weave	H·T·Z warp + H·T·S weft in 2/2 basket weave	H·T·Z warp + H·T·Z weft in 2/2 basket weave

* Note – M = 2/30Nm merino wool,
H·T·S = 1/30Nm high twist in S twist,
H·T·Z = 1/30Nm high twist in Z twist.

5.2.4.2 Evaluation of shapes of tubular samples

Three sets of shapeable tubular weaving trials were conducted to see how various combinations of yarns with structures influenced the shape of tubular samples resulting from the shrinkage. With regard to the shape of tubular samples, the shrinkage degree of each part in tubular samples was examined and compared to the samples of the first experiment.

In shapeable tubular weaving trial 1, 2/30Nm merino wool was used as a warp for both the top and bottom layer. The middle part of the samples shown in Figure 5.19 were woven with 1/30Nm high twist wool in Z twist. When these samples were compared to the shrinkage of 55% seen in the first experiment, the result showed less shrinkage; 43% in sample #46 and 47% in sample #47. As observed in the previous section, the difference in shrinkage degree was due to the higher number of weave sett.



Figure 5.19. Samples from shapeable tubular weaving trial 1.

In the second shapeable tubular weaving trial, 2/30Nm merino wool was used as the warp for the top layer and 1/30Nm high twist in S twist is used as the warp for the bottom layer. As seen in Figure 5.20, the bottom layer of each sample had a high degree of shrinkage in the vertical direction. When a different twist of 1/30Nm high twist wool was applied as the weft in alternating areas in sample #53, a number of differences in surface effects

and textures were observed that were more coarse and bold, but there was not a significant change in the shrinkage or shape of the sample. However, when 2/30Nm merino wool was applied as the weft in between areas using 1/30Nm high twist wool, bubble shapes with bold pleats appear, as can be seen in the sample #52. It was noticed that if the applied area was wider, larger bubble shapes with bold pleats could be obtained.



Figure 5.20. Samples from shapeable tubular weaving trial 2.

In the third set, various shapes of samples were produced by applying different combinations of yarns and weave structures according to the silhouette of the body. In the samples in Figure 5.21, combinations of yarns and weave structures for high shrinkage were applied to the middle part of the samples, corresponding to the waist of the body. Accordingly, diverse combinations were arranged above and below the middle part to create distinct shapes in the samples. It was also observed that the samples had dynamic shapes when 2/30Nm merino wool was applied between areas with high shrinkage. Moreover, the samples in Figure 5.21 showed how shapes could be more dynamic, depending on the size and proportions of the areas with different shrinkage, surface effects and textures.



Figure 5.21. Samples from shapeable tubular weaving trial 3.

5.3 Summary

This chapter has presented the two experiments in terms of three-dimensional surface effects and textures with shrinkage of shapeable woven textiles in a single-layer and tubular construction for seamless garments. Possible combinations of weave design with materials and their configuration have been examined through these experiments. The results have revealed a correlation between various combinations of weave design, materials and the degree of shrinkage in determining surface effects and textures, along with the fact that the arrangement of placing of a particular combination of weave design and materials can have different effects, depending on the combinations used in neighbouring areas.

This study has examined the inherent elasticity and stretchability along with three-dimensional surface effects and textures of woven fabrics, based on the selected materials (2/30Nm merino wool and 1/30Nm high twist wool) to determine their suitability for creating shapeable woven textiles. First, it was found that different weave designs resulted in different degrees of shrinkage. The findings have shown the potential of shapeable woven textiles for seamless garment design. Moreover, different weave design parameters were tested for both shapeable weaving trials in a single-layer and using a tubular

construction. The results of experimental data have proven the correspondence between particular weave designs and specific outcomes, in terms of degree of shrinkage and surface effects and textures obtained. Second, these experiments have demonstrated the multiple ways in which high twist wool yarns could be applied in creating shapeable woven textiles. Diverse three-dimensional surface effects and textures have been achieved by applying different combinations of weave designs. These surface effects and textures, such as pleats, ripple, wave and crinkle patterns, have more prominently appeared when two different twists of high twist yarn intersected with each other. Alongside the effect of yarns used, the choice of weave design has also affected the properties and appearance of shapeable woven textiles. Generally, it could be said that these experiments have proven that shapeable woven textiles can be achieved without the addition of synthetic fibres due to the characteristic of high twist yarn along with wool's inherent properties.

The second experiment has built upon the findings of the first, which looked at single-layer construction, when by creating tubular constructions, and also introduced the use of coloured yarns for different twists to enable us to more easily distinguish between them in the finished construction. The second experiment has made progress towards achieving shapeable woven textiles in that the three sets of samples have demonstrated that changes to the width and configuration of particular areas of the samples influenced the overall result in terms of the shapes and textures produced.

Overall, the results indicated that these experiments could provide a significant basis for the design of shapeable woven textiles. The results have proven not only the inherent elasticity and stretchability of woollen fabrics but also the distinctive surface effects and textures that may be obtained. Therefore, it was suggested that such advanced shapeable woven textiles provided opportunities for three-dimensional forms of seamless garments. Above all, the shapeable woven fabric samples in a single-layer and tubular construction produced here could be thought of as a prototype for shapeable seamless woven garments because of their potentially wide range of shrinkage. The proposed shapeable seamless woven garments were intended to have diverse forms in order to better suit the silhouette of the body. The applications and configurations of shapeable woven textiles will be presented in the next chapter, "Prototyping Shapeable Woven Textiles".

Chapter 6. Prototyping Stage: Shapeable Seamless Woven Garments

After the numerical analysis and evaluation of the shapeable weaving trials from the earlier ‘exploring stage’ of the research process, the prototyping stage focused on the creation of shapeable seamless woven garments that integrate yarns, weave setts and structures. In this prototyping stage, the creation of shapeable seamless woven garments was based on the analysis and evaluation of the ‘exploring stage’. Previously, both aesthetic and physical properties (such as three-dimensional, textural surface effect resulting from diverse degrees of shrinkages along with stretchability and elasticity) were examined in order to determine how best to utilise them in the prototype garments. A number of combinations of yarn types and weave designs was thus selected in order to create shapeable seamless woven garments.

As this research is based on the action research approach within a textile design discipline, creating prototype designs is the main explicit action phase, and “creating prototypes is in itself a potential generator of knowledge” (Stappers, 2007, p.87). Mäkelä (2007, p.163) states that “[the prototype designs] can also be seen as a method for collecting and preserving information and understanding”. Here, the prototype designs could be seen both as objects that make the design concept of shapeable seamless woven garments tangible and as ‘knowledge generators’ that may inform people regarding optimal ways of creating such garments. This chapter introduces alternative techniques for creating prototype designs of shapeable seamless woven garments through both hand-weave and the Jacquard weave process. Four primary prototypes were created by using hand weaving, and two initial prototypes by using the Jacquard weaving.

6.1 The Creation Procedure of Shapeable Seamless Woven Garments

Figure 6.1 illustrates the creation procedure of shapeable seamless woven garments in this research. The integrated prototype designs were first modified by utilising particular weave designs, which were a combination of specific yarns with selected colours, along with a chosen weave sett and structures. Through visual preparations for the hand weaving process, the configurations of weave designs for the final prototypes were confirmed. For the Jacquard weaving process, prototype designs were specified and approved by using Scotweave CAD software. The prototype designs were then woven.

After the finishing process, which involved a number of minor adjustments through such procedures as partial cutting, stitching (particularly of cut edges, to prevent fraying) and wet finishing, the final prototype designs were finally analysed and evaluated as outlined below in Figure 6.1.

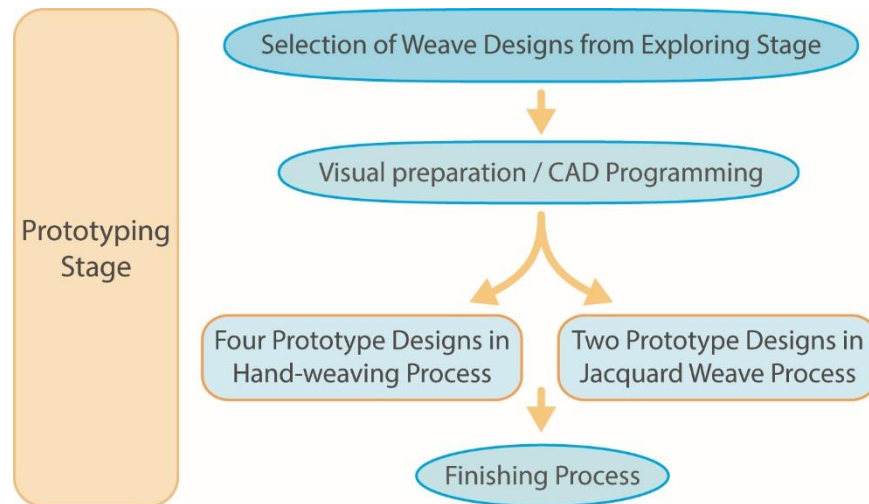


Figure 6.1. The creation procedure of shapeable seamless woven garments

6.1.1 *Prototype Designs on Hand Loom*

In this section, the creation of four prototype designs presents the hand-woven design practice of shapeable seamless woven garments with the configuration and application of shapeable woven fabrics, thus assisting in identifying promising ways of creating shapeable seamless woven garments.

6.1.1.1 *Design inspiration*

As mentioned in Chapter. 1, this research is a continuation of the researcher's master's degree project. Outcomes of that project were focused on the multi-way wearability of scarves in order to encourage consumers to use the product in diverse ways, with the aim of increasing the potential longevity of the product by making its long-term use more attractive to consumers due to its increased versatility (Koo, Dunne and Bye, 2013; Ma and Koo, 2016a). Therefore, the prototype designs in this continuing research process were based on the inspiration and concept of the previous project, and were expanded and developed from smaller fashion items such as scarves to larger products that are shapeable seamless woven garments (see section 1.1).

In order to achieve the aims of the research, versatility and seamlessness were the main considerations as far as the functional aspects of creating the prototype designs were concerned. Attempts were made to utilise the inherent qualities that become apparent in the prototype designs for shapeable woven fabrics (i.e. three-dimensional surface effects, textures and stretchability).

With a focus on prototyping seamless woven garments, it was considered that more colours should be added in order to enable clear three-dimensional effects and textures resulting from diverse combinations of yarns and weave structures. For making it more likely that the prototype garments would match the colour of garments already in a typical consumer's wardrobe, it was also decided to employ some of the colours that are generally used in the basic merchandise and styles of high-street clothing (King, 2012). According to King (2012) and Johnston (2015), the basic colours and the standard neutral colours (i.e. the ones useful to have as they are more likely to go well with other colours) are black, white, navy, cream, various tones of grey, denim and chambray along with beige, brown and khaki. In this creation of prototype designs, six colours from the basic and standard neutral colours were chosen for the purpose of suiting one another, such as black, white, beige, brown, grey and khaki (see Figure 6.2).

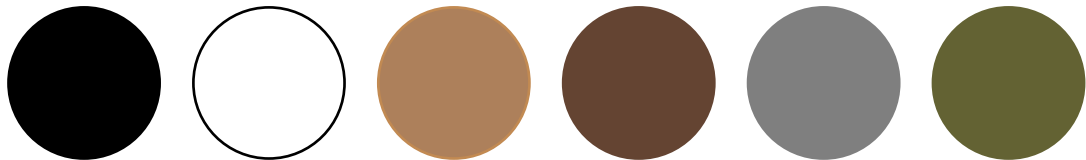


Figure 6.2. Six colours applied to prototype designs

Four different combinations of six colours were used for each hand-woven prototype design as each design was a part of a collection of hand-woven prototype designs. Black, white and beige colours were a set of the basis colours of the prototype designs because they could show other colours (brown and grey except for khaki) by intersecting them through warp and weft yarns. Brown, grey and khaki colours were gradually added as the versatility function would increase from the second to the last prototype designs, as well as creating more diversified colourways within a collection of the prototype designs.

For the first hand-woven prototype design (a tubular top), a set of the basis colours (black,

white and beige) were used to create the garment. In the creation of the second hand-woven prototype design (a tube dress), the brown colour was added to the base colours in order to make the shade of garment more varied, and thus a total of four colours were used. For the long sleeveless dress, two colours (brown and grey) were added to the base colours to be distinctive from the tube dress. For the last prototype design (a tubular jumper/jacket), all six colours were used in order to show full variations of selected colours since the garment could be worn as a jumper or a jacket. However, there was a slight difference in the tones of colours depending on the type of yarn used, due to the fact that the merino wool and the high twist wool yarns come from different manufacturers.

6.1.1.2 Prototype Designs

In the hand-woven prototype designs, three types of yarns (2/30Nm merino wool and 1/30Nm high twist wool yarns in S twist and Z twist) in six colours were used as, in the earlier ‘exploring stage’, they were found to enable three-dimensional surface effects and textures along with good inherent stretchability.

Four basic double-cloth weave structures were also utilised, namely a plain, 2/2 twill, 1/3 twill, 2/2 basket weave structures to create diverse shapes of the prototype design with three-dimensional surface effects and textures, resulting from various degrees of shrinkages (see details in Figure 4.16).

For the weave sett, 32epi was applied for both 2/30Nm merino wool and 1/30Nm high twist wool yarns in order to have even sett cloth (as mentioned in section 4.2.2.1).

For the hand-woven prototype designs, a 24-shaft Texel electronic floor loom was utilised. The four prototype designs are detailed in the following sections, including design preparation with visualisation, finished work and the versatility of the prototype designs.

6.1.1.2.1 Tubular top

(1) Design preparation

The prototype design was a tubular top that took its inspiration from Nakamichi (2012) who introduced an ‘off the shoulder garment’ that was multi-wearable. She used knitted jersey fabric with the ‘cut-and-sew’ method to make the ‘off the shoulder garment’. However, the tubular top was designed and woven with the key design elements of the research such as seamlessness and versatility.

Unlike the other prototypes, the tubular top did not need a large amount of shrinkage and stretchability due to the ways of wearing it being different from the other designs. The tubular top could be worn fitted around the hips using the tubular part of the garment, and then wrapped around the upper body in different ways using the rest of the garment with its two separate layers (see details in Figure 6.5). As a result, the main focus was on creating three-dimensional surface effects and textures through the use of various combinations of weave structures and yarns, while still maintaining a sufficient degree of stretchability (see details in Table 4.6 and Table 4.13). Therefore, all three yarns were utilised for the warp by changing from 2/30 merino wool yarn to both 1/30Nm high twist wool yarn in S and Z twist, and vice versa, after every 4.5 inches of sectional warp configuration of the garment (see details in Figure 6.3). For the weft, all three yarns were also utilised, and each weft was used alternately for 2.5 inches of the garment. As referred to section 5.1.1.1, a set of the base colours (black, white and beige) were used to create a tubular top garment as it was vital to show multiple versatile effects from a simple shape of the garment with a basic colour combination.

In order to create three-dimensional effects and textures on the surface of the garment, selected weave structures (a plain, 2/2 twill, 1/3 twill, 2/2 basket weave) were applied. As can be seen in Figure 6.3, two woven constructions were integrated to form the tubular top. The first 20 inches or so of tubular construction was intended to be fitted around the hips, and thus 2/2 basket weave structure was arranged in between other structures to give a higher level of shrinkage in the area of the garment. For the second part, approximately 35 inches, of construction with two separate layers was intended to be worn around the upper body. Hence a plain, 2/2 twill and 1/3 twill weave structures were utilised,

alternating every 2.5 inches within the second part. The specification of the tubular top was based on a toile made on a size 10 mannequin.

Total ends were 1,439 which consisted of 720 ends of the top layer and 719 ends of the bottom layer. A total of eight shafts were utilised, and the warp ends were threaded through each shaft in a straight draw configuration. Each shaft needed 180 heddles except for shaft #8, which needed 179 heddles because of the odd number of warp ends. The #30 reed that has 16 dents per inch was utilised, with four ends threaded per dent.

(2) Finished design

After cutting the prototype off the loom, basic stitches were applied at the edges to prevent unravelling and fraying of threads. As part of the finishing process, the tubular top was then submerged in water at 60°C, containing a soft detergent. As stated when describing the finishing process in section 4.1.3, a hand-wash was used in preference to machine wash as it was found that this maximised the three-dimensional, textural surface effects and shrinkage with the high-twist wool yarns that were used in the prototypes. The finishing process including basic stitches and a hand washing is identically applied to each prototype design. Figure 6.4 compares the tubular top when cut off the loom and after the finishing process.

According to the design purpose mentioned above, the tubular top showed overall stretchability with a slightly higher level of shrinkage in the hip area of the garment. Diverse three-dimensional surface effects and textures could also be seen throughout both the top and bottom layer of the fabric. Figure 6.5 displays how the tubular top could be worn in a number of ways by twisting, winding, knotting and wrapping using two separate layers. Although the tubular top shows four possible ways of versatility in Figure 6.5, it is expected that the wearing style can be modified and developed more when the user engages with this tubular top.

- * P - Plain
- T1 - 1/3 Twill
- T2 - 2/2 Twill
- B - 2/2 Basket
- M - 2/30Nm Merino Wool
- S - 1/30Nm S High-twist Wool
- Z - 1/30Nm Z High-twist Wool

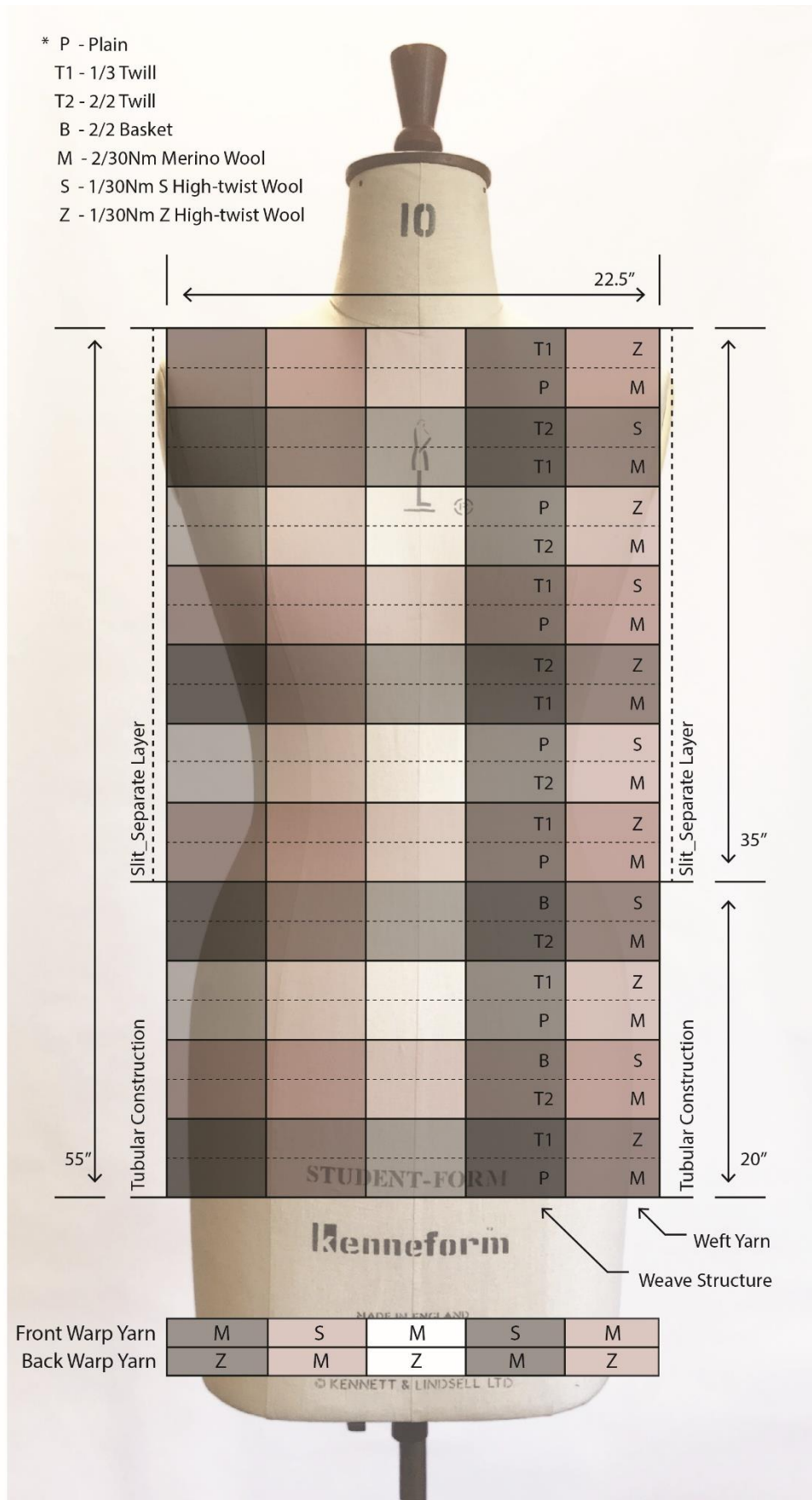


Figure 6.3. A visualised preparation sheet for the tubular top



Figure 6.4. A tubular top when cut off the loom (left) and after the finishing process (right)



Figure 6.5. Versatility of the tubular top

6.1.1.2.2 Tube dress

(1) Design preparation

The second prototype was a tube dress that was designed to be worn without additional features such as zips, buttons or waistband to fit the garment on the body, due to its high stretchability resulting from shrinkage of the waist part. This prototype design thus required a range of shrinkage degrees to follow the curved lines of the body. As the main design point was the arrangement of various shrinkage degrees, the prototype design focused on the use of combinations of weave structures and yarns that ensured a high degree of shrinkage with stretchability, particularly for the waist part of the design (see details in Figure 6.7).

In the creation of the tube dress, 4.5 inches of sectional warp configuration was derived from the first prototype design. However, the sectional warping was divided into a ratio of eight to one in order to emphasise the vertical lines of the tube dress as well as reduce the monotony of the square shapes from the first prototype design (see details in Figure 6.6). The sections for the weft yarns were also considered to highlight the curved lines of the waist area as well as decorative shapes of the garment. As the evaluation shows in section 4.2.4.2, the decorative shapes could be obtained when certain combinations of weave structures and yarns were applied to various areas of samples. Thus, in the tube dress, the areas for the weft yarns were diversely divided in order to maximise shrinkage on the waist part and on the decorative shapes of the garment along with three-dimensional surface effects.

For the warp, 2/30 merino wool yarn and 1/30Nm high twist wool yarn in both S and Z twist were utilised alternately for every section of the top and bottom layers (see details in Figure 6.6). Selected weft yarns and weave structures were applied to create a high level of shrinkage with stretchability, as well as to emphasise decorative shapes with three-dimensional surface effects and textures of the garment. Specifically, combinations of 1/30Nm high twist wool yarn in Z twist and weave structures (2/2 twill, 1/3 twill, 2/2 basket weave) that showed high degrees of shrinkage in the horizontal direction, were applied to the waist part. Accordingly, diverse combinations of 2/30 merino wool yarn and all weave structures were arranged above and below the waist part to maximise the

distinct shape of the garment due to merino wool yarn showing much lower shrinkage degrees (see details in Table 4.7). In order to create more dynamic shapes, high twist wool yarns were applied between the areas that used merino wool yarn.

As can be seen in Figure 6.6, tubular construction was utilised to form the tube dress. The size of the garment was 22.5 inches in widthwise by 65 inches in lengthwise. The first 6 inches or so of tubular construction was intended to be worn around the chest. Subsequently, approximately 15 inches of the garment was planned to be fitted around the waist of the body. The rest, 44 inches of the garment was designed to have balloon shapes worn around the lower body. The specification of the garment was based on a mannequin in size 10.

As referred to in section 5.1.1.1, the brown colour was added to the base colours in order to make the shade of garment more varied, and thus a total of four colours (black, white, beige and brown) were used in the tube dress.

Total ends were 1,439. This consisted of 720 ends of the top layer and 719 ends of the bottom layer. A total of eight shafts were utilised, and the warp ends were threaded through each shaft in a straight draw configuration. Each shaft needed 180 heddles except for shaft #8, which needed 179 heddles because of the odd number of warp ends. The #30 reed that has 16 dents per inch was utilised, with four ends threaded per dent.

(2) Finished design

Basic stitches were applied to each side of the tube dress to prevent unravelling and fraying of threads after cutting the garment off the loom. Continuing the finishing process, the tube dress was hand-washed with 60°C water containing soft detergent and manipulated to have proper shrinkage and to maximise the shape of the garment. After the finishing process, the dress was dried in a relaxed condition to have proper stretchability with shrinkage. Figure 6.7 compares the tube dress when cut off the loom and after the finishing process.

The tube dress showed a significant shrinkage degree with high stretchability in the waist part. This inherent stretchability enabled the dress to be worn and fitted on the body

without additional features. The tube dress also obtained maximised balloon shape along with three-dimensional surface effects and textures over the surface of the garment. Figure 6.8 exhibits the versatility of the garment, showing how the tube dress can be worn in a number of ways; as a full-length tube dress, a simple knee-length dress, a scarf and a shawl. Although the tube dress shows four possible ways of versatility in Figure 6.5, the versatility of the garment can be modified and developed as the length of the tube dress is adjusted by folding or twisting the dress. As the garment does not have specific front and the rear due to its tubular shape, the versatility can also be enhanced with different patterns of the garment by rotating it.

- * P - Plain
- T1 - 1/3 Twill
- T2 - 2/2 Twill
- B - 2/2 Basket
- M - 2/30Nm Merino Wool
- S - 1/30Nm S High-twist Wool
- Z - 1/30Nm Z High-twist Wool

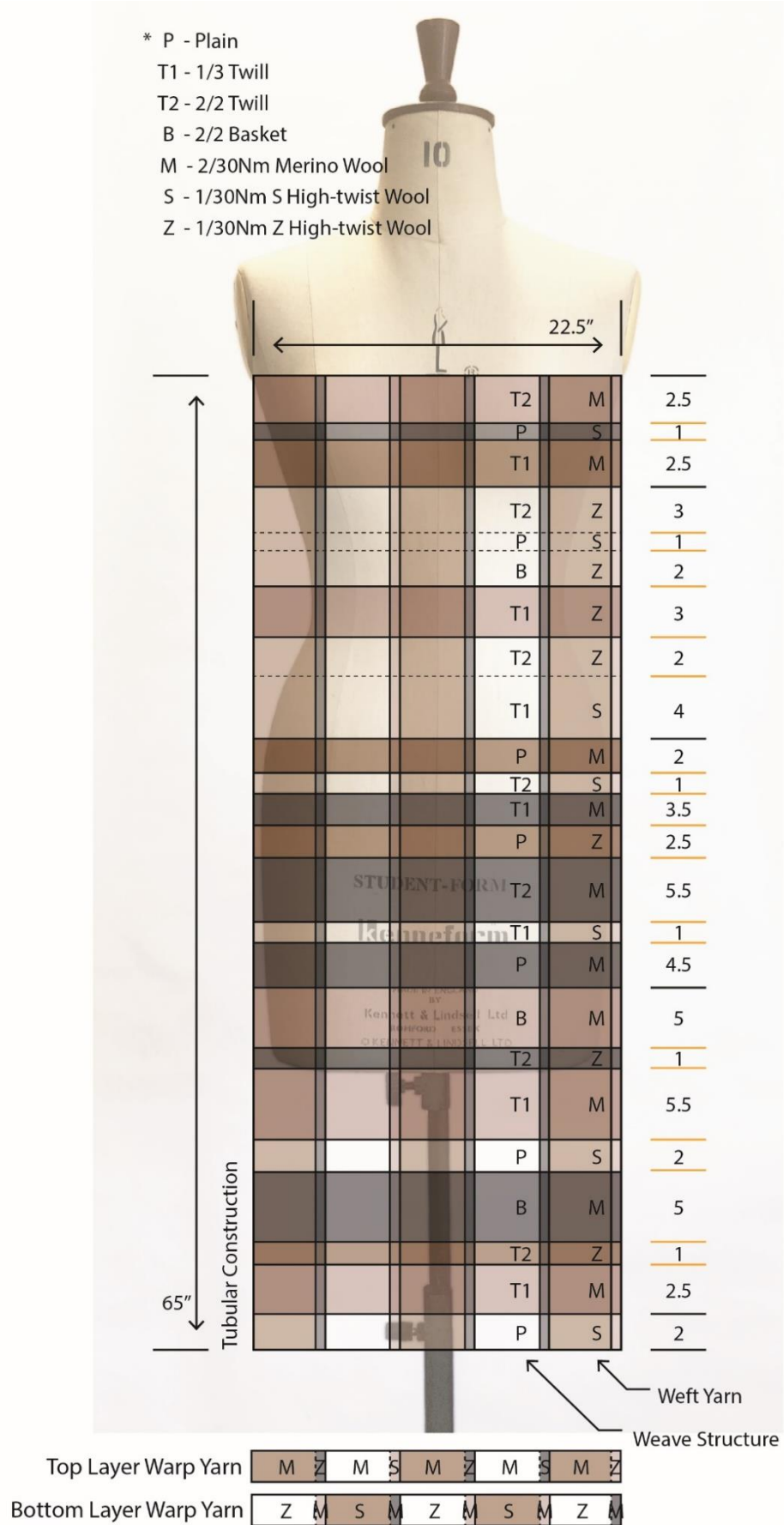


Figure 6.6. A visualised preparation sheet for the tube dress



Figure 6.7. A tube dress when cut off the loom (left) and after the finishing process (right)



A full-length tube dress



A knee-length tube dress



A scarf



A shawl

Figure 6.8. Versatility of the tubular jumper/jacket

6.1.1.2.3 Long sleeveless dress

(1) Design preparation

The third prototype was a long sleeveless dress that was an advanced form of the tube dress. This prototype design focused on forming armholes as a comfort feature that enhances wearability of the garment in an active situation, as well as the versatility of the garment by means of two armholes (see details in Figure 6.11). The prototype design also focused on creating a frill above the armholes as a decorative feature. This can be placed around the neck to cover the shoulder, or placed around the waist as a frill when the garment being worn as a sleeveless turtleneck top. Thus, the positioning of combinations of weave structures and yarns concentrated on having clear armholes, a frill and a high shrinkage degree with stretchability that followed the curved lines of the body as well as creating three-dimensional surface effects and textures.

In the creation of the long sleeveless dress, 4.5 inches of sectional warp configuration was derived from previous prototype designs in order to make the garment as part of a collection. However, if the area of sectional warp of the tube dress was regularly divided at the ratio of eight to one, the sectional warping of the long sleeveless dress was divided into irregular areas to give more dynamic variations as well as reducing the monotony of regularity (see details in Figure 6.9). The sections for the weft yarns were considered to have clear armholes with sufficient stretchability and to create a proper frill for decorative purpose. It was also planned to highlight the curved lines of the waist area as well as decorative shapes of the garment. Thus, the areas for the weft yarns were diversely divided in order to have sufficient stretchability around the shoulder part, a frill decoration on the neck part and a high level of shrinkage on the waist part along with three-dimensional surface effects.

As can be seen in Figure 6.9, 2/30 merino wool yarn and 1/30Nm high twist wool yarn in both S and Z twist were utilised as the warp in alternating sections of the top and bottom layers. Selected weft yarns and weave structures were applied to create a high shrinkage degree with stretchability along with three-dimensional surface effects and textures over the surface of the garment. Specifically, in order to have appropriate stretchability to the areas, combinations of 1/30Nm high twist wool yarn in Z twist and weave structures (a

plain, 2/2 twill, 1/3 twill, 2/2 basket weave) were applied to the shoulder and waist part of the garment depending on their degrees of shrinkage. Accordingly, as 2/30 merino wool yarn showed a very low degree of shrinkage (see details in Table 4.7), combinations of merino wool yarn and various weave structures were arranged around areas that had high shrinkage degrees in order to create distinct shapes of the garment. Moreover, 2/30 merino wool yarn and 1/30Nm high twist wool yarn in S twist with weave structures (1/3 twill and 2/2 basket weave) were applied to the area for the frill that is widely flared in shape. For the purpose of creating more dynamic shapes and three-dimensional surface effects and textures of the garment, diverse combinations of high twist wool yarns in S twist and weave structures were applied between the areas that used merino wool yarn.

As illustrated in Figure 6.9, during the preparation process, two woven constructions were integrated for the formation of the long sleeveless dress. The tubular construction was primarily applied to the main body of the dress, totalling 70 inches in length, and the construction using two separate layers was applied in order to create the armholes. The first 6 inches or so of tubular construction was planned to be a frill of the garment. Subsequently, approximately 10 inches of construction with two separate layers was intended to create the armholes. For the rest, 54 inches of the garment was designed to have dynamic shapes around the hips, with three-dimensional surface effects and textures. The specification of the garment was based on a toile making in a size 10.

As referred to in section 5.1.1.1, the brown and grey colours were added to the base colours in order to make the shade of garment more varied as well as to have a distinctive point from the previous design, and thus a total of five colours (black, white, beige, brown and grey) were used in the long sleeveless dress.

Total ends were 1,439. That consisted of 720 ends of the top layer and 719 ends of the bottom layer. A total of eight shafts were utilised, and the warp ends were threaded through each shaft in a straight draw configuration. Each shaft needed 180 heddles except for shaft #8, which needed 179 heddles because of the odd number of warp ends. The #30 reed comprising 16 dents per inch was utilised, with four ends threaded per dent.

The long sleeveless dress could also be worn without additional features such as zips or buttons because of the high stretchability of the waist part of the dress.

(2) Finished design

After the prototype dress was cut off the loom, basic stitches were applied to the edge of the dress to prevent unravelling and fraying of threads. As part of the finishing process, the long sleeveless dress was washed in hot water containing soft detergent. A hand-wash was preferred to manipulate the fabric, to ensure proper shrinkage during the wash. The prototype was then dried in a relaxed state to maintain precise shrinkage with stretchability along with three-dimensional effects and textures. Figure 6.10 compares the long sleeveless dress when cut off the loom and after the finishing process.

As the design planned, the long sleeveless dress showed frill and armholes at the top with diverse effects and textures on the surface, and full shrinkage in the waist area of the dress. Figure 6.11 demonstrates the versatility of the long sleeveless dress showing how it may be worn in many ways; as a full-length long sleeveless dress, a one-shoulder dress, a long skirt, a sleeveless turtleneck top or a scarf and a shawl. In this case, the long sleeveless dress has even more versatility, in that the armholes can be used as a fastener when being worn as a scarf and a shawl. Moreover, the dress can be worn upside down as a sleeveless turtleneck top.

- * P - Plain
- T1 - 1/3 Twill
- T2 - 2/2 Twill
- B - 2/2 Basket
- M - 2/30Nm Merino Wool
- S - 1/30Nm S High-twist Wool
- Z - 1/30Nm Z High-twist Wool

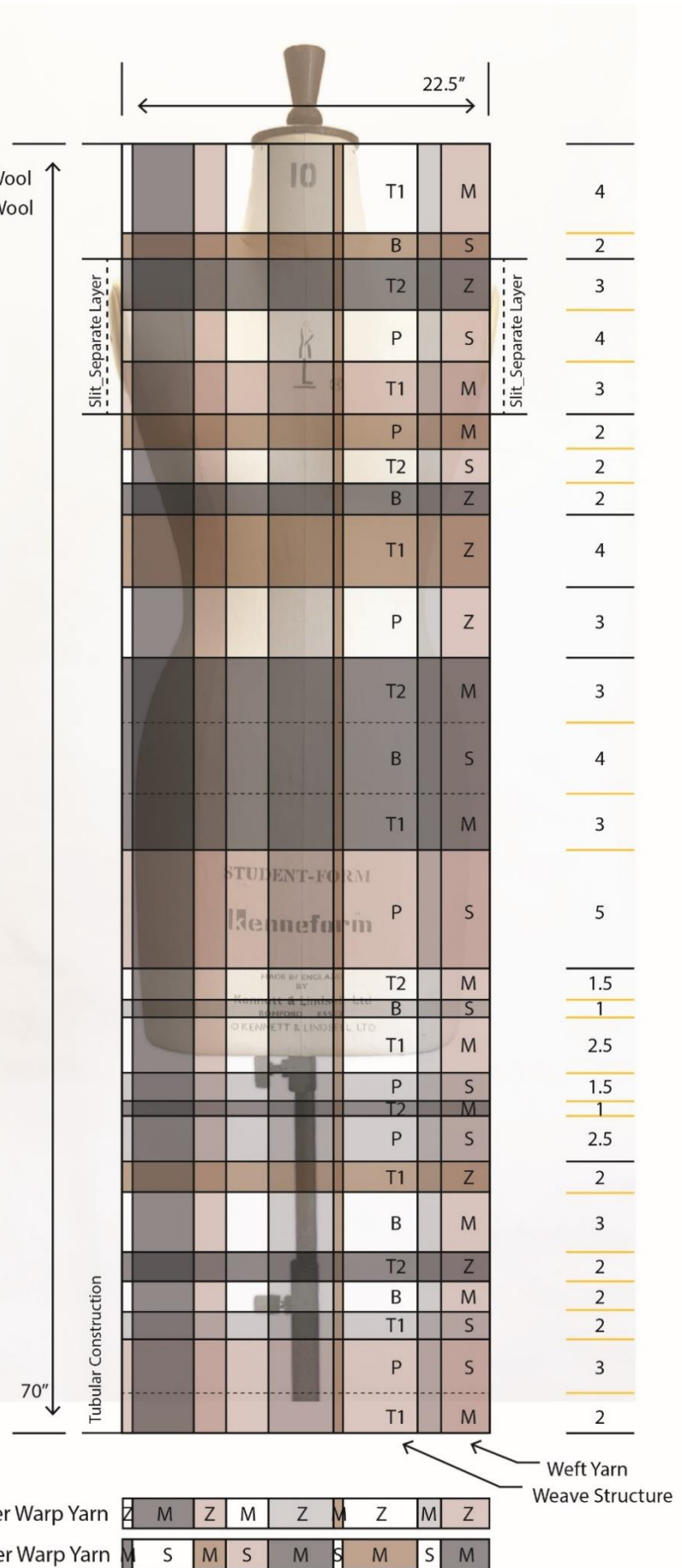


Figure 6.9. A visualised preparation sheet for the long sleeveless dress



Figure 6.10. A long sleeveless dress when cut off the loom (left) and after the finishing process (right)



A sleeveless dress



One shoulder dress



A skirt



A turtleneck sleeveless top



A scarf



A shawl

Figure 6.11. Versatility of the long sleeveless dress

6.1.1.2.4 Tubular jumper/jacket

(1) Design preparation

The last prototype was a tubular jumper/jacket that was designed to wear as a jumper, or as a jacket with an alteration. This tubular jumper/jacket could be worn without such additional features as zips or buttons by using the main hole in the middle of the prototype. The design focused on producing a long part of two separate layers in the middle of the prototype design as the main hole for the neck and the chest when the garment being worn as a jumper or a jacket (see Figure 6.12). The use of combinations of weave structures and yarns concentrated on creating a high level of shrinkage with stretchability that were intensely applied on the cuffs area of the sleeves, and creating three-dimensional surface effects and textures on the ruffled cuffs resulting from the high shrinkage.

In the formation of the tubular jumper/jacket, 6 inches of sectional warp configuration was used as a variation of the collection rather than using 4.5 inches of configuration from the previous prototype designs. It was also noted that the tubular jumper/jacket was applied to the upper body in a horizontal direction as opposed to the previous prototype designs which were vertical oriented garments. Based on 6 inches of configuration, the sectional warping was divided and combined in order to have dynamic variations as well as avoid the monotony of regularity (see details in Figure 6.12). The sections for the weft yarns were considered to have intensive shrinkage on the cuffs on the sleeves and to create a clear main hole for the body. It was also planned to highlight the ruffled cuffs and three-dimensional surface effects and textures on the sleeves for the decorative aspect of the garment. Therefore, the areas for the weft yarns were diversely divided in order to have the main hole in the middle of the design and a high degree of shrinkage around the cuffs areas, as well as three-dimensional surface effects and textures on the sleeves.

As can be seen in Figure 6.12, 2/30 merino wool yarn and both 1/30Nm high twist wool yarn in S and Z twist were utilised as the warp in alternating every section of the top and bottom layers. Selected weft yarns and weave structures were applied to create a high shrinkage degree with stretchability along with three-dimensional surface effects and textures over the surface of the garment. Especially, combinations of 1/30Nm high twist wool yarn in Z twist and weave structures (a plain, 2/2 twill, 1/3 twill, 2/2 basket weave)

were applied to the cuffs areas on the sleeves of the garment depending on their various degrees of shrinkage in order to have intensive shrinkage with stretchability. Accordingly, as 2/30 merino wool yarn showed much less degree of shrinkage (see details in Table 4.7), combinations of merino wool yarn and weave structures (2/2 twill, 1/3 twill, 2/2 basket weave) were used at the main hole area because that area did not need high shrinkage. Moreover, 2/30 merino wool yarn and 1/30Nm high twist wool yarn in S twist with weave structures (a plain and 1/3 twill) were applied to the end of the sleeves in order to have widely ruffled cuffs (see details in Figure 6.13). For the purpose of creating more dynamic shapes of the sleeves and three-dimensional surface effects and textures over the garment, combinations of high twist wool yarns in S twist and weave structures (a plain and 2/2 basket weave) were used.

As Figure 6.12 illustrated the preparation process, two woven constructions were integrated for the formation of the tubular jumper/jacket. The tubular construction was primarily applied to each sleeve of the prototype design, totalling 52 inches in length, and the construction using two separate layers was applied to create the main hole in the middle of the prototype design, with the length of 13 inches. The first 26 inches or so of tubular construction from each side of the garment was planned to be worn as a sleeve along with 6 inches of a ruffled cuff. Subsequently, approximately 13 inches of construction with two separate layers was intended to be worn around the chest. The specification of the garment was based on a size 10 toile.

As referred to section 5.1.1.1, the brown, grey and khaki colours were added to the basis colours to give variety to the collection of the prototype designs as well as to have a decorative point of the tubular jumper/jacket. Thus, a total of six colours (black, white, beige, brown, grey and khaki) were used.

Total ends were 1,151 ends that consisted of 576 ends of the top layer and 575 ends of the bottom layer. A total of eight shafts were utilised, and the warp ends were threaded through each shaft in a straight draw configuration. Each shaft required 144 heddles except for shaft #8, which needed 143 heddles because of the odd number of warp ends. The #30 reed with 16 dents per inch was utilised with four ends threaded per dent.

(2) Finished design

The basic running stitches were applied to each side of the prototype to secure the edge against unravelling and fraying of threads after the prototype was cut off the loom. Through the wet finishing process, the tubular jumper/jacket was hand-washed with 60°C water for manipulating fabric properly during the wash. In order to achieve the desired result from the finishing process, the tubular jumper/jacket was dried in a relaxed condition. Figure 6.13 displays the final prototype cut off the loom and after the finishing process.

As the design planned, the tubular jumper/jacket showed full shrinkage in the cuffs area of the sleeves. The main hole of the two separate layers in the middle of the design enabled the tubular jumper/jacket to be worn without additional features. Due to the high shrinkage of the sleeves, the prototype showed intensive three-dimensional surface effects and textures on the sleeves and ruffled cuffs at the edge of the sleeves. Figure 6.14 describes the versatility of the tubular jumper/jacket in different ways such as a jumper, a jacket and a scarf. In this case, the prototype can be worn as a jumper first; then the user can alter the jumper into a jacket or a cardigan by simply cutting in the middle of any layer of the jumper. The prototype can also be worn as a scarf with or without cutting.

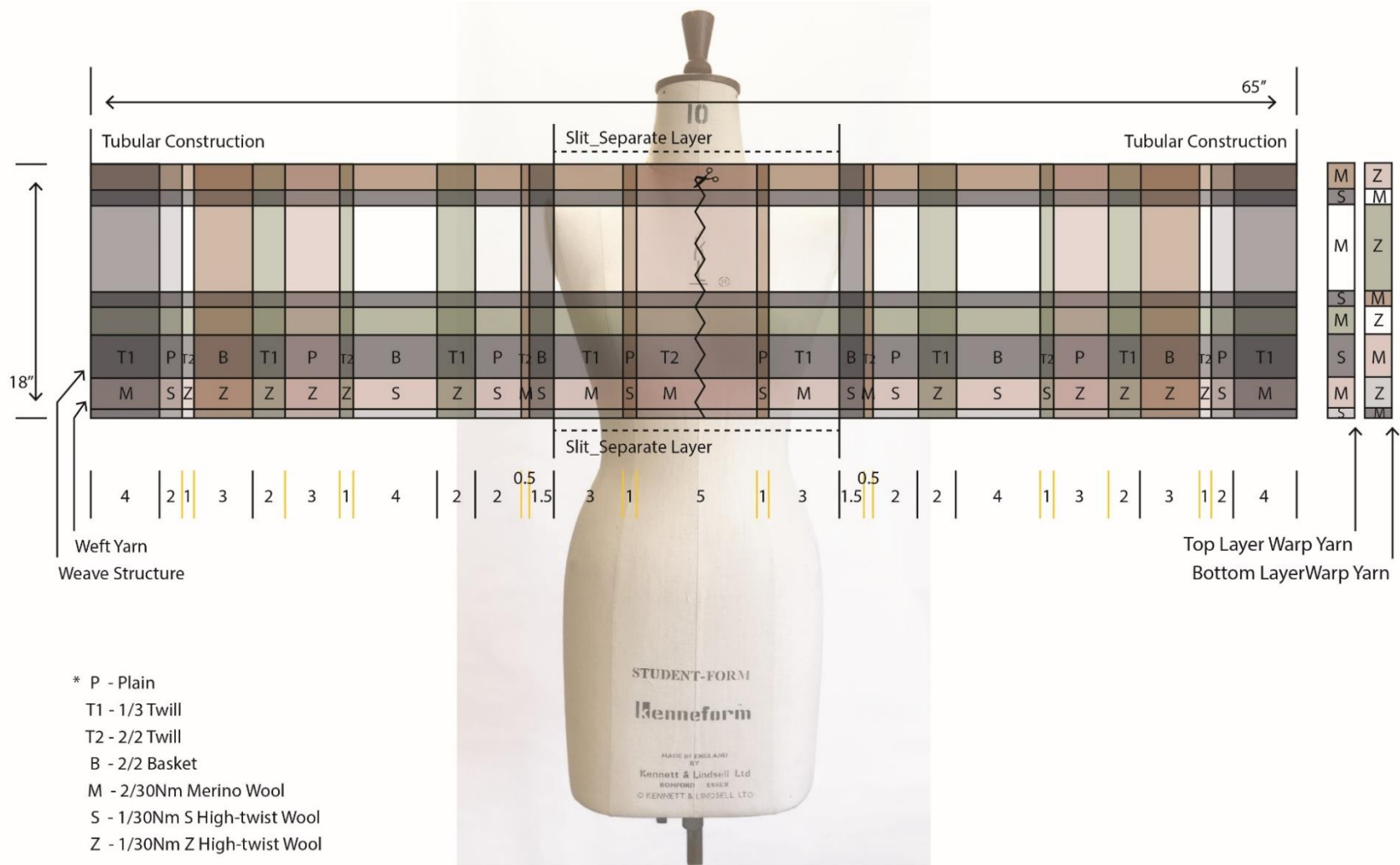


Figure 6.12. A visualised preparation sheet for the tubular jumper/jacket



Figure 6.13. A tubular jumper/jacket when cut off the loom (top) and after the finishing process (bottom)



A tubular jumper



A tubular jacket 1



A tubular jacket 2



A scarf

Figure 6.14. Versatility of the tubular jumper/jacket

6.1.2 Prototype Designs on Jacquard Loom

In this section, the design practice of shapeable seamless woven garments introduced two prototype designs through the Jacquard weaving process. In this creation on a Jacquard loom, the loom restrictions, such as predetermined width with yarn type, rectangularity and repeats in widthways of the warp, were taken into consideration. For the prototype designs, two types of warp were provided in Bonas Electrical Jacquard loom with three repeats of 12 inches, giving a total of 36 inches. For the prototype designs in Jacquard weave process, colour variations on the warp could not be used because of the predetermined warp colours that were set to facilitate the sharing of University resources. Thus, two colourways of the warp were provided to create the prototype designs in Jacquard weave process.

The first 2/20s cotton warp consisted of three colour combinations in each repeat such as white with cream, light grey with mid-grey, and sky blue with navy. The second warp was a white 2/20s cotton. These restrictions of the loom determined the size of prototypes that could fit in the miniature mannequin, which was a 60 per cent scale of a size 10. The prototype designs in this design practice, therefore, showed the technical development of shapeable seamless woven garments and focused on their potential in Jacquard weaving production.

6.1.2.1 Design inspiration

In the prototype designs in Jacquard weaving, the design practice was based on the previous hand-woven prototype designs that were produced with simple garment construction and design elements (three-dimensional surface effects and textures along with stretchability). The inherent qualities of shapeable woven textiles were integrated into the prototype designs for versatility and seamlessness that were the main considerations of the functional aspects of the design practice. In order to achieve seamlessness of the prototype designs, geometric forms were combined with simple lines in garment making by using a tubular construction. For the versatility function of the prototype designs, different ways of cutting the garment was considered by providing cutting options through the curved lines of the neck and armholes of the garments. In

order to obtain versatility, flexibility, and ability in shaping and fitting options, yarns and weave structures were selected through the ScotWeave CAD system.

The two basic prototype designs are described in the following sections with regard to their design intention and creation processes. The creation procedures are illustrated in detail including Jacquard CAD design, configurations of yarns and weave structures, and outcomes demonstrating the garments' versatility.

6.1.2.2 *Prototype Designs*

6.1.2.2.1 *Jacquard sleeveless top*

(1) CAD preparation

The first Jacquard prototype design was a simple sleeveless top. As shown in Figure 6.15, the simple sleeveless top was designed with seven different areas in order to show a clear shape of the garment and the use of different weft yarns on the CAD design.

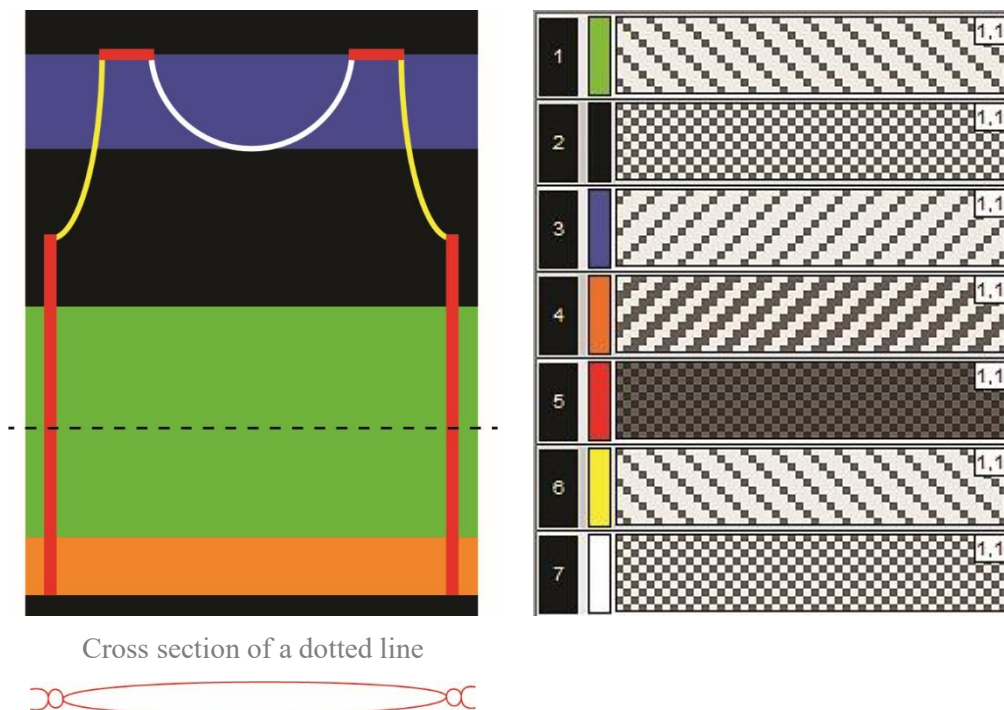


Figure 6.15. The ScotWeave CAD design of the Jacquard sleeveless top

Each colour represented its configuration of colour and type of yarn with a weave structure. The prototype design was woven into two separate layers with different weave structures depending on the colour of areas (#1, 2, 3, 4, 6 and 7). These two separate layers were then connected by the interchanging weave structure of the red lines (#5). As denoted by a dotted line in CAD design, the cross-section showed the interchanging double-cloth weave. Due to the interchanging construction of the red lines, the Jacquard prototype design formed a tubular shape and showed a simple form of the design. Through the curved lines of the white (#7) and yellow (#6) areas, the garment design presented the neck and the armholes. The area (#1) with green colour indicated the waist part of the garment woven for the inherent stretchability. The areas (#3 and 4) were added in order to add decorative features to the monotonous shape of the garment.

In this Jacquard prototype, 2/20s cotton yarn was used in areas #2, 4, 5, 6 and 7 while 1/30Nm high twist wool in Z twist was applied for the waist area of the prototype (area #1). For area #3 with blue colour, 1/30Nm high twist wool in S twist was applied in order to have three-dimensional surface effects.

(2) Finished design

The prototype design was woven in three different colourways of the first warp that consisted of three colour combinations in each repeat. Figure 6.16 shows a cloth of Jacquard sleeveless tops cut off the loom and the finished designs after the wet process. When the cloth was cut off the loom, the basic stitches were applied on the interchanging point of the structure in order to prevent the lines from fraying. The area where 1/30Nm high twist wool yarn in Z twist was applied showed a high degree of shrinkage with good inherent stretchability at the waist part of the Jacquard sleeveless top. The area where 1/30Nm high twist wool yarn in S twist was applied also showed three-dimensional surface effects and textures, but with a much low degree of shrinkage.

The Jacquard sleeveless top could be worn straight from the loom without any finishing process. However, after the wet finishing process, stretchability resulting from the shrinkage was permanently added to the waist part of the garment for the flexibility and ability in shaping and fitting options. Although three simple curved lines (the neck and armhole lines) were placed in the prototype design for the purpose of indicating to

direction of cutting, the user can customise the shape of the sleeveless top by simply cutting it in many different ways.



Figure 6.16. A Jacquard sleeveless top when cut off the loom (top) and after the finishing process (bottom)

Figure 6.17 demonstrates a number of ways to cut the design for versatile styles of Jacquard sleeveless top. Through cutting two different layers of the neck and shoulder areas, diverse designs can be obtained. As can be seen in Figure 6.17, the Jacquard sleeveless top can be worn after the finishing process without any cutting. The garment can then turn into three different designs by cutting either one of the layers of the neck area (A) or the shoulder areas (B) or cutting one of the layers of both the neck and shoulder areas (C). The versatile styles can then be obtained through cutting the rest of the layers

in different areas. In this case, three possible ways are shown to demonstrate the versatility however, the form of the garment can be varied in many other ways, depending on the cutting that the user decides upon.

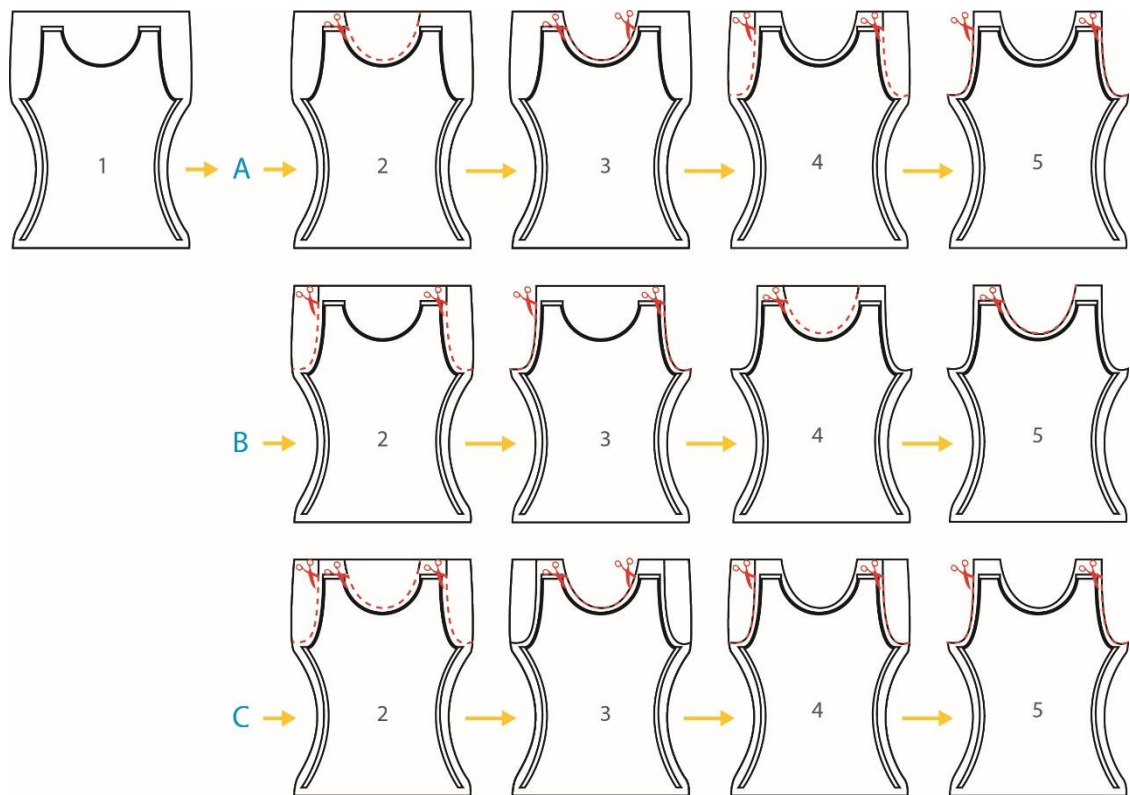


Figure 6.17. Versatility of the Jacquard sleeveless top by different ways of cutting

6.1.2.2.2 Jacquard tubular jumper/jacket

(1) CAD preparation

The second Jacquard prototype design was a tubular jumper/jacket. As shown in Figure 6.18, the tubular jumper/jacket was designed with seven different areas in order to have a clear shape of the garment and the use of different weft yarns through the CAD design preparation.

Each colour of the area represented its configuration of colour and type of yarn with a weave structure. In this Jacquard prototype design, two separate layers of double-cloth construction was used as the basis of the cloth for the areas with yellow (#1), black (#2), green (#3), blue (#4), orange (#6) and white (#7) colours. The interchanging weave

structure was then applied on the red lines (#5) in order to form a tubular shape for the sleeves of the garment by connecting two layers. The interchanging weave point can be seen from the cross-section of a dotted line in CAD design in Figure 6.18.

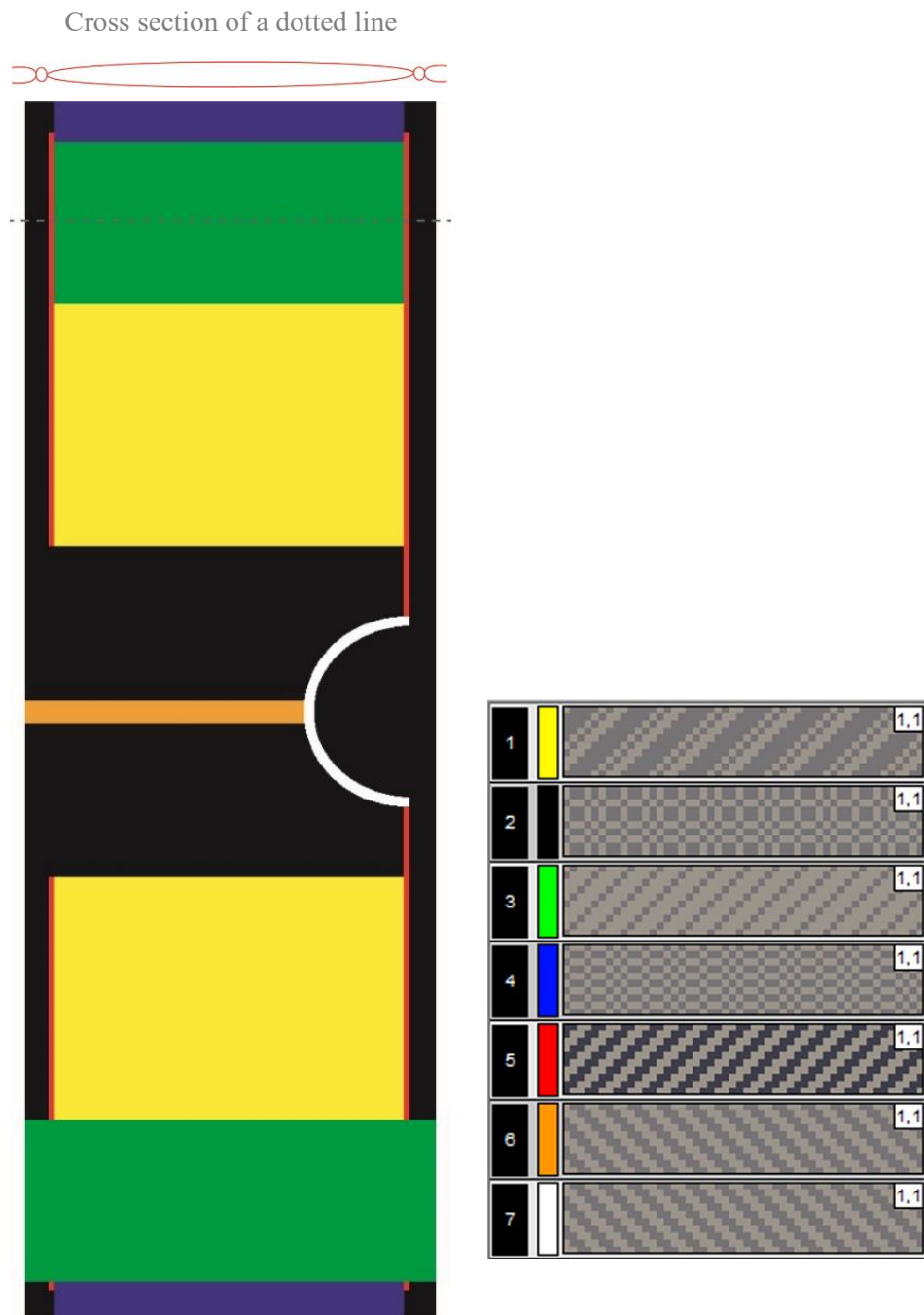


Figure 6.18. The ScotWeave CAD design of the Jacquard tubular jumper/jacket

Moreover, as can be seen at the bottom of the preparation, the addition to the design was to apply two separate layers of double-cloth construction on one of the cuff areas. The area was planned to be a hole in a horizontal direction by disconnecting the interchanging

weave structure of red lines, and the hole was a design feature that could be used as a tying point when the garment used as a scarf (see details in Figure 6.20). The Jacquard design thus formed tubular shapes for the sleeves, and construction of two separate layers for the head, upper body and one of the cuffs areas. The white line (#7) indicated the neckline of the prototype design while the orange area (#6) indicated the direction for cutting the garment when used as a jacket. The areas (#3) with green colour show the cuff part of the garment. The areas (#1 and 4) were added as decorative features to add variety to the monotonous shape of the garment.

In order to have sufficient stretchability resulting from a high degree of shrinkage, 1/3 twill weave structure was applied to the cuff part of the garment. For the basis of the garments, advanced weave structures were applied to each area of the garment in order to have rhythmic patterns rather than three-dimensional surface effects and textures that were not required in this prototype design.

For the use of weft yarns, 2/20s cotton and 2/32s worsted wool yarn were used for the basis of the cloth (area #1, 2, 4, 5, 6 and 7) while 1/30Nm high twist wool in Z twist was applied for the cuff area of the prototype (area #3) in order to have a high degree of shrinkage. As the construction was applied to the Jacquard sleeveless top, the interchanging double-cloth weave was used to form a single tubular shape of the prototype through the Jacquard CAD design.

(2) Finished design

The Jacquard tubular jumper/jacket was woven with the second warp of 2/20s white cotton. Figure 6.19 compares the cloth of the Jacquard tubular jumper/jacket cut off the loom and finished designs after the finishing process. The basic stitches were applied on the interchanging point of the structure in order to prevent the lines from fraying when the cloth was cut off the loom. For the purpose of having sleeve bands, 1/30Nm high twist wool yarn was applied to the cuff area, which showed three-dimensional pleats effects with stretchability that resulted from a high degree of shrinkage.

Figure 6.20 exhibits the versatile styles of the Jacquard jumper/jacket. Once the prototype design was cut off the loom, it can be worn as a woven jumper. After the finishing process,

high shrinkage with stretchability appeared at the cuffs area, which could be stretchable bands at the wrist of the woven jumper. Then it can also be worn as a scarf and can create a different look by using a hole at one of the cuffs areas to tighten a scarf. For having another look of the prototype design, the user can cut the line in the middle of the top or bottom layer to make the woven jumper into a jacket or a cardigan. The simple curved line was given through Jacquard CAD design, however the user can customise collar shapes of the jacket by cutting it. In addition, since the colour of the weft can be applied diversely and differently to each area and layer through Jacquard CAD design, the prototype design can have two different colours of layers that promote the versatility in styling and wearing.



Figure 6.19. A Jacquard tubular jumper/jacket when cut off the loom (top) and after the finishing process (bottom)



Figure 6.20. Versatility of the Jacquard tubular jumper/jacket

6.2 Summary

This chapter has presented the prototyping stage of shapeable seamless woven garments that are integrated with shapeable woven textiles from the previous exploratory phase. Firstly, through the hand-weave process, four prototype designs were created based on a 24-shaft Texel electronic floor loom. Selected combinations of weave designs (a plain, 1/3 twill, 2/2 twill and 2/2 basket weave) with materials (2/60Nm merino wool and 1/30Nm high twist wool yarn in S and Z twist in six colours) and their configuration have been applied through visual preparations as illustrated in each design preparation for each design. The visual preparations also illustrated forms and styles of the prototype designs based on a size 10.

Secondly, in the Jacquard weave process, two prototype designs were created based on the Bonas Electrical Jacquard loom with the pre-set of three repeats in 12 inches, a total of 36 inches. Through the Scotweave CAD design, configurations of selected weave structures and yarns were applied. In order to determine the potential usability of the Jacquard prototype designs and their opportunities as full size garments, the prototype designs were tested on the miniature mannequin (a 60 per cent scaled of a size 10).

Despite the loom restrictions (such as predetermined width, rectangularity, colours and type of the warp and repeats in widthways of the warp), diverse forms and styles (from the simple 2D flat forms into the unique 3D forms) of shapeable seamless woven garments were demonstrated. The prototype designs were accomplished in six diverse forms along with functional aspects such as seamlessness, versatility, inherent elasticity and stretchability as well as three-dimensional surface effects and textures. The first four prototype designs from the hand-weave process concentrated on the versatile ways to wear each design, while the two designs from the Jacquard weave process were concerned with changes in the form of the designs by means of varying the cutting of the garments.

Overall, this prototyping stage has presented a visual presentation of the detailed processes and further enhanced the theoretical basis and design intention to the seamless woven textiles. In addition to demonstrating several prototype designs and their creation procedures, the possibility of shapeable seamless woven garments for a greater design has offered opportunities to broaden the collaborative effects of textiles and fashion. The diverse aesthetic and physical aspects of the prototype designs would be explored and

developed through further attempts of advanced combinations of weave designs and materials as well as colours (e.g. three-dimensional surface effects and textures resulting from different degrees of shrinkage can make a great change in the shapes and forms of the prototype designs).

Chapter 7. Observing and Reflecting Stage: Questionnaire and a Focus Group

This chapter documents the analysis of a questionnaire and a focus group responses that were conducted in two phases to evaluate and reflect on the practical experiments, along with the prototype designs of the research.

7.1 Aim and Objectives

The aim of conducting the questionnaire and focus group was to gain external perspectives and evaluation on practical outcomes of the research, such as shapeable woven textiles and their effectiveness in the prototype designs. The objectives of the questionnaire and focus group were to:

- understand how the prototype designs using the shapeable seamless woven textiles were perceived,
- generate external evaluation of the aesthetic and physical qualities of the shapeable woven fabrics along with the prototype designs,
- evaluate user experiences and responses regarding the versatility of the prototype garments
- assess how the prototype designs contribute to circular design for sustainable fashion and textiles,
- identify the limitations of the practical outcomes of the research and develop potential design process for further research.

In order to do this, the questionnaire was given to members of the public attending an exhibition of the research, and a semi-structured focus group consisting of fashion and textile design experts was used to get further relevant feedback.

7.2 Questionnaire

The questionnaire was conducted during the exhibition of the research outcomes at the Borders Textile Towerhouse in Hawick, Scotland from 7th April to 2nd Jun 2018. The

questionnaire consisted of “itemized rating scale” measurements in the form of balanced scales, “attitudinal rating scale” measurements in the form of the Likert scale (Brace, 2008, p.66,73), and an open ended question. The questionnaire was a paper-based self-completion and voluntary method, which benefited from “the complete absence of an interviewer from the process” and the process “removes a major source of potential bias in the responses” (Brace, 2008, p.27). The questionnaire planned to explore diverse perspectives from the public in the form of people’s personal views on the design attempt of the research along with the prototype designs, and to understand, review and evaluate the opinions of a representative samples of the general public.



Figure 7.1. Works on display at the exhibition and a questionnaire stand

7.2.1 The Questionnaire Design

The questionnaire given to the public was entitled ‘From the Loom to Wear: shapeable tubular textiles for seamless fashion’. A short introduction and instruction stating the purpose of the questionnaire were included, followed by a statement regarding the confidentiality of the questionnaire. The approved ethics form and plain language statement are attached to Appendix E and F respectively.

As the method was self-administered questionnaire, the form of questionnaire should be clear and short to make respondents carry the question instantly. Therefore, various format of questions were used in order to provide the questions and collect data in effective ways. The format of questions used in the questionnaire were:

- **classification questions:** for example, asking respondents about basic personal information of such as their gender, age group, education background and postcode (question no.1),
- **balanced scales:** asking respondents to show their degree of preference, understanding and satisfaction. Responses to such questions ranged from ‘always’ to ‘never’, from ‘fully understand’ to ‘not at all’ and from ‘excellent’ to ‘very poor’ (question nos.2, 3, 4) ,
- **the Likert scales:** for instance, when asking respondents to indicate their opinion, they were offered scales that ranged from ‘strongly agree’ to ‘strongly disagree’ and from ‘definitely’ to ‘definitely not’ (question nos.5, 6), and
- **open response question:** asking respondents to write their suggestions or comments (question no.7).

The form of a questionnaire is attached to Appendix G.

7.2.2 Potential Limitations of the Questionnaire

Since the method was a voluntary basis and self-completion, it was challenged to collect a number of responses due to the fact that one of the limitations of the questionnaire was the possibility of lower response rates (Bourque and Fielder, 1995; Milton and Rodgers, 2013). Bryman (2016) claims that the risk of bias in finding can be relatively greater if the response rate is low.

Self-completion method is also more likely to have a greater risk of missing data that could result in less precision of information from representation (Bryman, 2016). Moreover, self-administered questionnaire cannot collect additional information or data from the respondents because the questionnaire should be clear and short as there is no interviewer available (Bourque and Fielder, 1995; Bryman, 2016).

7.2.3 Quantitative Data Analysis of the Questionnaire Results

The questionnaire was located in the exhibition area, and all respondents were recruited on a voluntary basis from among visitors at the Borders Textile Towerhouse. A total of 30 respondents responded to the questionnaire. Ireland (2003) suggested that at least thirty individual samples should be used in order to make findings from the questionnaire valid.

The analysis and comparison of the data indicated that an overwhelming number of respondents were female, with 28 women (90% of respondents) completing the questionnaire while only two men (10%) responded. This perhaps indicated that the prototype designs in being a women's garment range, would attract the interest of female visitors more than male visitors.

According to the data analysis, 25 out of 30 respondents provided the postcode for the area in which they live, indicating that the data was obtained not only from the local area, but also from other areas in the U.K as well as from overseas countries. Overall, respondents from Scotland were in the majority (72% of respondents), coming from such area as the Scottish Borders, Edinburgh, Glasgow and Aberdeen, five respondents (20%) were from England and Wales, with two (8%) being from the Netherlands and France.

When looking at the data relating to the age group, the respondents' age group was generally broad; from under 21 to over 60. However, respondents in their 60s and over had the highest participation rate with 26.7% followed by those in their 50s with 20%.

Twenty-nine out of 30 respondents indicated their education level, of which 22 respondents with 75.8% have a bachelor's degree or master's degree with a rate of each 37.9% respectively. Two respondents, 6.9%, had a doctorate, and two respondents, 3.4% per individual, had high school degree or associate degree respectively. Three respondents, 10.3%, stated that they attended college level.

In Figure 7.2, data relating to the respondents' age group and education level are integrated using a sunburst chart to identify the education level of respondents within particular age ranges. From the data, it can be seen that all respondents from under 21 up to 50 have a bachelor's degree or higher. In the age groups of 50-60 and over 60, it can be seen that they have more diverse education levels when compared to other age groups.

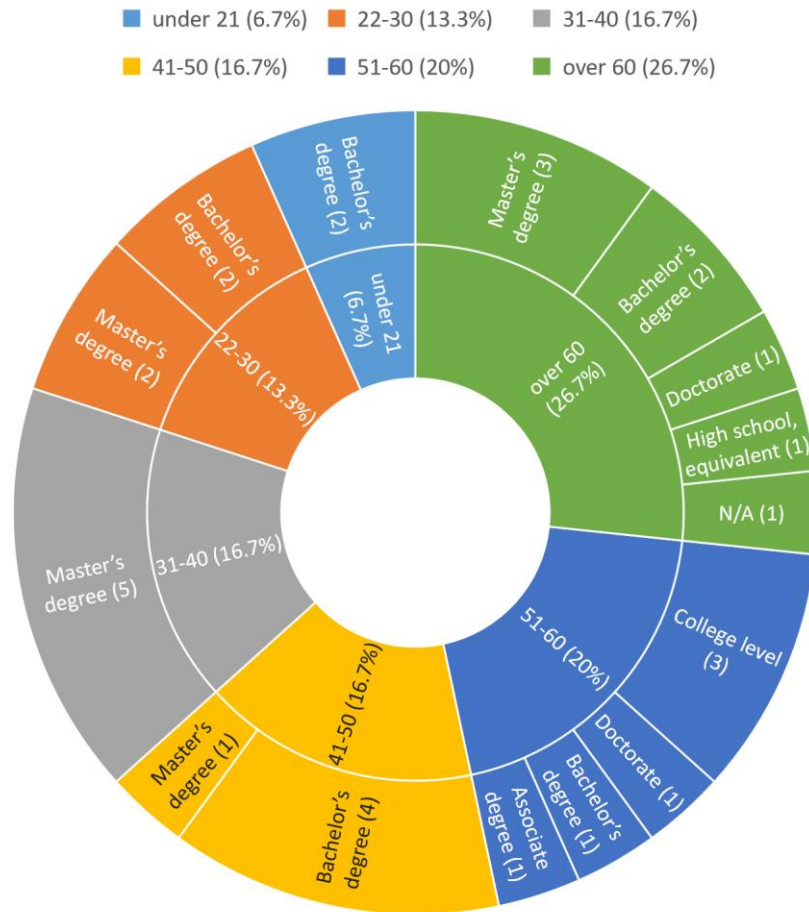


Figure 7.2. Number and proportion of repondents by age group and education level

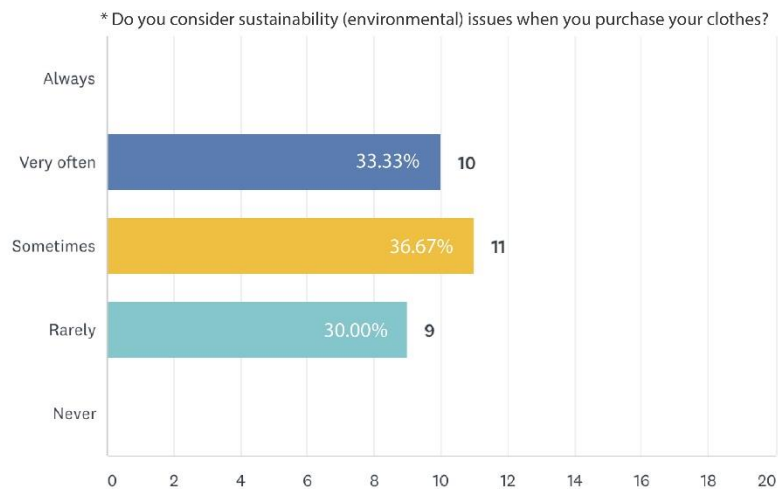


Figure 7.3. Number of reponses to question no.2.

For the answer to the question in the Figure 7.3: Do you consider sustainability (environmental) issues when you purchase your clothes?: 'sometimes' (36.7%) is closely followed by 'very often' (33.3%) and 'rarely' (30%), and there were no respondents who

always or never consider sustainability issue when they purchase clothes.

From the data analysis shown in Figure 7.8, it can also be seen that there is no correlation between the academic achievement of respondents and their consideration of sustainability issues when purchasing clothing. With specific reference to individual respondents, while there is a tendency for the highly-educated respondents no.1 and 4 to think more about sustainability when purchasing clothing, it is not the same for all highly-educated respondents such as nos.11, 14, 18, 19 and 30. It can also be seen when comparing with respondent no.6 who attended college level, that respondent is often considered the sustainable issue than other respondents.

Although respondents do not consider sustainability issues very often, when all respondents think about the design process and versatility of the prototype designs in regard to the product longevity in sustainable fashion and textiles, 80% of respondents agree (30% of strongly agree with nine respondents and 50% of agree with fifteen respondents) that the seamless woven garments, which can be worn as a scarf, a shawl and a dress or a jacket, would encourage them to wear the garments more often and keep the garment longer (see Figure 7.4). Thus, it may be concluded that the versatility of shapeable seamless woven garments was effectively introduced and applied to the prototype garments, and it may enhance product longevity and thus improve sustainable fashion and textile design.

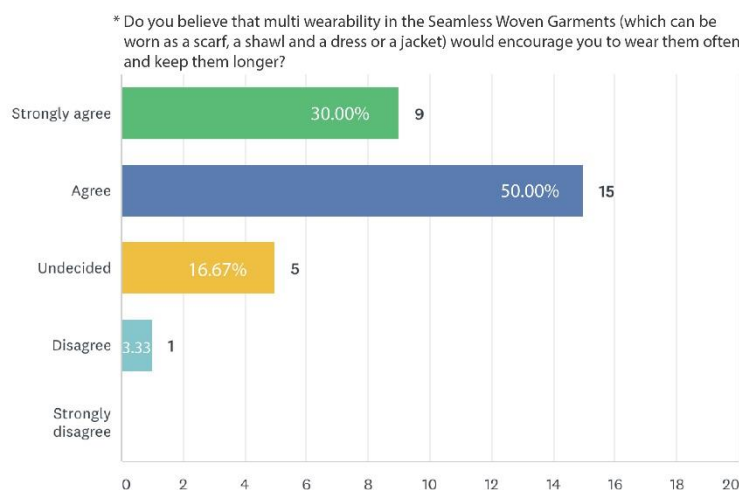


Figure 7.4. Number of reponses to question no.5.

More than half (53.3%) of respondents fully understood a concept of the design practice behind the exhibition of the prototype designs, while more than one third (36.7%) of respondents mostly understood, and only 10% of respondents moderately understood (see Figure 7.5). Due to the fact that a total of 26 (90%) respondents understood a concept of the design practice, it may be concluded that a sustainable approach, through the versatility of shapeable seamless woven garments, was clearly introduced to the public and that related design practice was properly integrated into the garments.

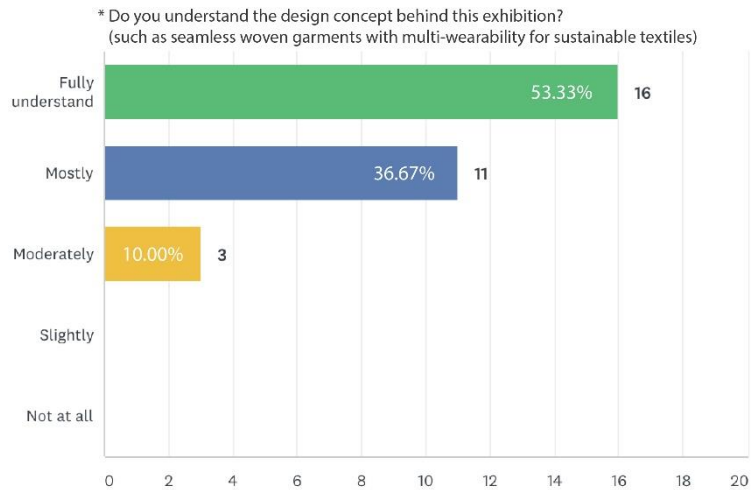


Figure 7.5. Number of responses to question no.3.

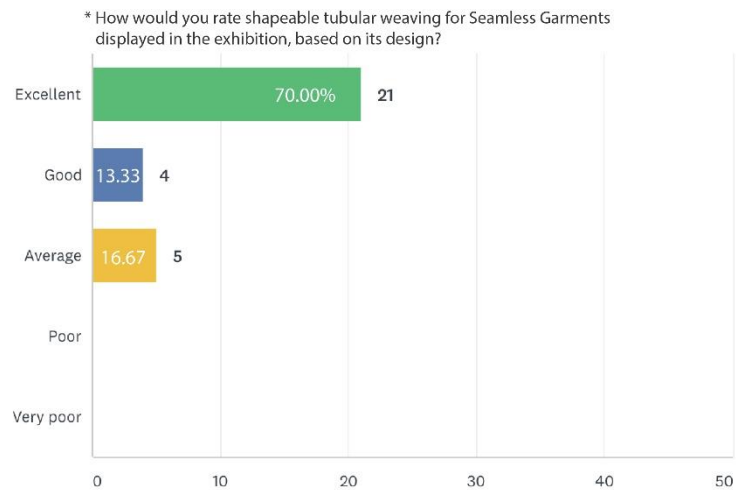


Figure 7.6. Number of responses to question no.4.

With regard to the question no.4 relating to the overall design of shapeable tubular woven fabrics for seamless garments in the exhibition in Figure 7.6, almost three quarters (70%) stated that the design is excellent while one-sixth (13.3%) said that it is good, and others

(16.7%) responded that the design is average in their opinion. As more than 80% of respondents positively responded to the question about the overall design of the prototype garments, it could be inferred that shapeable seamless woven garments may have potential for the commercial market.

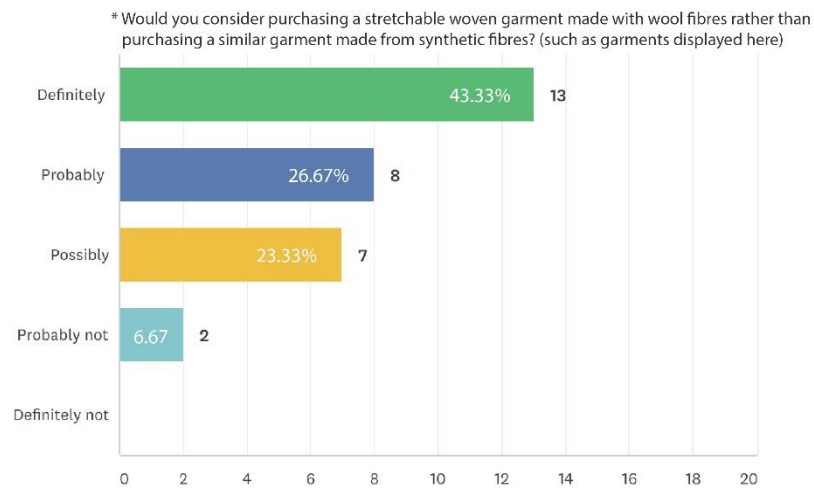


Figure 7.7. Number of responses to question no.6.

In the question about using natural wool fibres rather than synthetic fibres enable stretchability in the garments in 오류! 참조 원본을 찾을 수 없습니다., 43% of respondents said that they would definitely buy products using wool fibres, and 26.7% of respondents responded that they would probably buy wool products, while 23.3% of respondents stated they would possibly buy wool products rather than products using synthetic. Only two respondents (6.7%) stated that they would probably not buy products using natural wool. Based on the comments from the open response question, respondents who answered that they would probably do not buy wool products because they are reluctant to use animal fibres for clothing or considered wool products more difficult to wash.

The line graph in Figure 7.8 integrates the data analysis of questions that are related to design perspectives of the prototype garments such as question no.2: understanding of a concept of the design practice, question no.4: satisfaction with the design of the prototype, question no.5: the versatility of the prototype and question no.6: preference for using wool fibres.

When comparing the correlation between respondents' understanding of a concept of the

design practice and their satisfaction with the design of prototype garments, the graph shows that satisfaction with design of the prototypes was high while more than two-thirds of respondents sufficiently understood a concept of the design practice. As the chart shows a degree of correlation between understanding and satisfaction among respondents, it is tempting to infer that the two are causally related and concluded that greater understanding leads to, or is necessary for, greater satisfaction. However, although respondents fully or mostly understand a design concept of the prototype, this does not mean that they prefer to buy such prototype garments made of wool fibres rather than artificial fibres. Moreover, the line graph the perceived versatility of the prototype garments shows no correlation with the graph of understanding of a concept of the design practice, despite the positive responses to the question about the versatility of the prototype garments.

In summary, there are mostly positive responses to the question about understanding a concept of the design practice and their attempt of the research and the overall design of the prototype garments. However, even though the results reveal some correlation, though not necessarily a causal relationship, between respondents' understanding of a concept of the design practice and their satisfaction with the prototype designs, it is hard to see a correlation between the respondents' perception of their sustainability practices when purchasing clothing and their perception of this research projects with regard to its sustainable garment design. When looking at the other elements of the data analysis, there is no similarity between the responses to questions about the versatility of the garments, satisfaction with the design of the garment and preference for using wool. As a result, the data shows that responses may vary from question to question, irrespective of age group, gender or level of education of respondents, and seem to be dependent only upon the respondents' subjective opinion at any given time. It is moreover difficult to connect some links between respondents' perspectives on the design, function, material and sustainability as a composite feature of the prototype design. The questionnaire responses suggest that the design, function, material and sustainability would be better evaluated as individual elements, and the research also needs to seek ways that how people understand each design element as an integrated design solution.

In order to compare the analysed data from the questionnaire, the following section discusses the focus group. Mapping the discussion through transcription, video recording

footage, and detailed observational notes, promises to enhance the understanding of professionals' perspectives on the prototype designs and the entire design practice of the research, and to demystify differences between the qualitative and quantitative data analysis.

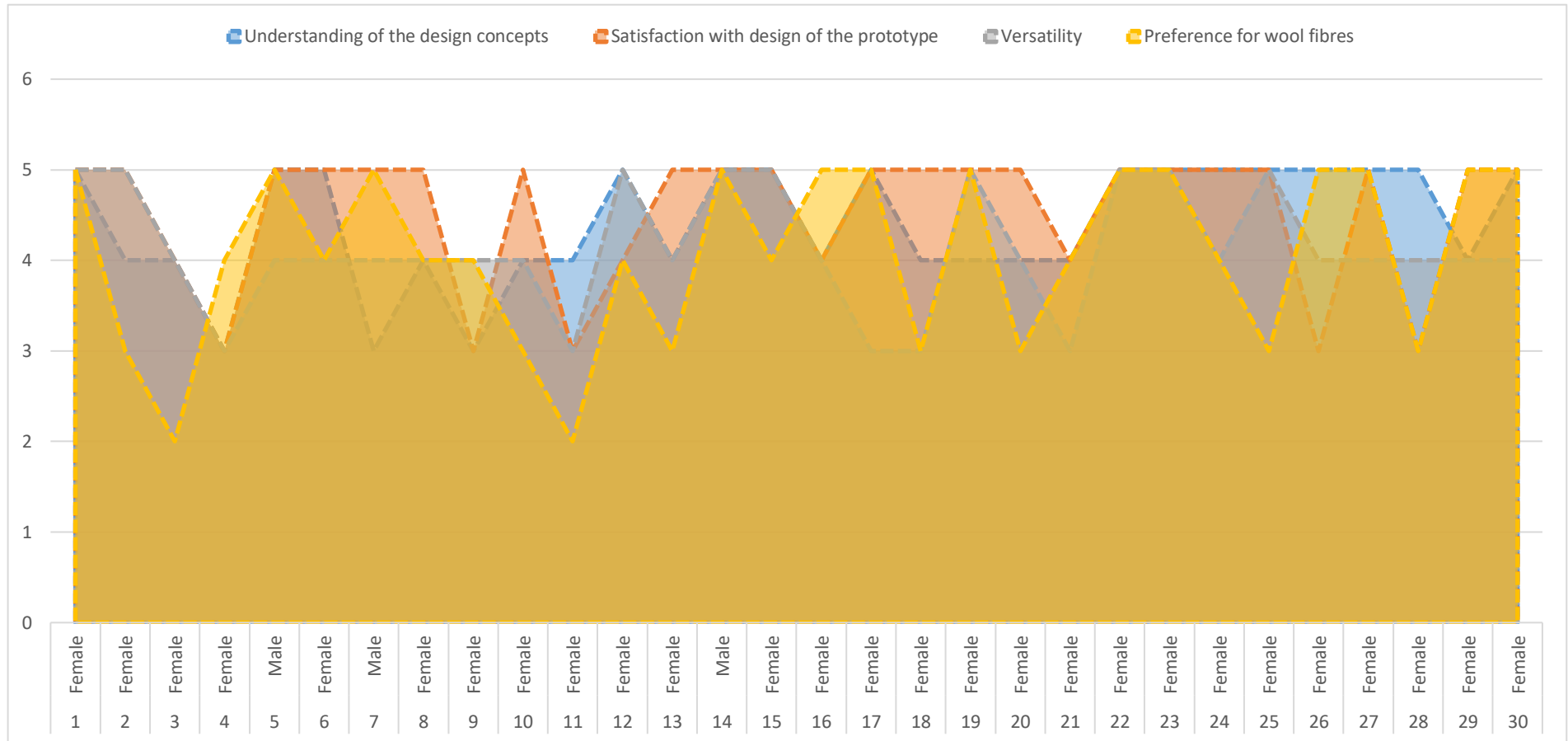


Figure 7.8. The overall data analysis of questions related to the design of shapeable seamless woven garments.

7.3 Focus Group

A focus group was built on responses from questionnaire in order to ascertain the breadth and depth of the information gathered with regard to the design practice and its attempts of the research as well as practical outcomes of shapeable woven textiles and the prototype designs that were part of the research.

7.3.1 Participants

For the purpose of the focus group discussion, “it is vital to identify the target group as precisely as possible”, and the participants of the group need to “ have certain things in common” (Krueger, 1994, p.76; Barbour, 2007). Since the research is focused on establishing relationships between design practice (based on woven textile design for the seamless fashion) of the prototypes and circular design perspective for sustainable fashion and textiles, the chosen participants are professionals from fashion and textile design disciplines. A group of 4 to 6 participants is preferred among researchers as it makes it relatively easy to recruit suitable members and host discussions (Ibid). It is also a sufficient number to enable broad-based information, as well as more personal and insightful experiences to come to light (Krueger, 1994; Barbour, 2007). Ireland (2003) also states that a focus group with such a small number of people provides a chance to have deeper discussions and questioning that could be tailored more specifically for each group member. Therefore, in order to analyse and evaluate the aesthetic and physical properties of shapeable woven textiles along with prototype designs within the broader context of fashion and textile design, the group was made up of two researchers in 3D printing fashion/textiles and woven textile design, one academic in woven textile design, one consultant in fashion/textile design and one undergraduate student in fashion marketing.

7.3.2 Focus Group Environment

The focus group was conducted for two hours, allowing the participants to discuss the research issues and to interact with fabric samples and the prototype designs within an adequate time frame. The researcher of this study who ran the focus group discussion also served as the moderator guiding the discussion. As Bryman (2016) points out a moderator

can take alternate positions of ‘intervention and non-intervention’, and takes a ‘non-intervention’ approach so that participants can be encouraged to engage in the discussion based upon their own varied experiences. In light of such consideration, the moderator in this research played a dual role, sometimes intervening and sometimes not, in order to glean diverse idea and perspectives from participants and control the flow of conversation resulting from group behaviours at the same time.

The whole discussion was documented by using video recording, and additional notes were taken. The confidentiality of participants was assured prior to holding the focus group, and all the participant are anonymous in the data analysis. The approved ethics form, plain language statement and informed consent form are attached in Appendix G, H and I respectively.

7.3.3 Potential Limitations of the Focus Group

The focus group discussion was chosen as it is an advantageous and appropriate way to explore particular topics from the diverse perspectives of participants (Bryman, 2016). It was also decided to keep the size of the group small in order to more effectively facilitate and manage discussion, however it is recognised that a smaller group may not be as diverse as in its perspectives and experience as a larger group. Krueger (1994) points out that groups in which participants already know each other, and regularly converse may be problematic in that their responses may be based on past discussions or experiences with each other, rather than an immediate reaction to topics raised by the moderator. In addition, as Bryman (2016) observes, if a focus group’s participants not only know each other but also have a hierarchical relationship, as was the case with the group used in this research, this may lead to a degree of discomfort or reluctance on the part of some members to express themselves. In light of such considerations, it was decided to use a facilitator in addition to the moderator with the aim of stimulating conversation and discussion between participants and encourage all participants to express themselves and air their views, reflecting their own unique perspectives, as fully as possible.

7.3.4 Contents and Structure

The focus group was designed to run for two hours, allowing participants to engage with the issues and factors, and enabling debate and discussion relating to the most critical areas of the research within an adequate time frame. The focus group consisted of two

phases: firstly, discussion from the broad perspective of sustainability in fashion and textiles and circular design to the specific perspectives of the design practice and its attempt of the research and the prototype garments; secondly, activities that involved the testing of shapeable woven fabrics and participants' prototype garments trials, aimed at observing participants' reactions to the the prototype designs. The focus group discussion was planned as follows:

- Discussion phase (guiding questions)
 - sustainability and circular design consideration?
 - general opinions regarding seamless fashion or garments?
 - impression of “shapeable tubular weaving”?
 - physical and aesthetic qualities of shapeable woven fabrics?
 - perception of stretchability and elastic properties of natural fibre (wool) compared to synthetic fibre?
 - versatility and colour of the prototype designs
- Activity phase
 - testing shapeable woven fabrics
 - participants' prototype trials
 - idea generations and suggestions

As outlined above, questions were open-ended and semi-structured to explore the discussion in breadth and depth through the active engagement of participants. The key points were listed alongside instruction and guidelines, allowing the researcher as a moderator to make the discussion progress productively.

Within the first phase of the focus group discussion, participants were asked about what they thought about seamless fashion regarding sustainability and circular design in fashion and textiles, and specifically, how they perceived the relevance of shapeable woven fabrics along with the prototype designs. A clear description was given to the participants of what is meant by ‘shapeable’, ‘tubular weaving’ and ‘versatility’, and how these elements were integrated in the prototype designs.

During the second phase, a brief explanation of how each garment could be worn in different ways was introduced to the participants. The participants were then given the

opportunity to try on shapeable seamless woven garments in any way that they wanted to wear them. Further, the participants were asked to suggest any necessary improvements or essential advice with regard to the research issues, problems and the design practice or the prototype designs.

7.3.5 Qualitative Data Analysis of the Focus Group

The analysis of the focus group is discussed in this section and summarised under the themes outlined within the questions raised for discussion. In order to analyse the discussion consistently with the data analysis of the questionnaire, the results and discussion are explored in relation to the overarching analytical framework of ‘form (aesthetic perspective and physical properties of the prototype designs)’, ‘function (versatility)’, ‘material’ and ‘sustainability with circular design perspectives’.

Sustainability and Circular Design Perspectives

General idea about sustainability in fashion and textiles and circular design perspectives regarding the prototype design were discussed. Participant-S firstly highlighted that the word ‘sustainable’ needs to be further clarified if it is to be useful because of it being so misunderstood even in the education sector that she is heavily involved in. Highlighting this, she also stated: “we all understand different things by the word ‘sustainable’... polyester [itself] is sustainable [in some cases] but it is not good for the world [as it has to go into landfill because it is hard to be recycled], and that is the issue”.

All participants agreed on the issue of landfill and the incineration of fashion and textile waste. As participant-B explained: “we have more than enough clothes and need to stop making or buying more clothes to fill our wardrobe, and need to deal with what we already have. Moreover, she added a comment: “the question really is what do we mean by the word ‘sustainable’... people place a lot of value on the word ‘sustainable’, but it is often misused, and we need to be careful about how we use it”. Participant-B thus suggested considering other terms for describing the value of the prototype garments because these garments have a lot of advantages such as multi-wearability, flexibility and biodegradability that are more meaningful and precise than the word ‘sustainable’.

The participants’ responses to the question about general idea about circular design and economy had a few negative aspects. Particularly, when mentioning consumers’

perspectives, participant-M explained: “within the industry, they certainly understand what circular economy and design is for the future, however, the majority of people, they are not worrying about their t-shirt whether it is going to be recycled ... although they possibly understand because they may have read or heard about the circular economy and design through the media”. In addition, participant-F stated that “the majority of plastic waste that causes pollution of the oceans comes from five rivers in Asia... people may know where the plastics and waste are coming from but, the majority of people there, they do not care and are just surviving”. She outlined that people in those counties need to meet the basic human needs for life rather than think about the circular economy, which is far removed from their everyday lives. There is thus evidently a significant difference between academic theory and reality, in the form of industrial practice and consumer behaviour when it comes to sustainability and circular design in fashion and textiles.

With regard to sustainable products in the market within the circular economy, participants agreed that the products labelled as ‘sustainable’, such as using organic cotton, recycled cotton or polyester, are usually more expensive than the other products. However, participant-S argued that organic cotton is not always sustainable because the process sometimes uses more water and more pesticides than normal cotton. She also pointed out that the issue of certificates on organic cotton manufacturing, which can be purchased from uncertified organisations in India and China at a low cost.

Moreover, participant-M indicated the problem of using terms such as ‘sustainability’ or ‘circular design’ as a marketing tool in the fast fashion industry without making substantial efforts to actually improve the way goods are produced. Participants also agreed on the issue of ‘greenwash’ and mentioned that one of the fast fashion brands had recently invested in research into the recycling of polyester for the circular economy and launched their sustainable clothing line using recycled polyester for marketing purposes. Particularly, mentioning this circular economy issue with regard to a fast fashion brand, participant-A explains: “manufacture is only taking in one-fifth of their sales for recycling, and you can only recycle products with 100% mono-fibre at the moment ... they call this recycling as [part of] the circular economy, and it is how they close the loop, simply recycling chemicals by using chemicals [and as such they do not use or create ‘better’ chemicals, they are still dangerous]”. In addition, participant-S suggested that wool fibre can be the most suitable material for the circular economy if its ‘end of life’ and biodegradability are taken into consideration.

Seamless Fashion or Garments

The participants were then asked to express their general idea regarding, and what factors they consider relevant and when they think about, seamless fashion or garments. Participant-S firstly outlined considering seamless knitting and stated that “seamless knitting is undoubtedly the hot topic within the industry at the moment and it has become highly developed as a technique”. She also mentioned the potential of 3D weaving for seamless garments and stated that “experts, who are capable of 3D weaving, are only a few at the moment and they mostly are orientated industrially. 3D weaving is mainly available for a large scale production due to the high cost of process”.

Participant-A mentioned that she immediately thought of underwear and activewear when asked to consider seamless fashion or garments because those products are commercially viable in the market at the moment. She then mentioned that seamless woven garments give her an idea of innovation and a breakthrough on the path to the evolution of the weaving loom. Participant-F also highlighted the current development of the Jacquard loom, which is weaving clothes flexibly, in changing widths, and is thus an example of the seamless weaving. Participant-M moreover argued that research in seamless woven textiles also need to be more supported and investigated to surpass the restrictions of woven textiles’ characteristic in order to create diverse seamless garments.

The participants recognised seamless knitting technology as being representative of seamless fashion or garments and, as discussed above, seamless fashion seems to be led by knitted textiles when considering to the commercial viability of current seamless products on the market. However, the discussion highlighted that seamless woven textiles have not been fully investigated in order to create seamless garments, and there is the potential for seamless weaving technology.

Initial Responses

In the group discussion, participants cite a number of opinions with regard to ‘shapeable woven textile’ and their first impression of it. The general design practice of ‘shapeable woven textile’ were explained to participants prior to the discussion, and the participants then related their impressions and idea, and individual opinions based on their first impressions regarding both the concept of shapeable woven textile and the design samples they were presented with.

Since ‘*shapeable*’ and ‘*tubular*’ were essential elements of the design process of the research outcomes, it is significant to ascertain exactly how participants viewed those elements as being embodied in the fabric samples, and to what extent they saw the prototype garments as a complete design attempt. Participant-B mentioned that the first impression of the ‘*shapeable tubular weaving*’ sounds very innovative and he read that it is interesting to see. Participant-S, however, said that “knitting can do tubular technique effectively and quickly with more commercial opportunities compared to weaving, but there are different fields to consider: educational side and commercial side”.

In this regard, other participants agreed that it is difficult to compare commercial aspects of shapeable tubular weaving to those of knitting technology. Participant-M, however, highlighted that solely considering commercialisation of research kills every piece of research, and there could be niche opportunities for such shapeable tubular weaving. Participant-F also stated that it is not necessary to consider commercial aspect of the research here, and suggested collaborating with technical professions in order to explore various potential applications of the research such as architectural textiles rather than only looking at fashion applications.

In general, participants agreed that the overall commercial aspects of the research are different from knitting technology when looking only at the technique of shapeable tubular weaving, however, they also agreed that there could be a niche market for these prototypes, such as zero-waste pattern-cutting garments, and also the possibility of improving the technique for other purposes, such as architectural textiles.

Material

The use of wool fibre was highlighted as the key element of shapeable seamless woven garments and also as a suitable material for sustainable fashion and textiles and circular economy. All participants understood how wool fibre in the form of the high-twist yarns are used to make shapeable fabrics that enable the elasticity and stretchability of the prototype garments.

The participants agreed that wool fibre, as a natural renewable resource, is a good candidate for consideration as a sustainable material in terms of its biodegradability, recyclability and other great advantages such as breathability, and fire, stain and odour resistance. However, despite all those advantages, wool is rated as being a low grade

candidate in the evaluation of sustainable materials for the natural environment. Explaining this, participant-S pointed out that “it is because the processing of wool ... requires intensive use of water and chemicals. So do other fibres ... but the evaluation [of wool] has not taken ‘the end of life’ into consideration, and has not taken ‘biodegradability’ into consideration [either]”. It may be seen that the evaluation of sustainable fibres often focuses more on how much water, chemicals and energy are used to create the fibres rather than considering the whole life cycle of the fibres. Moreover, participant-F mentioned the responsible processing of wool manufacturing with regard to the carbon footprint that is also one of the assessments for sustainable fibres. In this case, when considering a material’s carbon footprint when assessing its sustainability, participants agreed and suggested using locally produced wool fibres to reduce the carbon footprint.

In terms of using high twist wool yarns for creating three-dimensional surface effects and textures of the shapeable woven fabrics, participant-F stated that the technique of using different twists to create surface effects has been used for a decade, and the garments where the technique is applied are similar to Issey Miyake’s collection. However, participant-M argued that Miyake’s garments are mostly synthetic and use a different type of synthetic fibre and adhesive chemicals to create pleats or shapes, and she pointed out that the prototype garments were different in that they only use natural fibre to enable many functions, such as surface effects and textures along with elasticity and stretchability. These advantages of using wool fibre can be a distinctive point of the prototype designs when consumers are aware of sustainable fashion and textiles, and willing to compromise possible design elements for the circular economy.

Form (physical and aesthetic design of the prototype garments)

Prior to the start of trying on the prototype garments, a brief explanation of the design practice, in regard to physical and aesthetic considerations was provided. The participants were then given the opportunity to try wearing the prototype garments in many different ways.

Once participants had tried wearing prototype garments, most of them fully understood the design practice of the garments, and showed positive responses to all the design considerations, namely shapeability, seamlessness and longevity through both quality and

versatility for circular design and sustainable fashion and textiles.

In terms of seamless weaving of the prototype garments, participant-S mentioned that she was impressed; “the design of the garments is very interesting ... I have never come across garments made like this”. She also suggested using shrink resistance treatment on the merino wool yarn in order to maximise three-dimensional surface effects and textures resulting from the shrinkage of high twist wool yarn. It was also noted by participant-M that the use of different counts of yarns, 2/30Nm merino wool and 1/30Nm high twist wool, within the same weave sett makes some parts transparent, which could add an aesthetic element to the prototype designs. It was suggested that the use of dissolving ‘Solvlon’ yarn could create more transparency within the garment, while keeping the product woven with 100% wool that is fully biodegradable.

In regard to the versatility of the prototype garments, all participants agreed that improved function and versatility could encourage wearers to keep the garments longer and not have to buy so many clothes as they can use the ones they have in many different ways. A participant A stated and the others agreed that she would be prepared to pay more for a product that can be worn in versatile ways. She also suggested that if the garments have more holes to play around with, the versatility of the garments may increase, and this would also enhance the product life cycle. In addition to versatility, it is interesting to note that one of the prototype garments, a sleeveless dress, can be used as a bag, as participant-B demonstrated when he tied the ends of the garment together, and used the armholes to put something inside. .

7.4 Summary

This chapter outlined methods that were used to evaluate and reflect on the practical experiment along with the prototype designs of the research. The data analyses of the questionnaire and a focus group discussion were discussed and the findings of the data analyses can be summarised under each of objectives.

To understand how the prototype designs using the shapeable seamless woven textiles were perceived.

The focus group discussion emphasised that seamless fashion is dominated by knitting technology and there may be a gap between seamless knitting and seamless weaving due

to the characteristics of woven fabric. However, it was observed that a distinctive element of the research could be the way in which it examines the potential of seamless weaving using both conventional looms and Jacquard technology in enabling integrated design considerations that may result in greater versatility and longevity of garments, in turn resulting in more sustainable fashion and textiles and circular economy.

To generate external evaluation of the aesthetic and physical qualities of the shapeable woven fabrics along with the prototype designs.

Most respondents and participants from the questionnaire and a focus group had showed positive responses to the design (aesthetic and physical quality) of shapeable seamless woven textiles. Through the questionnaire, 70% of respondents answered that the design of the shapeable woven textiles was good. The focus group discussion enabled participants to express specific opinions regarding the details of the design of the shapeable woven textiles.

The participants also had a good opinion of using only natural (wool) fibres to create three-dimensional surface effects and textures resulting from diverse degrees of shrinkage that enable the fabrics to be elastic and stretchable. Although the use of a different twist of yarns for creating such effects has employed before, affirmative responses revealed that combining the use of a various twist of wool yarns with the tubular weave structure to make shapeable seamless woven garments could be a distinctive feature of the research.

To evaluate wearers experiences and responses regarding the versatility of the prototype garments and how the prototype designs contribute to circular design for sustainable fashion and textiles.

The design elements of the prototype designs were set within the context of circular design and sustainable fashion and textile design. The findings showed that versatility function was an essential element of the prototype designs, which could enhance the product life cycle by way that wearers to maximise the use of the garments in different ways and keep them longer. Most respondents and participants clearly understood the design practice with regard to circular design for sustainable fashion and textiles, and agreed that the outcomes of the research may fulfil the requirements of such considerations in terms of material, design (function), quality of the product and sustainable production. The prototype designs can thus contribute circular design for sustainable fashion and textiles

design by integrating such considerations into design process. An analysis of the data also indicated that it would be beneficial for the research to include an element of consciousness raising making people more aware of the fact that the prototype garments successfully integrate multiple aspects of circular design and sustainable fashion and textiles, such as seamlessness, versatility, materials, products longevity, biodegradability and cyclability.

To identify the limitations of the practical outcomes of the research and develop potential design process for further research.

The findings showed that versatility as the key element of the prototype garments could encourage people to wear them more often and keep them longer. Thus, it was suggested that the idea of adding holes to the garments should be further explored as it may increase versatility, and that such exploration might engender new alternative design solution for the next cycle of the research. However, it could be seen that various size ranges and colours of the design need to be considered in order to improve the commercial viability of the prototype garments.

In terms of using colours, it was observed that using solid colours might increase the versatility of the garments in that using different colours on the warp and weft results in highly recognisable check patterns, although one of the respondents from the questionnaire suggests that the prototype garments need more colour variations in order to create a further complete collection.

Chapter 8. Conclusion

This chapter presents the overall conclusion and the main findings of the exploratory practical research 'Shapeable Woven Textiles for Seamless Fashion'. By offering a final overall reflection and an examination of limitations, this chapter concludes with how the research contributes to the current discussion and practices regarding woven textiles for seamless fashion within the circular design perspectives for sustainable fashion and textiles, before suggesting a future direction for the research.

8.1 Conclusion

This research has demonstrated the viability of shapeable seamless woven garments based on the integrated design process of materials, weave designs and current weaving technology. The research has evaluated how the design practice could enhance the product lifecycle and contribute to sustainability in fashion and textiles as well as circular design. The design practice that initiated shapeable woven textiles (inherent stretchability with three-dimensional surface effects and textures from the use of wool fibre) with variable forms into ultimate seamless garments has expanded the creative possibilities of woven textiles for seamless fashion. This design practice is also capable of providing additional value to shapeable seamless woven garments by wearing them in versatile ways, thus giving each garment more than one function throughout its life span. These features of shapeable seamless woven garments can enhance sustainability in fashion and textiles by lengthening garment life and so reducing wastage. The conclusions regarding the design attempts of the research, practical explorations and the creation of shapeable seamless woven garments, are addressed in the following sections by reiterating summaries of the previous chapters of the research.

8.1.1 The Design Process of Shapeable Woven Textiles for Seamless Fashion

The first aim of this research was to create shapeable woven textiles for seamless garments that are versatile (i.e. can be worn and used in many different ways). With regard to sustainable fashion and textiles, seamlessness in garment making has been researched as a part of ways to minimise environmental impact from fashion and textile waste. There have been a number of drawbacks of using 'cut and sew' method in garment making with

woven textiles. Fabric scraps are produced by the method, resulting in fabric waste. During the sewing process, heddle hole-related fibre damage could also adversely affect the quality of the fabric leading to the reduction in quality of the finished garment. The stress concentration at the seam may result in product failure and bulkiness of seams may cause user discomfort. Moreover, the method is the most labour intensive process in garment construction and thus the manual process of ‘cut and sew’ method is highly susceptible to human error. Therefore, the need of seamlessness in woven textiles was proposed for the research in order to create shapeable seamless garments.

A contextual review established that there have been several techniques and attempts to create shapeable textiles that enable seamless garments to be manufactured, but they are all with their limitations. The current techniques and attempts have either limited their purposes and sizes to craft use, limited garment shapes and uses, are restricted to the use of synthetic materials, require additional integral processes to construct a garment or require specialised machines and software.

The second aim was to explore how shapeable seamless woven garments can improve the user engagement phase of the product lifecycle and contribute to sustainability and circular design in fashion and textiles. Previous studies have presented a number of creations of seamless woven garments in variable forms of dresses with the main focus on the applications of elastic fabrics using synthetic fibres such as spandex. However, creating seamless garments with versatile functions by employing shapeable woven textiles relating to circular design perspective or sustainable fashions and textiles has not been investigated and researched. Thus, the design process focused on integrating key design elements, such as seamlessness, choice of material and versatility for circular design and sustainability, in order to create complete seamless woven garments. Therefore, this research exclusively introduced the integrated design process that forms shapeable woven textiles into seamless garments based upon a wool fibre (that enables inherent stretchability and three-dimensional surface effects and textures of shapeable woven fabrics).

As stated in section 2.4, the use of natural and mono fibre was considered in order to facilitate biodegradability and recyclability for circular design and sustainable fashion and textiles. It was understood that the biodegradability of wool fibre could improve

circular design by closing the loop, as the fibre goes back to the resource stage again. Additionally, The biodegradability could also reduce environmental pollution caused by the emission of microplastic from the domestic laundry of synthetic textiles and clothing. The use of mono fibre could also enhance cyclability that promotes circular design perspectives of shapeable seamless woven garments.

The creative design practice has identified shapeable woven textiles from the existing woven textiles that were capable of creating seamlessness, surface effects, textures and stretchability using only natural wool fibre. Unlike other shapeable textiles that were using synthetic fibres or additional chemical treatments enabling those features of the fabrics, shapeable woven textiles in this research had the capability of fulfilling physical qualities (seamlessness and inherent stretchability from divers degrees of shrinkage), and aesthetic qualities (overall shapes of the garments along with three-dimensional surface effects and textures) for seamless woven garments. Moreover, it has identified that the versatile function of garments can lengthen the user engagement phase by wearing them in many different ways, and this led to improving product lifecycle for circular design perspectives and sustainability.

8.1.2 Practical Exploration

From the design practice through to practical exploration, two stages of practical experiments were conducted in Chapter 4: forming shapeable woven textiles in a) a single-layer and b) tubular construction, and a prototyping stage was then conducted in Chapter 5: prototyping shapeable seamless woven garments. The results of practical experiments were critically analysed with technical details of materials, weave designs, weave sett and fabric formations. The practical experiments have identified combinations of yarn properties and technical features that determine physical qualities (inherent stretchability from divers degrees of shrinkage), and aesthetic qualities (three-dimensional surface effects and textures) of shapeable woven textiles. Therefore, such advanced shapeable woven textiles have shown their potential of physical and aesthetic qualities for creating seamless woven garments. The data resulting from the two stages of experiments have provided a significant basis for the design of shapeable woven textiles, and this empirical data has contributed to create shapeable seamless woven garments. The detailed conclusion of each experiment is discussed in the following sections.

8.1.2.1 Forming Shapeable Woven Textiles

(1) Forming shapeable woven textiles in a single-layer

As stated in section 4.1.1, inherent elasticity and stretchability of fabrics were necessary design elements to enable seamlessness of woven garments. Thus, based on wool fibre, high twist yarns were utilised in order to make shapeable woven fabrics that were stretchable with degrees of shrinkage, instead of using synthetic fibres, such as Spandex, Lycra and elastane fibre. Therefore, the first practical experiment focused on using high twist wool yarn aimed at exploring various three-dimensional surface effects and textures of shapeable woven textiles resulting from various degrees of shrinkage.

The first experiment used the basic simple weave structures (namely a plain, 2/2 twill, 1/3 twill, 2/2 basket and 2/3 basket) and different types of wool yarn (a 2/30Nm merino wool, 1/30Nm high twist wool yarns in S twist and Z twist) to develop the three-dimensional, textural surface effects and examined the degree of shrinkage of the shapeable woven textiles.

The results of the first experiment and subsequent discussion demonstrated the effects of different types of material and weave designs with regard to surface effects of shapeable fabrics in a single-layer. The visual analysis resulting from the first experiment revealed that combinations of yarn properties, technical features of weave design and its formation of woven fabrics could determine the form of shapeable woven textiles that show the three-dimensional surface effects and textures along with inherent stretchability. As demonstrated in section 4.1.4.1, the experiment has found six distinctive characteristic patterns that were identified as having potential for use in creating shapeable woven fabrics.

As inherent elasticity and stretchability properties were necessary elements in order to create shapeable woven textiles for seamless garments, a total of 45 samples (sample type from A to I) from the first experiment were evaluated in order to assess to what extent they are successful in achieving the desired result of shrinkage. From the nine types of samples, the results revealed the fact that the use of different types of weave designs and yarns determined the degree of shrinkage in shapeable woven fabrics both lengthwise and

widthwise. Except for the sample type A (2/30Nm merino wool yarn used as both the warp and weft), the degree of shrinkage showed a range between the lowest shrinkage with 52% and the highest shrinkage with 80%. As indicated in section 4.1.4.2, the experiments resulted in significant data relating to the degree of shrinkage for each weave design and yarn type. The experiments explored the three-dimensional and textural surface effects along with the inherent stretchability resulting from the various degree of shrinkage.

Regarding shapeable woven fabrics consisting of different types of wool yarns used in the warp and weft, the impacts of four sets in the experiment were compared, and the degree of shrinkage of each combination of yarn and weave structure was analysed. In general, the lowest degree of shrinkage was expected from the plain weave due to the structure making a high number of intersections with fewer spaces. It was these spaces that allow high twist wool yarns to move. However, samples with the plain weave showed a higher shrinkage degree than twill weave. The overall data showed remarkable shrinkage in the horizontal direction when compared to the vertical direction, so it could be concluded that high twist wool yarn has a great impact on shrinkage when used as weft yarn.

(2) Forming shapeable woven textiles in tubular construction

The second experiment was conducted to explore how the shrinkage results of the first experiment could be applied to create various forms using tubular construction. Each sample was divided into three parts in order to examine how the degree of shrinkage may interact with each part that used different weft yarns (2/30Nm merino wool, 1/30Nm high twist wool yarns in S twist and Z twist) and weave structures (a plain, 2/2 twill, 1/3 twill, 2/2 basket weave), and how this interaction influences the surface effects and overall shapes of shapeable woven fabrics that may be obtained through the use of tubular weave construction.

In order to create shapeable tubular fabrics, four basic double-cloth weave structures were selected from the first experiment due to the fact that samples woven with 2/3 basket weave structure showed unrecognisable collapsed effects and textures as a result of a remarkably high degree of shrinkage. Therefore, four basic simple weave structures were

utilised (a plain, 2/2 twill, 1/3 twill and 2/2 basket weave). In this second experiment, tubular construction required double-cloth weave construction, which needs double the number of weave sett for the top and bottom layer. In accordance with the weave sett calculation as stated in section 4.1.2.1, 32epi, a weave sett was applied in all three sets of this tubular weaving trial.

The three sets of the experiment indicated that changes to the weave designs and variations in the weft yarn used in different areas of the samples all influenced the surface effects, textures and shapes of shapeable tubular fabrics to a certain extent. The result showed that surface effects and textures were influenced by the width of the applied area and the surrounding areas of the fabric, which have different combinations of yarns and weave structures. As stated in Section 4.2.4, a total of nine distinctive surface effects and textures were identified from the possible combination of warp and weft yarns with weave structures.

In general, there were similarities in surface effects and textures of fabric samples between the first and second experiments, however, the sample I showed less clear surface effects and textures, such as weakened and decreased ripples and pleats due to the slightly higher weave sett applied to the second experiment. Although sample I showed less clear effects, other shapeable tubular samples (II and III) had clearer tracking lines of patterns or bolder vertical pleats with combined horizontal wave and ripple patterns due to changes of type of yarns and weave structures.

The combinations of yarns and weave structures produced a number of distinctive shapeable tubular samples in diverse shapes with varying degrees of shrinkage. The samples of shapeable tubular weaving trials highlighted a significant point; that dynamic bubble shapes with bold pleats were obtained when merino wool yarn was applied to points between areas with high shrinkage. The volume and size of dynamic shapes with bold pleats effect was depending on the size and proportions of the areas with different shrinkage, surface effects and textures.

8.1.2.2 Prototyping Shapeable Seamless Woven Garments

Previously, diversity in yarn types with weave designs and their various configurations were investigated, and this prototyping phase focused on the creation of shapeable

seamless woven garments. As demonstrated in section 5.1.1.1, the creation procedure started with the design inspiration and intention that the garments should be seamless in construction and versatile in use. The form and construction of shapeable tubular woven textiles then integrated with fashion styles into rectangular geometric shapes due to predetermined weaving loom condition. Specified weave designs were carefully chosen for the configuration of shapeable woven textiles in order to apply in each prototype design.

This prototyping stage demonstrated the visually detailed processes, and it helped to understand the practical basis of the integrated design process of the research. Through the prototyping stage, four prototype designs using hand-weave process were created concentrating on the versatile ways to wear each design, and two prototype designs using Jacquard weave process were presented, altering the design with changes to the cutting. In spite of the loom restrictions (section 5.1.2), the prototype designs were accomplished in six diverse forms with functional aspects such as seamlessness, versatility, inherent elasticity and stretchability as well as three-dimensional surface effects and textures. Through the presentation of versatility in stylings (in section 5.1.1, 5.1.2), each prototype garment has managed to integrate a key design element into seamless woven garments that could be worn in many different ways. Each prototype garment demonstrated distinctive versatile stylings from 4 to 6 ways depending on its type of garment, such as a tubular top, a tube dress, a long sleeveless dress and a tubular jumper/jacket.

The integrated design process in Jacquard weave has also achieved seamlessness in woven textile designs from flat 2D fabrics to 3D forms, which could be applicable for fashion or other purposes. The Jacquard prototype designs presented two types of basic seamless woven garment using Bonas Electrical loom (section 5.1.2). These prototype garments illustrated their potential for customisation by cutting the Jacquard fabric in the way that users want to change the shape of the garment. The customisation and versatility functions of the Jacquard prototype designs could also enhance the user-engagement stage of the product lifecycle. The prototype designs could contribute to the physical and aesthetic expressions of shapeable woven textiles and their potential for fashion applications. The possibility of shapeable seamless woven garments for a wider spectrum of designs could also broaden the collaborative effects of textiles and fashion.

8.1.3 Evaluation and Reflection through Questionnaire and a Focus Group Discussion

In order to evaluate and reflect on the practical experiments and the prototype designs, questionnaire and a focus group discussion were conducted as an observation phase of the research. The aims of the questionnaire and focus group were: 1) understand how designs using the shapeable seamless weaving technique were perceived, 2) generate external evaluation of the physical and aesthetic qualities of the shapeable woven fabrics along with the prototype designs, 3) evaluate user experiences and responses regarding the versatility of the prototype garments and how the prototype designs contribute to sustainability and circular design, 4) identify and understand the limitations of the research and the challenges that would need to be overcome in order for the research to be implemented in the fashion industry, 5) develop potential design process for further research. Therefore, the questionnaire was conducted during the exhibition of the research outcomes at the Borders Textile Towerhouse in Hawick, and a total of 30 respondents responded to the questionnaire based upon a voluntary basis and self-completion. The focus group was then conducted for two hours, and the group was made up of two researchers in 3D printing fashion/textiles and woven textile design, one academic in woven textile design, one consultant in fashion/textile design and one undergraduate student in fashion marketing.

The focus group discussion emphasised a gap between seamless knitting and weaving due to the characteristics of woven fabric. However, it examined the potential of seamless weaving using both conventional looms and Jacquard technology in enabling an integrated design process that could result in greater versatility and longevity of garments. The data analysis indicated that respondents and participants from the questionnaire and a focus group mostly had positive responses regarding the design (physical and aesthetic quality) of shapeable seamless woven textiles and understanding of an overall concept of the design practice and the design of the prototype garments.

From a focus group discussion, it could be able to get participants' specific opinions about the details of the shapeable woven textiles. Most participants had positive perspectives on using wool fibre to create three-dimensional and textural surface effects resulting from diverse degrees of shrinkage that enable the fabrics to be elastic and stretchable. These affirmative responses revealed that combining the use of a various twist of wool yarns with the tubular weave structure to make shapeable seamless woven garments could be a

distinctive feature of the research. It was also suggested that using solid colours may increase the versatility of the garments, and the garments may need more colour variations in order to create a more complete collection. As well as the various size ranges and colours of the design need to be improved for the commercial viability, the findings suggested that the idea of adding holes to the garments should be a further exploration in order to increase versatility, and it may engender new design practice for the next stage of the research.

As stated in section 6.2.3, the data analysis indicated that increased environmental awareness might not influence their purchasing behaviour, even though people might have been made aware of sustainable issues and circular design within fashion and textiles due to the media coverage. The affordability of clothing could be the main consideration when people meet their first basic needs due to the products labelled as ‘sustainable’ are usually more expensive than the other products as discussed in 6.3.5.

However, despite the above result, most respondents and participants clearly understood the design considerations regarding sustainability in fashion and textiles and circular design. The findings showed that the prototype garments could fulfil the requirements of such considerations of sustainability and circular design in fashion and textiles in terms of choice of material, design (function), quality of the product and production. Thus the research could contribute sustainable fashion and textiles design and circular design by integrating such considerations into an alternative design solution. It is also suggested that it would be beneficial for the research to include an element of consciousness-raising making people more aware of the fact that the prototype garments successfully integrate multiple aspects of sustainable fashion and textiles and circular design, such as materials, products longevity and cyclability.

8.2 Final Reflection and Limitations of the Research

Limitations of the research were identified through discussing the practical explorations and evaluating and reflecting the research outcomes. First, the research, within limited time and resources, focused on the use of wool fibre to attain the key design elements of the integrated design process, such as inherent stretchability and elasticity, three-dimensional and textural surface effects and the need for circular design perspective. The related explorations have not been investigated on the other natural fibres such as linen

and silk that can also be used as high twist yarn enabling stretchability of fabrics or beneficial to sustainable fashion and textiles and circular design perspective due to their biodegradability. Accordingly, relevant potential applications using an extensive range of materials could provide more beneficial results.

Second, the shape of the prototype garments was limited due to the restrictions of the conventional weaving looms, such as an inflexible set of weft and warp condition and predetermined width of the loom. Additionally, the researcher's background, as a textile designer, should be taken into account because the design process of the research was from a textile design point of view and that a fashion design aspects to the research would add valuable insights. Further investigations that are collaborative interactions between fashion and textile designers with high-end weaving technology could impact favourably upon the dimensional variations of seamless woven garments the shapes and designs would then exceed what is presently possible.

Third, as stated in Chapter 6, the methods used for the evaluative and reflective phase of the research had limitations in terms of the design of the questionnaire and a focus group discussion. As the questionnaire was a self-completion and voluntary method, it had lower response rates that could lead to a greater risk of bias in the findings, although it achieved thirty valuable responses to make the findings valid. Correspondingly, the questionnaire was limited to asking additional information that related to salient points of interest from participants or visitors during the exhibition. The main limitation of the focus group discussion was the time element, in addition to the potential limitations that mentioned in section 6.3.3.

8.3 Contribution to Knowledge

The research has proven that seamless woven garments can be achieved based on shapeable woven textiles through informed material, weave structures and construction, and design selection. Seamless woven garments in four different styles were formed directly from the weaving loom and suggested possible ideas of wearing the garments in many different ways. The creative design solution proposed in this practice-based research focused on enabling versatile functionality of the garments through stretchability of shapeable woven fabrics and three-dimensional, textural surface effects by means of

the use of wool fibre. The contributions to knowledge of the research encompass not only the design process (from technical experiments to design prototype garments) but also the corresponding the design consideration regarding circular design perspective and sustainable fashion and textiles. The major contributions to knowledge raised by the research are as follows:

- The research realises the creation of seamless garments from shapeable woven textiles, which are directly cut from the loom, and contributes to the development and the creative aspect of woven textile design for seamless fashion using conventional weaving looms and the basic Jacquard weave.
- The research proposes a design process of creating seamless woven garments based on shapeable woven textiles by integrating key design considerations such as
 - shapeability with inherent stretchability, three-dimensional textures and surface effects (physical and aesthetic elements of the prototype designs),
 - versatility and material choice (functional elements of the prototype designs),
 - circular design perspectives for sustainable fashion and textiles (theoretical elements of the prototype design).

Techniques include:

- The use of wool fibre enables inherent stretchability along with three-dimensional, textural surface effects of shapeable woven textiles.
- The use of mono (wool) fibre also enhances products' biodegradability and recyclability that contributes circular design.
- The research results show that the versatility of shapeable seamless woven garments improves the user engagement phase of the product lifecycle by enabling users to wear garments in many different ways, thus enhancing product longevity, leading to more sustainable fashion and textiles.
- The proposed design process and outcomes provide the potential for improving seamlessness in woven textile designs and developing commercial aspect for fashion designs.

8.4 Future Direction of the Research

The recommendation and suggestion raised by the research outcomes lead to a future direction of the research. The improved design process and the relevant design elements

of the research can be developed further.

The range of both size and colour of shapeable seamless woven garments can be improved with further research. Thus, the garments with flexible and extended properties would fulfil the specific needs of the wearer and consequently enhance product lifecycle. Moreover, an extended investigation into physical and aesthetic qualities of diverse materials, such as unique tactile feel, performance and appearance resulting from diverse shrinkage would offer a various selection for the user preference; for instance, people who do not buy animal products can choose another option with non-animal fibre.

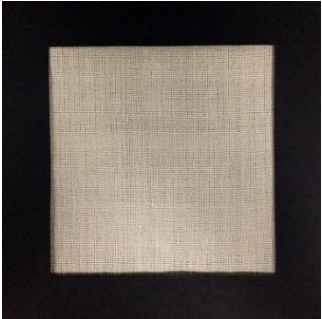

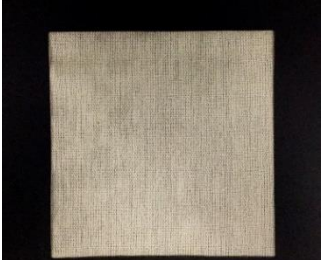

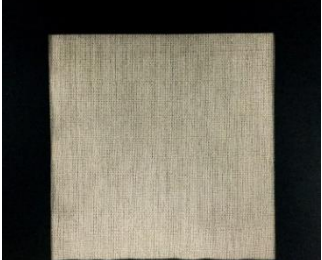

In order to further improve the versatility and range of functions of shapeable seamless woven garments, collaborative research projects between textile and fashion designers, together with weaving technicians would be beneficial in advancing the design practice and further the commercial application. Moreover, utilising highly up-to-date weaving technology would be worthwhile for the purpose of creating effective openings, detailed shapes and more intricate three-dimensional textures and forms of shapeable seamless woven garments as well as precise edges to fully eliminate 'cut and sew' method at the finishing processes.

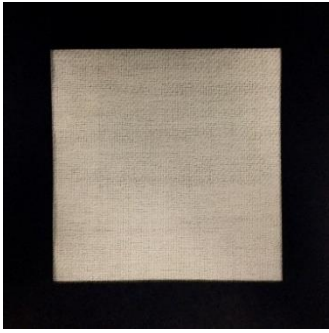
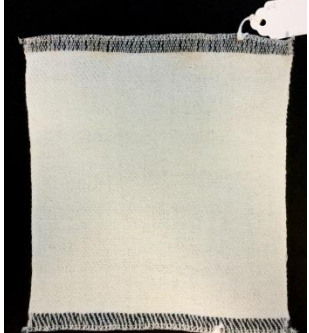
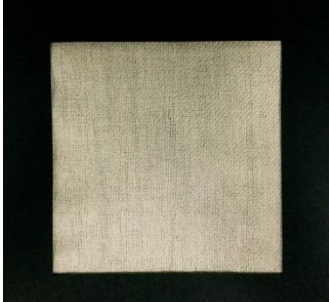

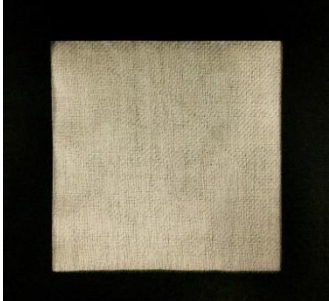

Appendix A: The data analysis of shapeable woven textiles in a single layer

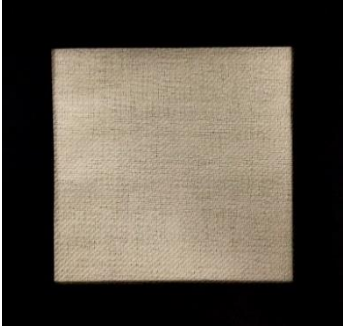
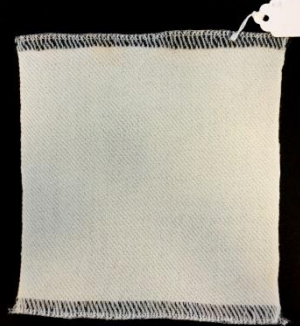
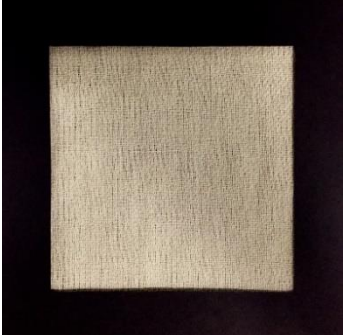



A datasheet of the first set of weaving trials in shapeable woven textiles in a single layer

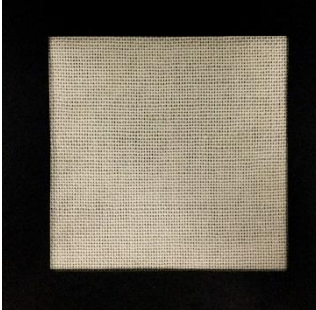

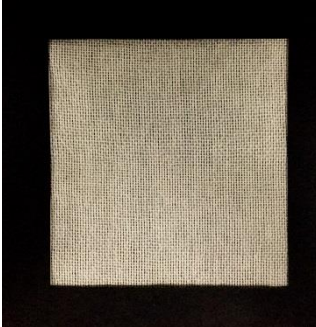

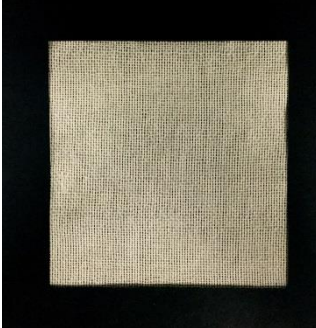

No.	Weave Structure	Warp Yarn	Weft Yarn	EPI	Width% / Length Off Loom In(cm)	Width% / Length After Finishing In(cm)	Shrinkage (%) W-Loss% / L-Loss% / Overall %
1 A	Plain	2/30Nm merino wool	2/30Nm merino wool	28	8.3×7.8 (21×19.8)	8.2×7.2(20.7×18.4)	1% / 7% / 8%
2 B			1/30Nm high twist wool Z	28	8.1×8.2 (20.5×20.8)	4×7.5(10.1×19)	51% / 9% / 55%
3 C			1/30Nm high twist wool S & Z	28	8.1×8.6 (20.5×21.8)	4.3×7.9(10.8×20)	47% / 8% / 52%
4 A	2/2 Twill		2/30Nm merino wool	28	7.9×8.1 (20×20.5)	7.6×8(19.2×19.3)	4% / 6% / 10%
5 B			1/30Nm high twist wool Z	28	7.9×7.8 (20×19.7)	4.6×7.5(11.8×19)	41% / 4% / 43%
6 C			1/30Nm high twist wool S & Z	28	7.9×7.9 (20×20)	4.7×7.5(12×19)	40% / 5% / 43%
7 A	1/3 Twill		2/30Nm merino wool	28	7.9×7.8 (20×19.8)	7.6×7.3(19.2×18.6)	4% / 6% / 10%
8 B			1/30Nm high twist wool Z	28	7.9×8 (20×20.4)	4.3×7.7(10.9×19.5)	45% / 4% / 48%
9 C			1/30Nm high twist wool S & Z	28	7.9×8.4 (20×21.3)	4.4×8(11.1×20.3)	45% / 5% / 47%
10 A	2/2 Basket		2/30Nm merino wool	28	7.9×8 (20×20.3)	7.4×7.6(18.9×19.2)	6% / 5% / 11%
11 B			1/30Nm high twist wool Z	28	7.9×8.1 (20×20.5)	3.7×7.6(9.3×19.4)	53% / 5% / 56%
12 C			1/30Nm high twist wool S & Z	28	7.9×7.9 (20×20)	3.9×7.5(9.8×19)	51% / 5% / 53%
13 A	2/3 Basket		2/30Nm merino wool	28	7.9×7.7 (20×19.5)	7.3×7.2(18.5×18.3)	6% / 6% / 12%
14 B			1/30Nm high twist wool Z	28	8.1×8.3 (20.5×21)	3.3×7.9(8.3×20.1)	60% / 4% / 61%
15 C			1/30Nm high twist wool S & Z	28	8×8.5 (20.3×21.5)	3.3×7.9(8.5×20.2)	58% / 6% / 61%

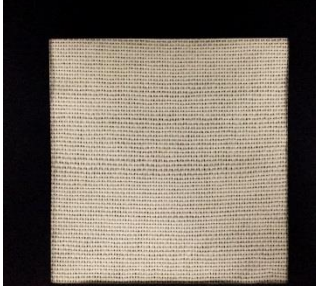

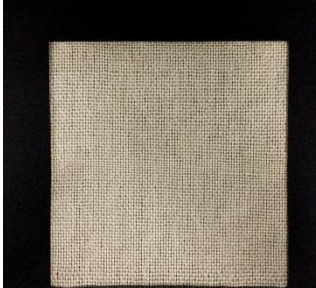

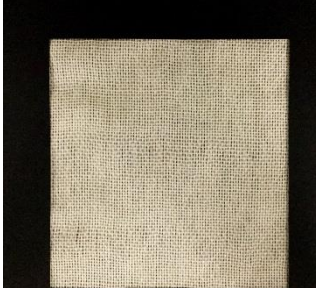

An analysis of shapeable woven samples from the first set of weaving trials

No.	Samples off the loom	Samples after the finishing	Comments
1 A			<p>Plain weave, overall 8% of shrinkage.</p> <p>This sample was a general woven cloth using 2/30Nm merino wool yarn in both the warp and weft.</p>
2 B			<p>Plain weave, overall 55% of shrinkage.</p> <p>This sample showed wavy pleats with rip pattern in the vertical direction resulting from the use of high twist wool in Z twist in the weft. The sample had a much higher degree of shrinkage in the horizontal direction than vertical. The use of 2/30Nm merino wool yarn (the warp) and 1/30Nm high twist wool in Z twist (the weft) showed regular wavy pleats in the vertical direction.</p>
3 C			<p>Plain weave, overall 52% of shrinkage.</p> <p>This sample showed pleats effect, but it slightly differed from sample #2. It showed vertical wavy patterns with horizontal lines that were situated at the points where the weft yarn changed from high twist wool yarn in S twist to Z twist. The sample showed pleats pattern all over the surface, but the areas using high twist wool in Z twist had more firm and fine wavy patterns with pleats effect.</p>

No.	Samples off the loom	Samples after the finishing	Comments
4 A			<p>2/2 Twill, overall 10% of shrinkage.</p> <p>This sample was a general woven cloth using 2/30Nm merino wool yarn in both the warp and weft.</p>
5 B			<p>2/2 Twill, overall 43% of shrinkage.</p> <p>1/30Nm high-twist wool yarn in Z twist was used for the weft. The sample showed pleat effects in the vertical direction with horizontal flattened areas that had no surface effects.</p>
6 C			<p>2/2 Twill, overall 43% of shrinkage.</p> <p>When compared to the sample #5, it showed more clear patterns with pleats and flattened areas using high twist wool yarn in S and Z twist in the weft. The areas intersected with merino wool (warp) and high twist wool yarn in S twist (weft) showed flattened surface, and the other areas intersected with merino wool (warp) and high twist wool yarn in Z twist (weft) showed clear vertical pleats.</p>

No.	Samples off the loom	Samples after the finishing	Comments
7 A			<p>1/3 Twill, overall 10% of shrinkage.</p> <p>This sample was a general woven cloth using 2/30Nm merino wool yarn in both warp and weft.</p>
8 B			<p>1/3 Twill, overall 48% of shrinkage.</p> <p>This sample showed a similar effect to the sample #5, however, flattened lines between vertical pleats were less clear than the sample #5. The sample showed indistinct vertical wavy pleat effects.</p>
9 C			<p>1/3 Twill, overall 47% of shrinkage,</p> <p>The overall effects were similar to the sample #6 (clear patterns with pleats and flattened areas using high twist wool yarn in S and Z twist in the weft). Due to the weave structure (1/3 twill) of the sample, it had 4% more shrinkage in overall than the sample #6.</p>

No.	Samples off the loom	Samples after the finishing	Comments
10 A			<p>Basket 2/2, overall 11% of shrinkage.</p> <p>This sample was a general woven cloth using 2/30Nm merino wool yarn in both warp and weft.</p>
11 B			<p>Basket 2/2, overall 56% of shrinkage.</p> <p>The sample had slightly different patterns that vertical pleats partially appeared, and flattened lines and wavy patterns were irregularly showed on the surface.</p>
12 C			<p>Basket 2/2, overall 53% of shrinkage.</p> <p>This sample also had horizontal lines that were situated at the points where the weft yarn changed from high twist wool yarn in S twist to Z twist. In the sample, wavy pleat and rib patterns in between horizontal lines slightly link to each other, and horizontal lines were not clearly appeared as the sample #6 and #9.</p>







No.	Samples off the loom	Samples after the finishing	Comments
13 A			<p>Basket 2/3, overall 12% of shrinkage.</p> <p>This sample was a general woven cloth using 2/30Nm merino wool yarn in both warp and weft.</p>
14 B			<p>Basket 2/3, overall 61% of shrinkage.</p> <p>The sample had similar effects to sample #2 but showed 6% more overall shrinkage. Although the same type of weft yarn (high twist wool in Z twist) used, the effects showed stronger and bolder pleats in the vertical direction due to the weave structure (2/ 3 Basket weave).</p>
15 C			<p>Basket 2/3, overall 61% of shrinkage.</p> <p>It generally showed a similar effect to the sample #14, however, the sample had clear horizontal lines for changing weft yarns from high twist wool yarn in S twist to Z twist.</p>







A datasheet of the second set of weaving trials in shapeable woven textiles in a single layer







No.	Weave Structure	Warp Yarn	Weft Yarn	EPI	Width% / Length Off Loom In(cm)	Width% / Length After Finishing In(cm)	Shrinkage (%) W-Loss% / L-Loss% / Overall %
16 D	Plain	1/30Nm high twist wool S	1/30Nm high twist wool S	32	8×8.9 (20.3×22.5)	5.3×4.8(13.4×12.3)	34% / 45% / 64%
17 E			1/30Nm high twist wool Z	32	8×8.3 (20.3×21)	2.5×5.6(6.5×14.2)	68% / 32% / 78%
18 F			M + H·T·S + H·T·Z	32	8×9.3 (20.3×23.5)	3.4×6.8(8.7×17.3)	57% / 26% / 68%
19 D	2/2 Twill		1/30Nm high twist wool S	32	8×8.3 (20.3×21)	3.4×6.5(13.1×16.4)	35% / 22% / 50%
20 E			1/30Nm high twist wool Z	32	8×8.5 (20.3×21.5)	2.5×7.3(6.4×18.6)	68% / 13% / 73%
21 F			M + H·T·S + H·T·Z	32	8×7.7 (20.3×19.5)	3.7×6(9.4×15.3)	54% / 22% / 64%
22 D	1/3 Twill		1/30Nm high twist wool S	32	8×8.5 (20.3×21.5)	4.5×6.2(11.5×15.8)	43% / 27% / 58%
23 E			1/30Nm high twist wool Z	32	8×8.1 (20.3×20.5)	2.7×5.6(6.8×14.1)	67% / 31% / 77%
24 F			M + H·T·S + H·T·Z	32	8×8.1 (20.3×20.5)	3.5×6(9×15.4)	56% / 25% / 67%
25 D	2/2 Basket		1/30Nm high twist wool S	32	8×8.1 (20.3×20.5)	3.2×7(8.2×17.8)	60% / 13% / 65%
26 E			1/30Nm high twist wool Z	32	8×7.9 (20.3×20)	2.4×5.6(6.1×14.2)	70% / 26% / 79%
27 F			M + H·T·S + H·T·Z	32	8×8.3 (20.3×21)	3×6.1(7.5×15.6)	63% / 32% / 75%
28 D	2/3 Basket		1/30Nm high twist wool S	32	8×7.7 (20.3×19.5)	3.2×6.6(8.1×16.8)	60% / 14% / 66%
29 E			1/30Nm high twist wool Z	32	8×7.9 (20.3×20)	2.3×5.4(5.9×13.8)	71% / 31% / 80%
30 F			M + H·T·S + H·T·Z	32	8×8.7 (20.3×22)	2.8×5.8(7.2×14.8)	65% / 33% / 76%







* M - 2/30Nm merino wool yarn, H·T·S - 1/30Nm high twist wool S, H·T·Z - 1/30Nm high twist wool Z

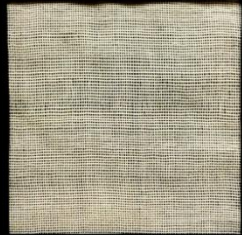

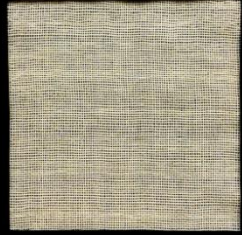

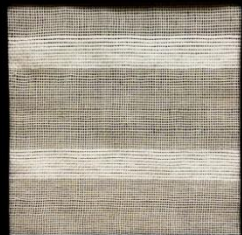

An analysis of shapeable woven samples from the second set of weaving trials

No.	Samples off the loom	Samples after the finishing	Comments
16 D			<p>Plain, overall 64% of shrinkage.</p> <p>For the effects of the samples from #16 to #30, a weave sett at 32epi was used that enabled yarns to have more space to move. In general, it showed an irregularly distorted pattern on the surface resulting from the use of high twist wool yarn in S twist for the warp and weft. The irregularly distorted pattern showed horizontal lines with crooked vertical lines.</p>
17 E			<p>Plain, overall 78% of shrinkage.</p> <p>When compared to the sample #2, this showed more dramatic effects and textures on the surface. It had strong vertical pleats forming in vertical curly wavy patterns along with an irregular horizontal wavy pattern.</p>
18 F			<p>Plain, overall 68% of shrinkage.</p> <p>The sample showed distinctive areas that were filled with different types of weft yarns on the surface. The areas using merino wool yarn had much less shrinkage, however, the areas showed curly pleats resulting from the high shrinkage degree of surrounding areas.</p>

No.	Samples off the loom	Samples after the finishing	Comments
19 D			<p>2/2 Twill, overall 50% of shrinkage.</p> <p>The sample also showed a similar distorted pattern to sample #6, but the pattern appeared on the surface in the opposite direction. In this case, more strong crooked horizontal lines were occurred.</p>
20 E			<p>2/2 Twill, overall 73% of shrinkage.</p> <p>The sample showed very fine vertical pleats forming in vertical wavy patterns with horizontal wavy lines.</p>
21 F			<p>2/2 Twill, overall 64% of shrinkage.</p> <p>The sample generally showed a similar effect to sample #18.</p>

No.	Samples off the loom	Samples after the finishing	Comments
22 D			<p>1/3 Twill, overall 58% of shrinkage.</p> <p>When compared to sample #16 and #19, this sample had a more regular pattern on the surface. It showed vertical pleats and wavy patterns in overall. Moreover, the sample showed horizontal wavy lines in between vertical pleats.</p>
23 E			<p>1/3 Twill, overall 77% of shrinkage.</p> <p>The sample showed a similar effect to sample #20, however, the sample had a more clear horizontal wavy pattern.</p>
24 F			<p>1/3 Twill, overall 67% of shrinkage.</p> <p>This sample has similar effects to sample #18 and #21.</p>

No.	Samples off the loom	Samples after the finishing	Comments
25 D			<p>Basket 2/2, overall 65% of shrinkage.</p> <p>The sample showed similar effects to sample #2 and #14. It showed strong vertical pleats and rib pattern on the surface.</p>
26 E			<p>Basket 2/2, overall 79% of shrinkage.</p> <p>The sample showed a similar effect to sample #20 and #23, however, the sample showed bolder curly wavy lines in the vertical direction and horizontal rib patterns on the surface.</p>
27 F			<p>Basket 2/2, overall 75% of shrinkage.</p> <p>This sample has similar effects to sample #18, #21 and #24.</p>







No.	Samples off the loom	Samples after the finishing	Comments
28 D			<p>Basket 2/3, overall 66% of shrinkage.</p> <p>Due to the weave structure (2/3 Basket) used in this sample, the sample showed stronger and bolder vertical pleats effect than sample #25. However, some patterns were distorted and collapsed as the structure enabled yarns to have more space to move although it had a similar shrinkage degree to sample #25.</p>
29 E			<p>Basket 2/3, overall 80% of shrinkage.</p> <p>When compared to the #26, this sample had bolder vertical wavy pleats and stronger horizontal rib pattern.</p>
30 F			<p>Basket 2/3, overall 76% of shrinkage.</p> <p>When compared to sample #24 and #27, it showed unrecognisable and collapsed effects and textures due to a high degree of shrinkage resulting from the use of 2/3 Basket weave structure.</p>







A datasheet of the third set of weaving trials in shapeable woven textiles in a single layer







No.	Weave Structure	Warp Yarn	Weft Yarn	EPI	Width% / Length Off Loom In(cm)	Width% / Length After Finishing In(cm)	Shrinkage (%) W-Loss% / L-Loss% / Overall %
31 G	Plain	1/30Nm high twist wool S & Z	1/30Nm high twist wool S & Z	32	8×9.3 (20.3×23.5)	3.6×5.2(9.1×13.1)	55% / 44% / 75%
32 H			M + H·T·S + H·T·Z	32	8×9.8 (20.3×25)	4.1×4.9(10.4×12.4)	49% / 50% / 75%
33 G	2/2 Twill		1/30Nm high twist wool S & Z	32	8×7.5 (20.3×19)	3.2×5.4(8.2×13.7)	60% / 28% / 71%
34 H			M + H·T·S + H·T·Z	32	8×9.4 (20.3×24)	3.3×6.5(8.4×16.6)	59% / 31% / 71%
35 G	1/3 Twill		1/30Nm high twist wool S & Z	32	8×8.2 (20.3×20.8)	3.1×5.6(8×14.2)	61% / 32% / 73%
36 H			M + H·T·S + H·T·Z	32	8×8.7 (20.3×22)	3.5×5.8(8.8×14.8)	57% / 33% / 71%
37 G	2/2 Basket		1/30Nm high twist wool S & Z	32	8×7.9 (20.3×20)	2.9×6(7.3×15.2)	64% / 24% / 73%
38 H			M + H·T·S + H·T·Z	32	8×8.9 (20.3×22.5)	3×6.2(7.6×15.8)	63% / 30% / 74%
39 G	2/3 Basket		1/30Nm high twist wool S & Z	32	8×8.7 (20.3×22)	2.7×6.2(7×15.8)	66% / 28% / 75%
40 H			M + H·T·S + H·T·Z	32	8×9.3 (20.3×23.5)	3.2×5.7(8.1×14.5)	60% / 38% / 75%



* M - 2/30Nm merino wool yarn, H·T·S - 1/30Nm high twist wool S, H·T·Z - 1/30Nm high twist wool Z

An analysis of shapeable woven samples from the third set of weaving trials

No.	Samples off the loom	Samples after the finishing	Comments
31 G			<p>Plain, overall 75% of shrinkage.</p> <p>The sample generally showed protruding square shapes when using high twist wool yarn in S twist for both the warp and weft. The areas that high twist wool yarn in Z twist was used for the warp and weft showed less distorted surface effects than the areas that high twist wool yarn in S twist was used for the warp and weft. The areas that high twist wool yarn in S twist used for the warp and Z twist for the weft showed vertical curly wave pattern.</p>
32 H			<p>Plain, overall 75% of shrinkage.</p> <p>It generally had a similar effect to sample #31.</p> <p>The area that high twist wool yarn in S twist used for the warp and merino wool yarn used for the weft showed an unclear horizontal wavy effect on the surface. The area that high twist wool yarn in Z twist used for the warp and high twist wool yarn in S twist used for the weft showed strong horizontal curly wave pattern.</p>
33 G			<p>Twill2/2, overall 71% of shrinkage.</p> <p>When compare to sample #31, the sample showed a horizontal rib pattern and pleats effect. The area that high twist wool yarn in S twist used for both the warp and weft showed distorted effects and protruding square shapes.</p>

No.	Samples off the loom	Samples after the finishing	Comments
34 H			<p>2/2 Twill, overall 71% of shrinkage.</p> <p>The sample showed similar effects to sample #32</p>
35 G			<p>1/3 Twill, overall 73% of shrinkage.</p> <p>When compared to sample #33, it showed a stronger vertical curly wave pattern due to the weave structure.</p>
36 H			<p>1/3 Twill, overall 71% of shrinkage.</p> <p>It generally had a similar effect to sample #34.</p>



No.	Samples off the loom	Samples after the finishing	Comments
37 G			<p>2/2 Basket, overall 73% of shrinkage.</p> <p>The surface effects and textures were similar to sample #33 and #35, however, it showed irregular vertical rib pattern and wave effect on the surface.</p>
38 H			<p>2/2 Basket, overall 74% of shrinkage.</p> <p>In general, the effects on the surface were similar to sample #32 and #34, however, irregular patterns were occurred in this sample due to the weave structure.</p>
39 G			<p>2/3 Basket, overall 75% of shrinkage.</p> <p>When compared to sample #37, this sample showed stronger curly wave pattern resulting in having an irregular pattern on the surface.</p>







No.	Samples off the loom	Samples after the finishing	Comments
40 H			<p>2/3 Basket, overall 75% of shrinkage.</p> <p>This sample showed both vertical and horizontal curly wave patterns, however, the patterns showed uncontrollable textures due to the weave structure that allowed yarns to have much more space to move than other weave structures.</p>

A datasheet of the fourth set of weaving trials in shapeable woven textiles in a single layer

No.	Weave Structure	Warp Yarn	Weft Yarn	EPI	Width% / Length Off Loom In(cm)	Width% / Length After Finishing In(cm)	Shrinkage (%) W-Loss% / L-Loss% / Overall %
41 I	Plain	2/30Nm merino wool	2/30Nm merino wool	16 / 32	9×9.4 (22.9×24)	4.1×6.7(10.4×17.1)	55% / 29% / 68%
42 I	2/2 Twill	+	+	16 / 32	9×9.6 (22.9×24.5)	3.7×8(9.4×20.3)	59% / 17% / 66%
43 I	1/3 Twill	1/30Nm high twist wool S	1/30Nm high twist wool S	16 / 32	9×9.3 (22.9×24.5)	3.7×7.8(9.4×19.8)	59% / 19% / 67%
44 I	2/2 Basket	+	+	16 / 32	9×9.4 (22.9×24)	3.6×7.7(9.2×19.5)	60% / 19% / 67%
45 I	2/3 Basket	1/30Nm high twist wool Z	1/30Nm high twist wool Z	16 / 32	9×9.6 (22.9×24.5)	4×6.9(10.3×17.5)	55% / 29% / 68%

177 **An analysis of shapeable woven samples from the fourth set of weaving trials**

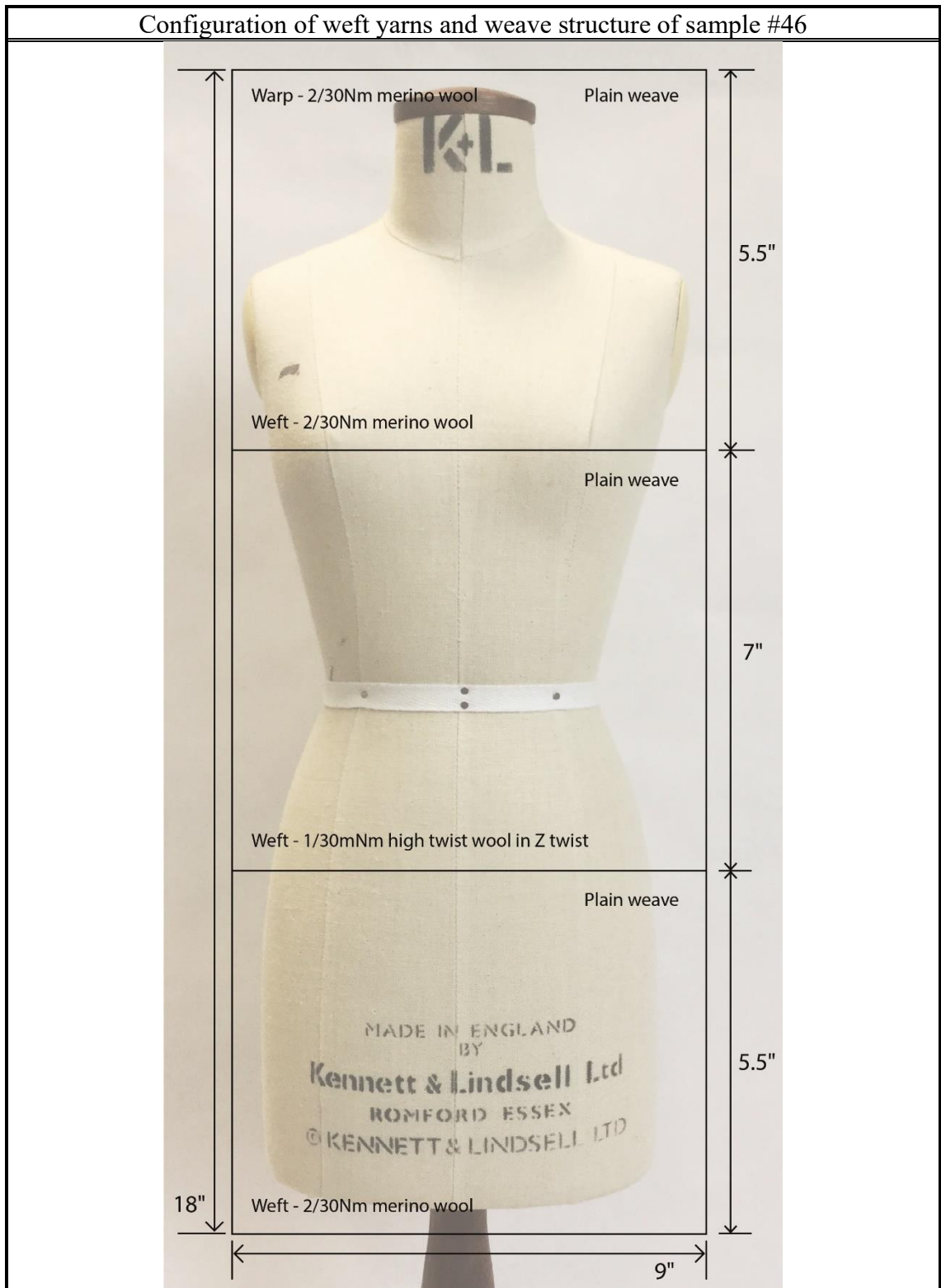
No.	Samples off the loom	Samples after the finishing	Comments
41 I			<p>Plain, overall 68% of shrinkage.</p> <p>In this set of weaving trials, samples showed all the distinct effect from each combination of the warp and weft.</p> <p>In general, samples showed similar surface effects and textures to the others, however, sample #42 showed stronger effects than sample #41 due to the weave structure. It could be seen that when using weave structures that enable yarns to move more, the surface effects and textures became unclear and uncontrollable</p>

42 I			<p>Each combination of the warp and weft created its own distinctive pattern on the surface.</p> <p>M warp + H·T·S weft – irregular vertical curly wave pattern</p> <p>M warp + H·T·Z weft – vertical pleats with a ripple pattern</p> <p>H·T·S warp + H·T·S weft – irregular distorted pattern in the horizontal direction</p> <p>H·T·S warp + H·T·Z weft – fine curly pleats in the vertical direction</p>
43 I			<p>H·T·S warp + H·T·Z weft – fine curly pleats in the vertical direction with a horizontal coarse wave pattern</p> <p>H·T·Z warp + H·T·S weft – irregular distorted pattern in the vertical direction</p> <p>H·T·Z warp + H·T·S weft – distorted pattern in the vertical direction</p>
44 I			

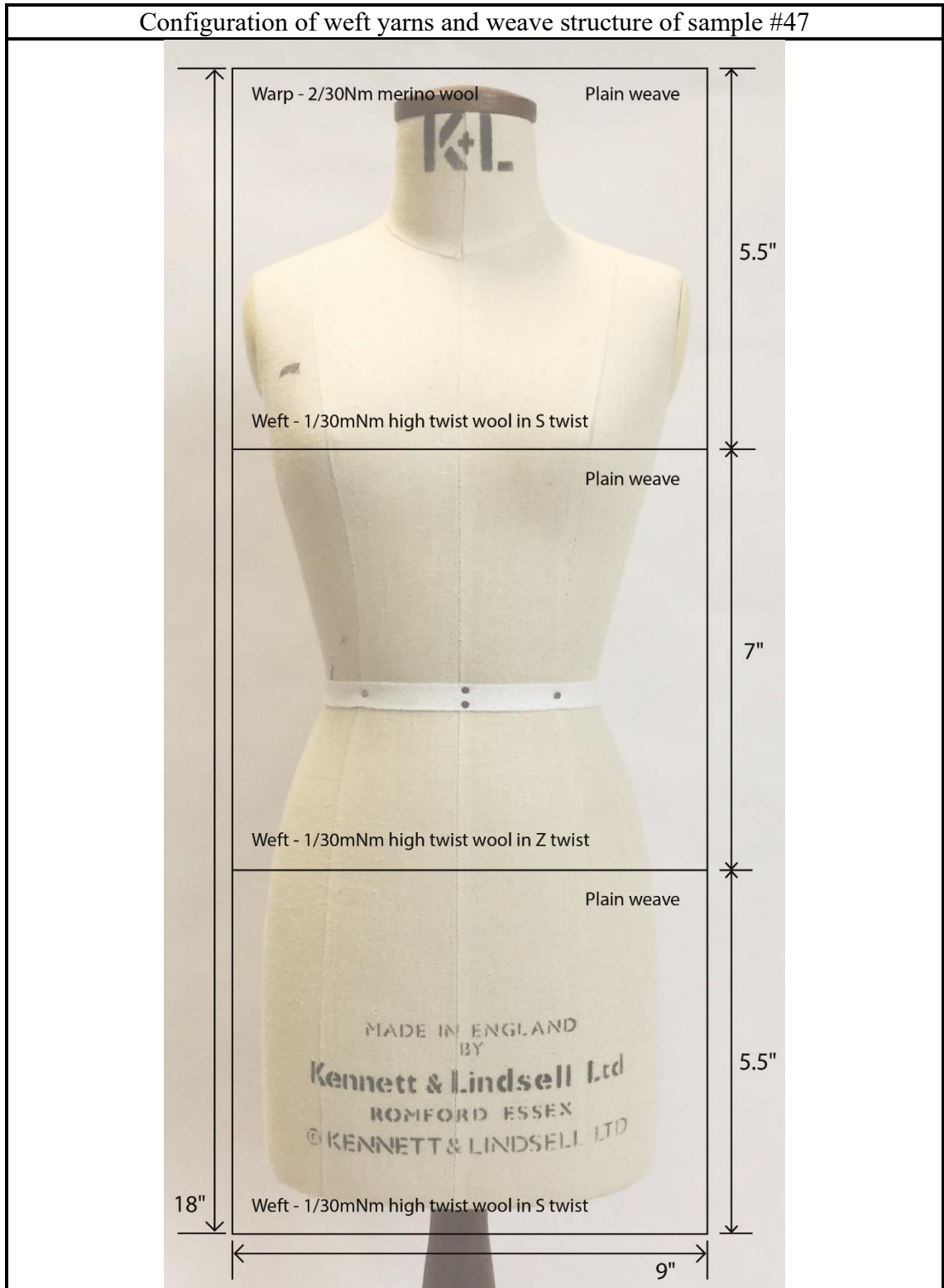
45 I



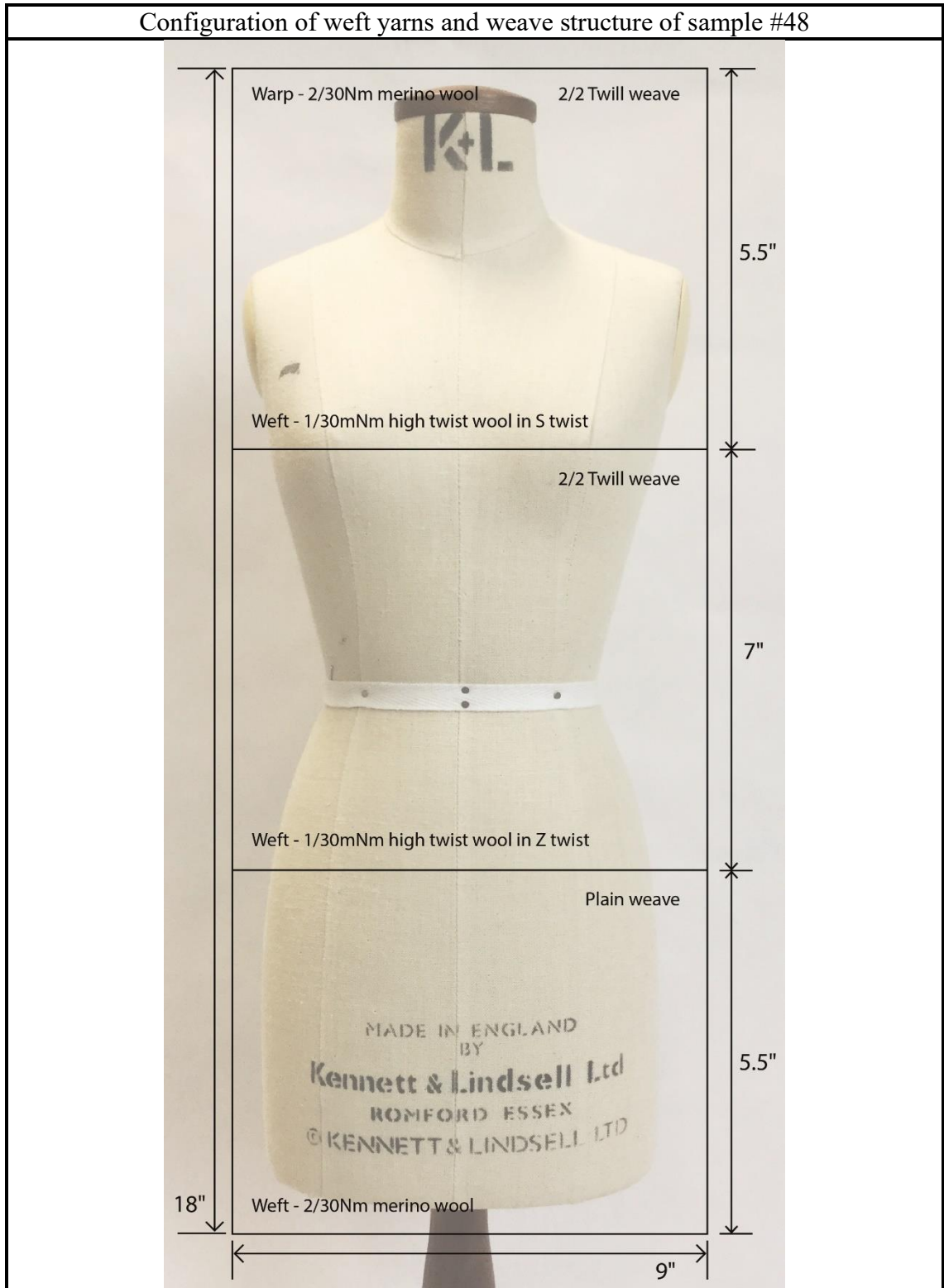
Appendix B: Configuration and variations of weft yarns and weave structures of shapeable woven textiles in tubular construction



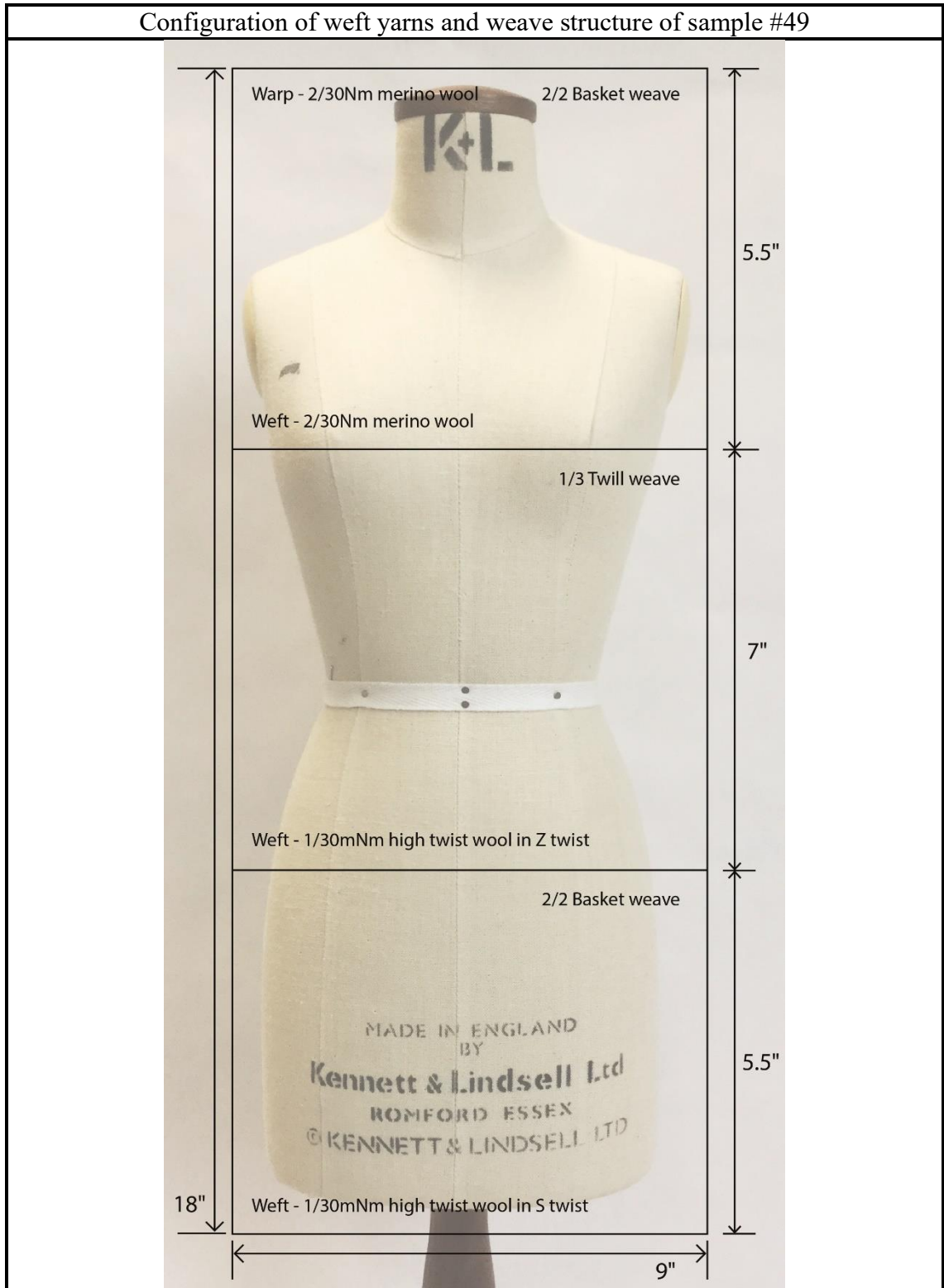
Configuration of weft yarns and weave structure of sample #47



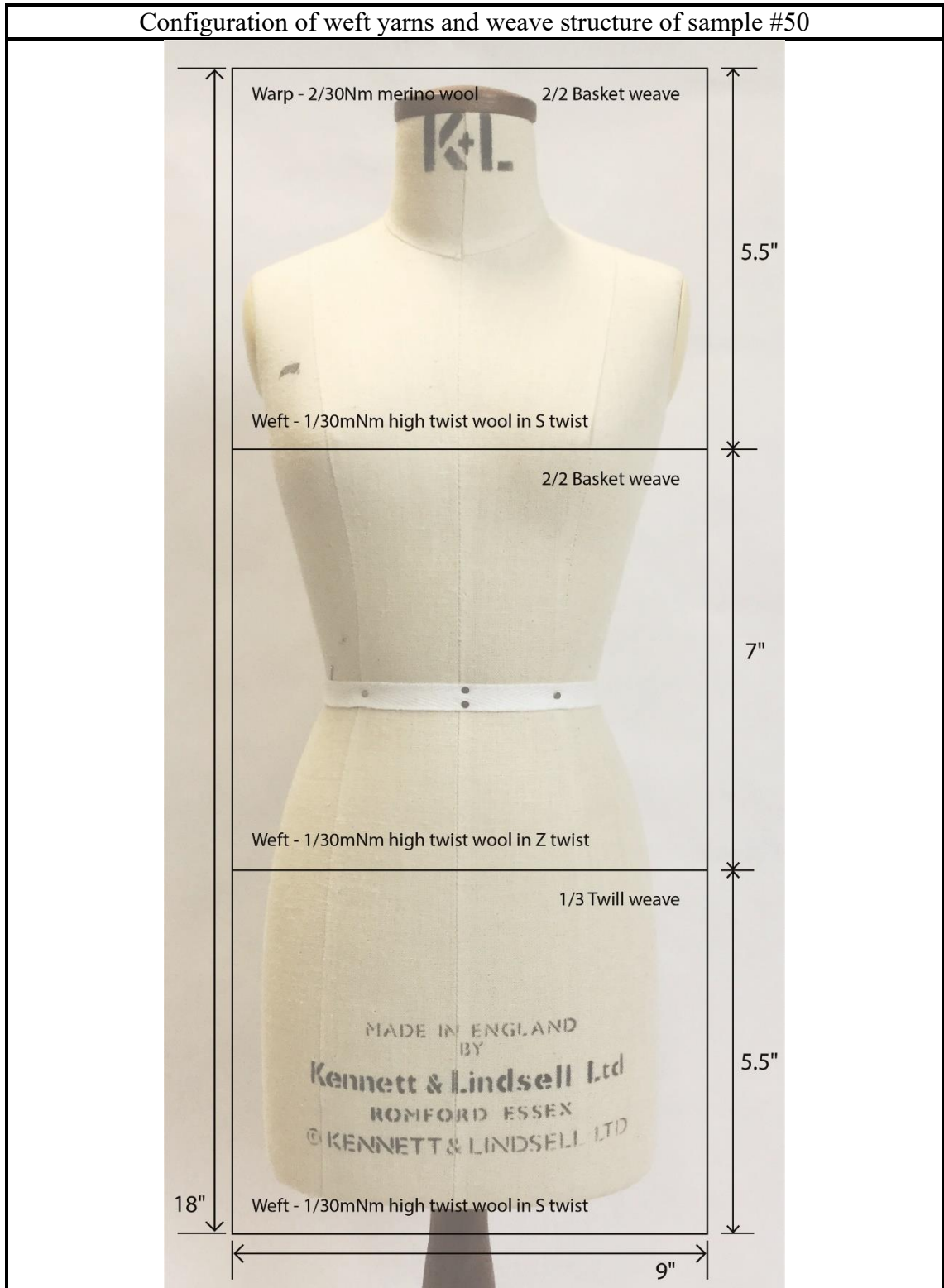
Configuration of weft yarns and weave structure of sample #48



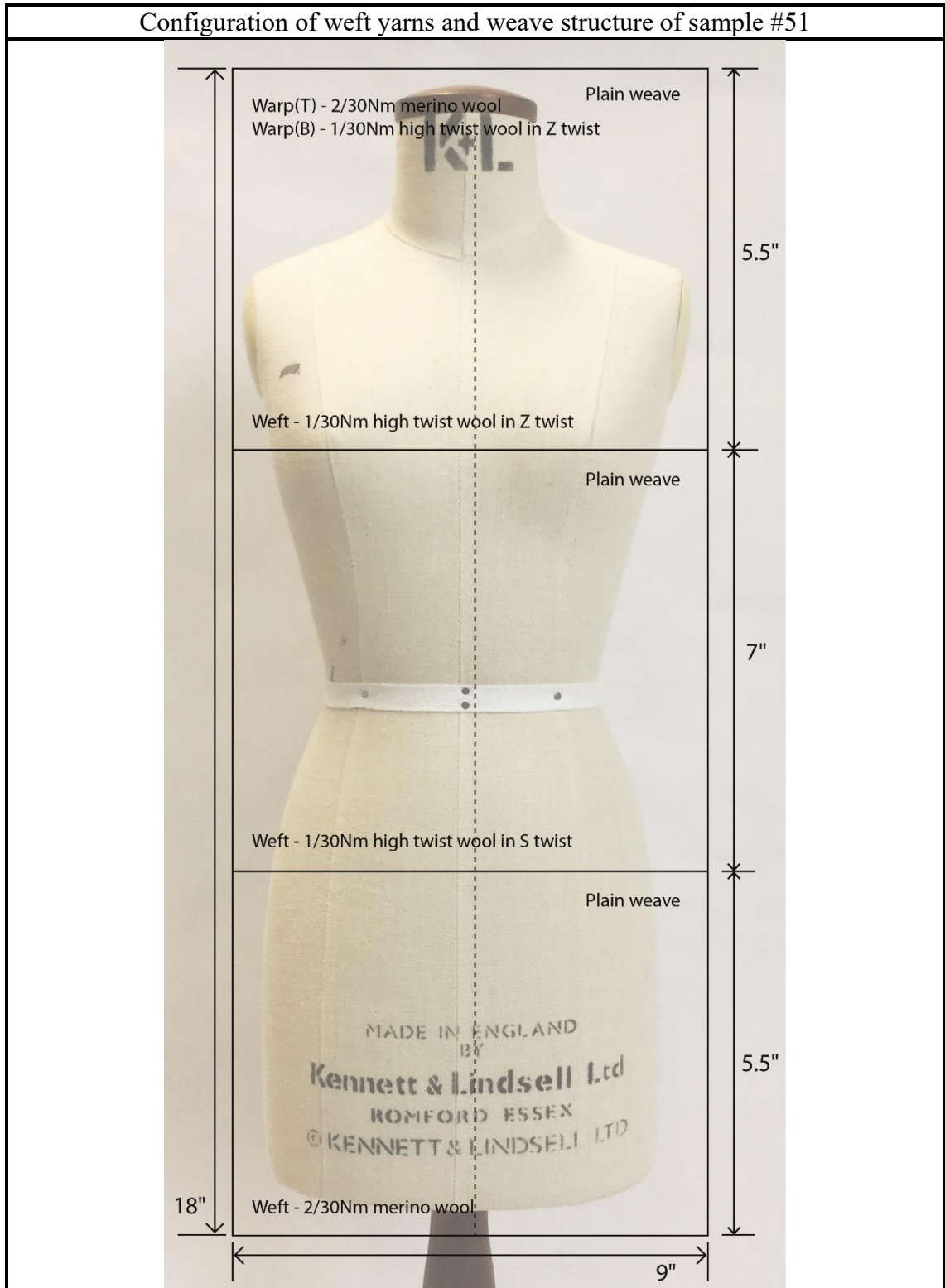
Configuration of weft yarns and weave structure of sample #49



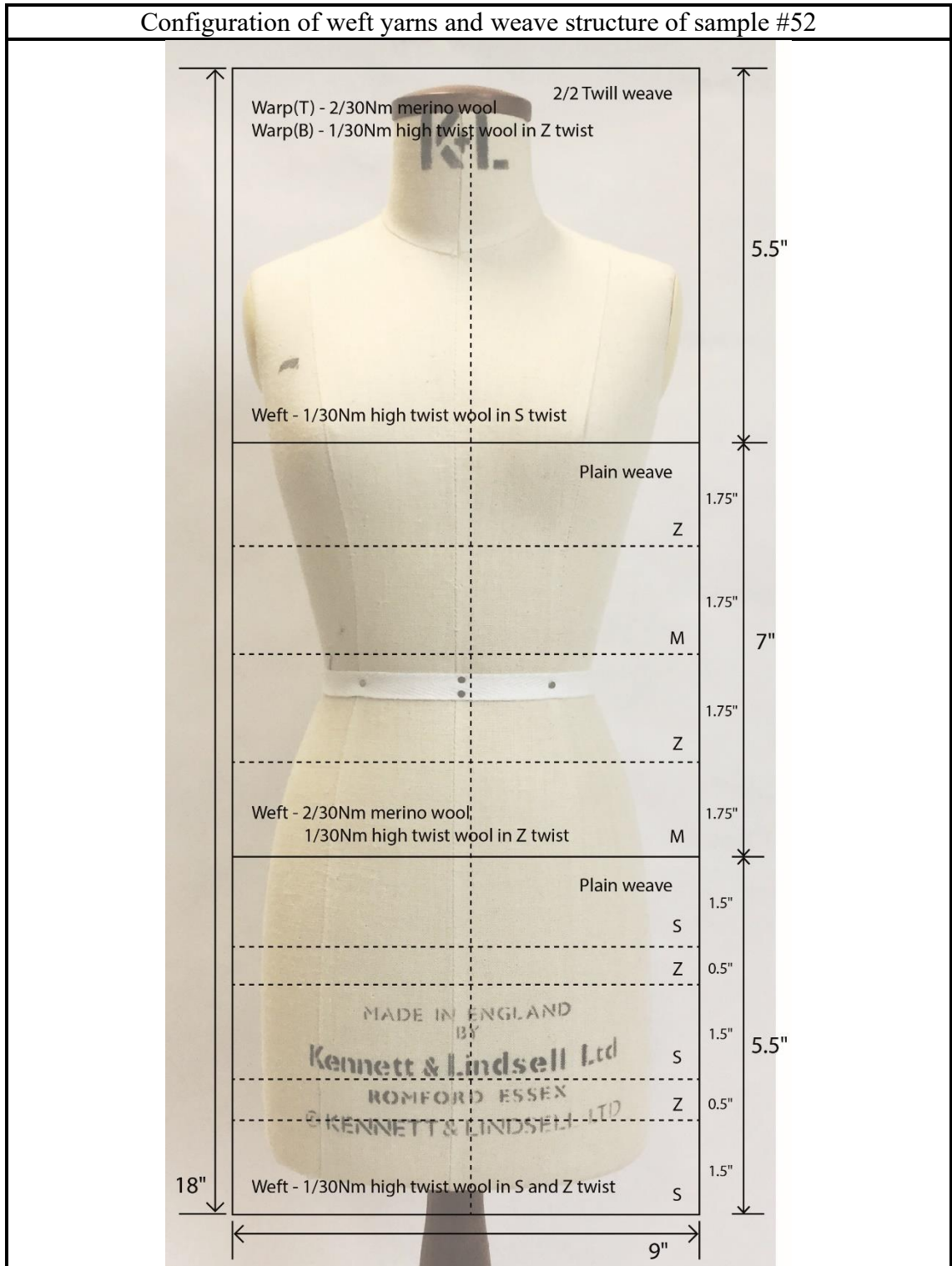
Configuration of weft yarns and weave structure of sample #50



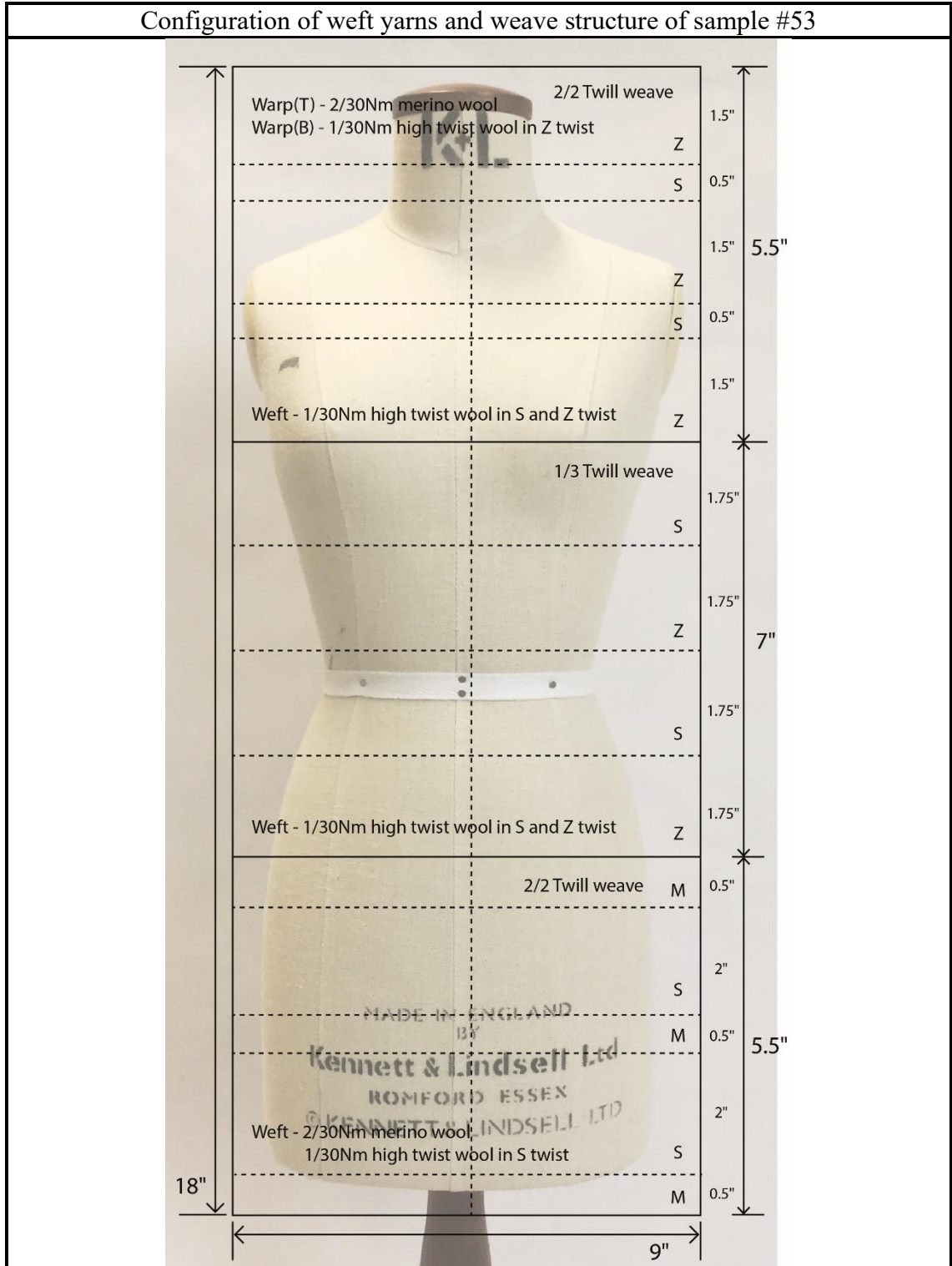
Configuration of weft yarns and weave structure of sample #51



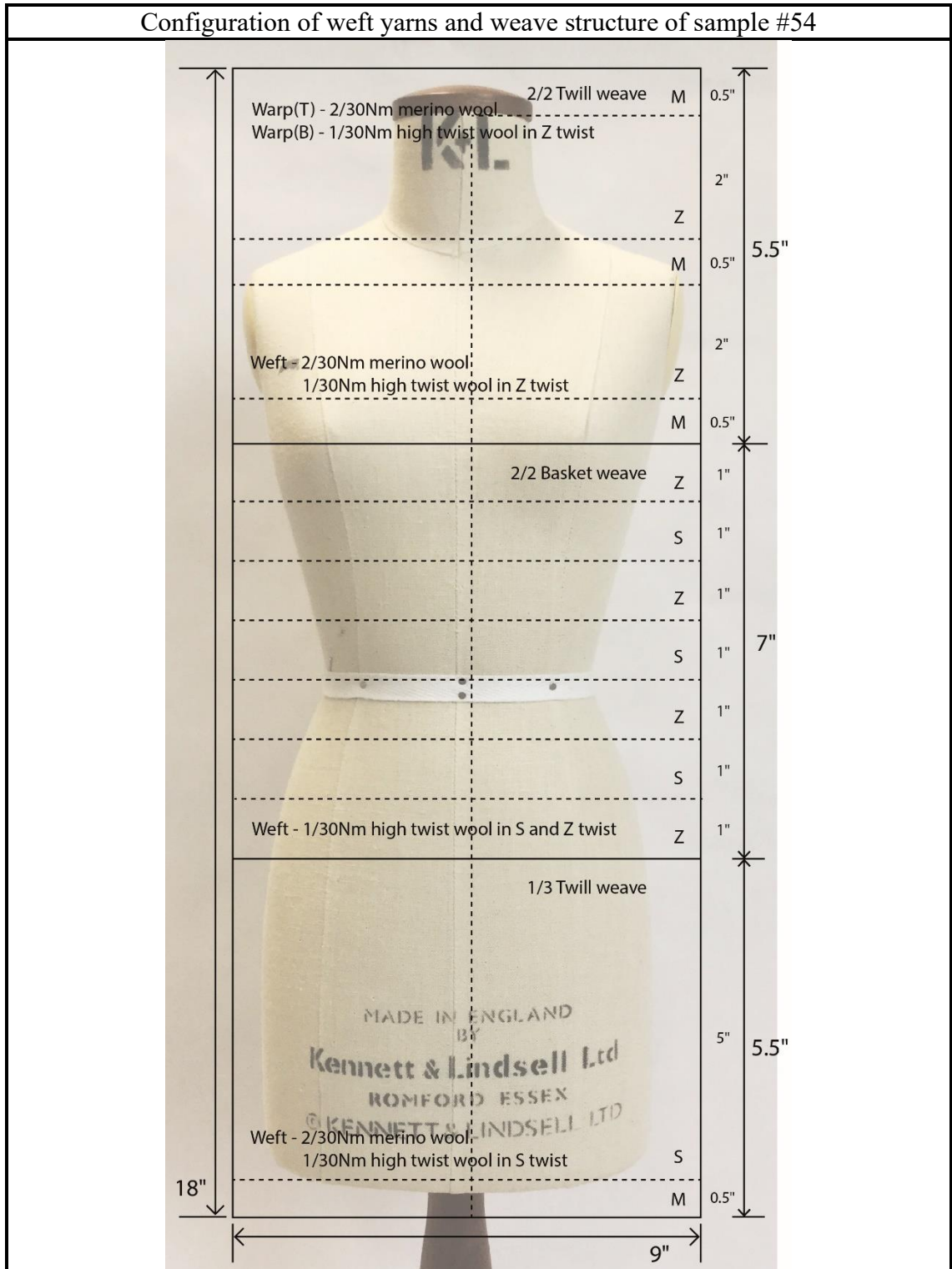
Configuration of weft yarns and weave structure of sample #52



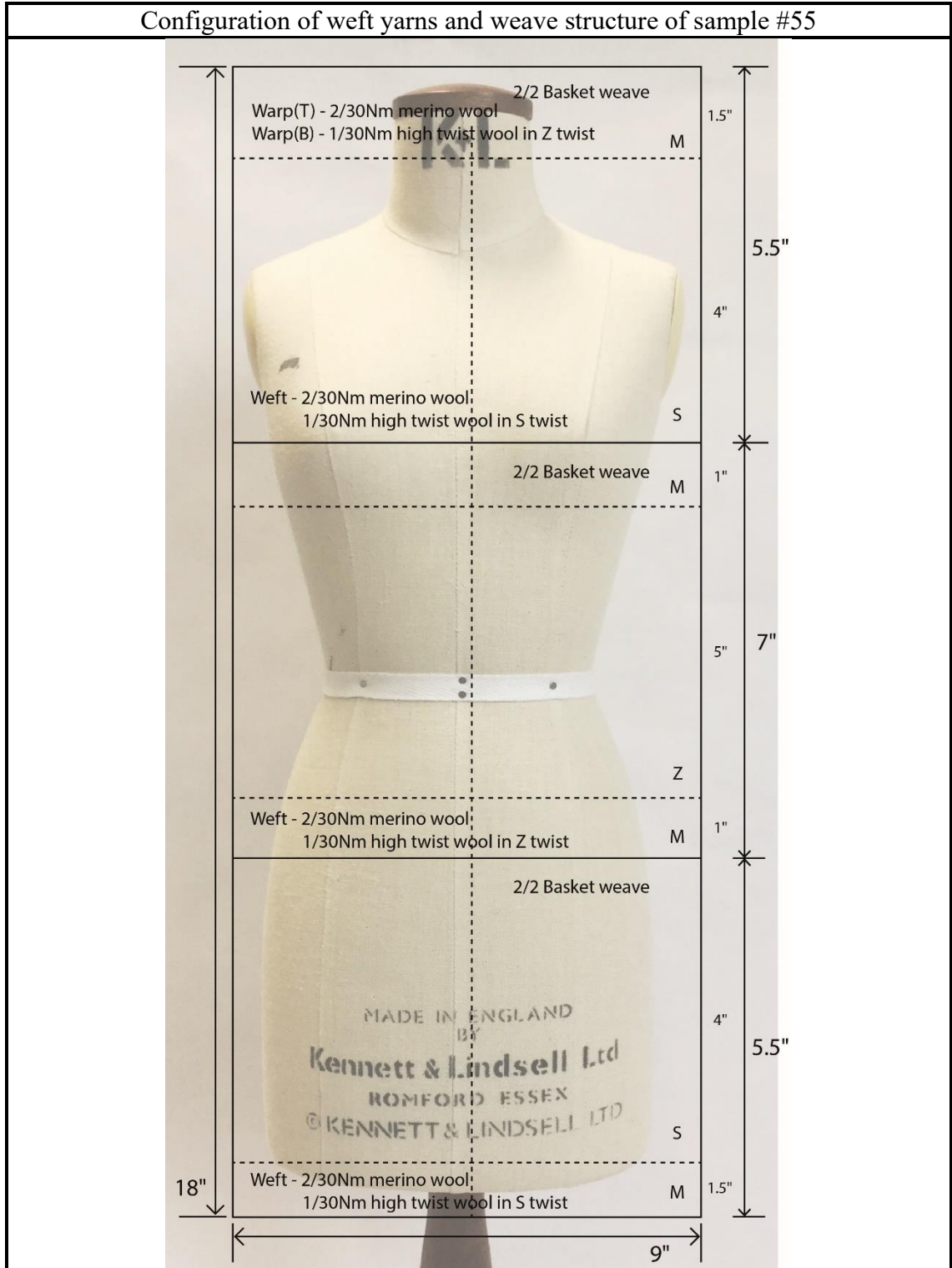
Configuration of weft yarns and weave structure of sample #53



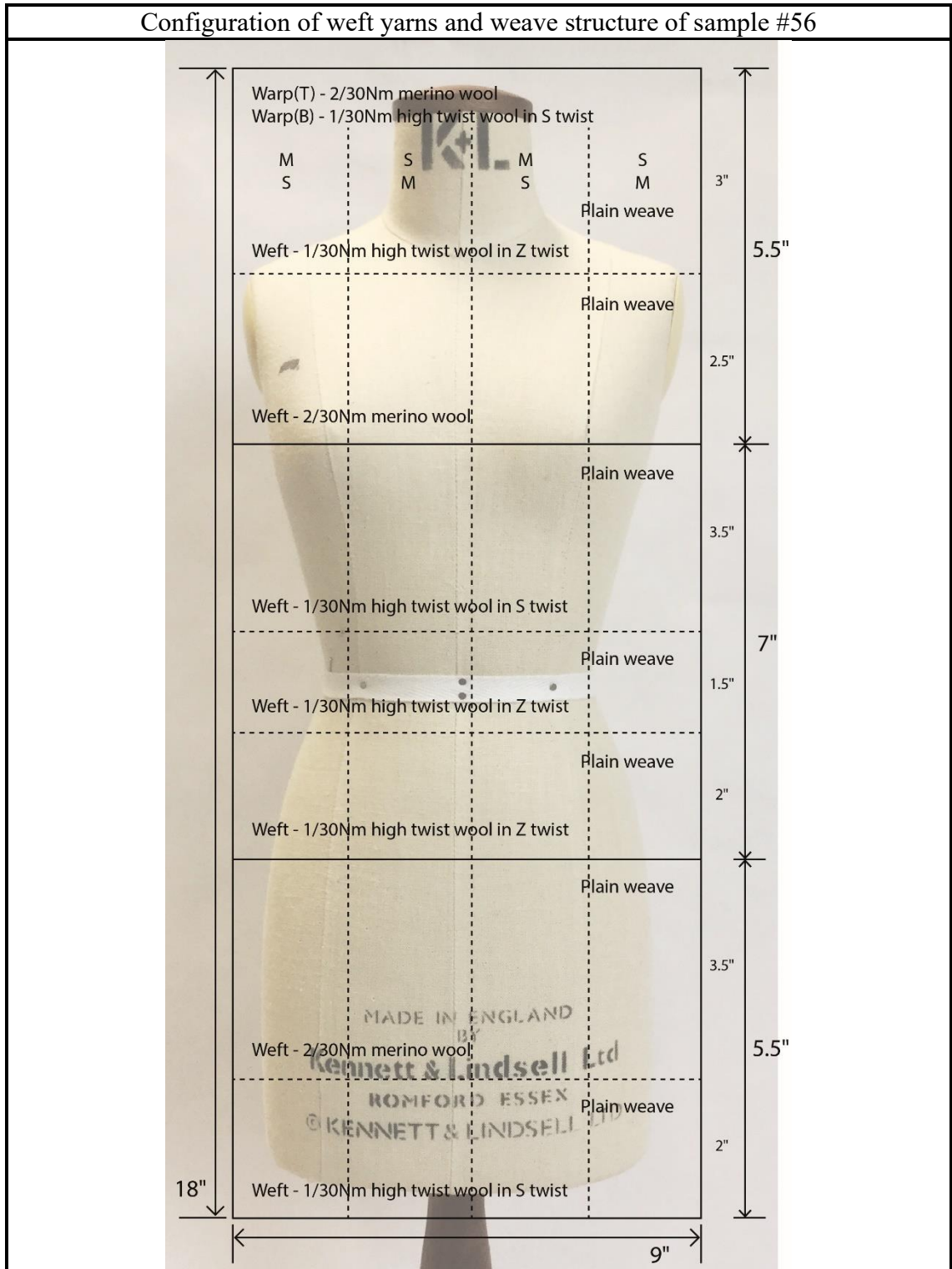
Configuration of weft yarns and weave structure of sample #54



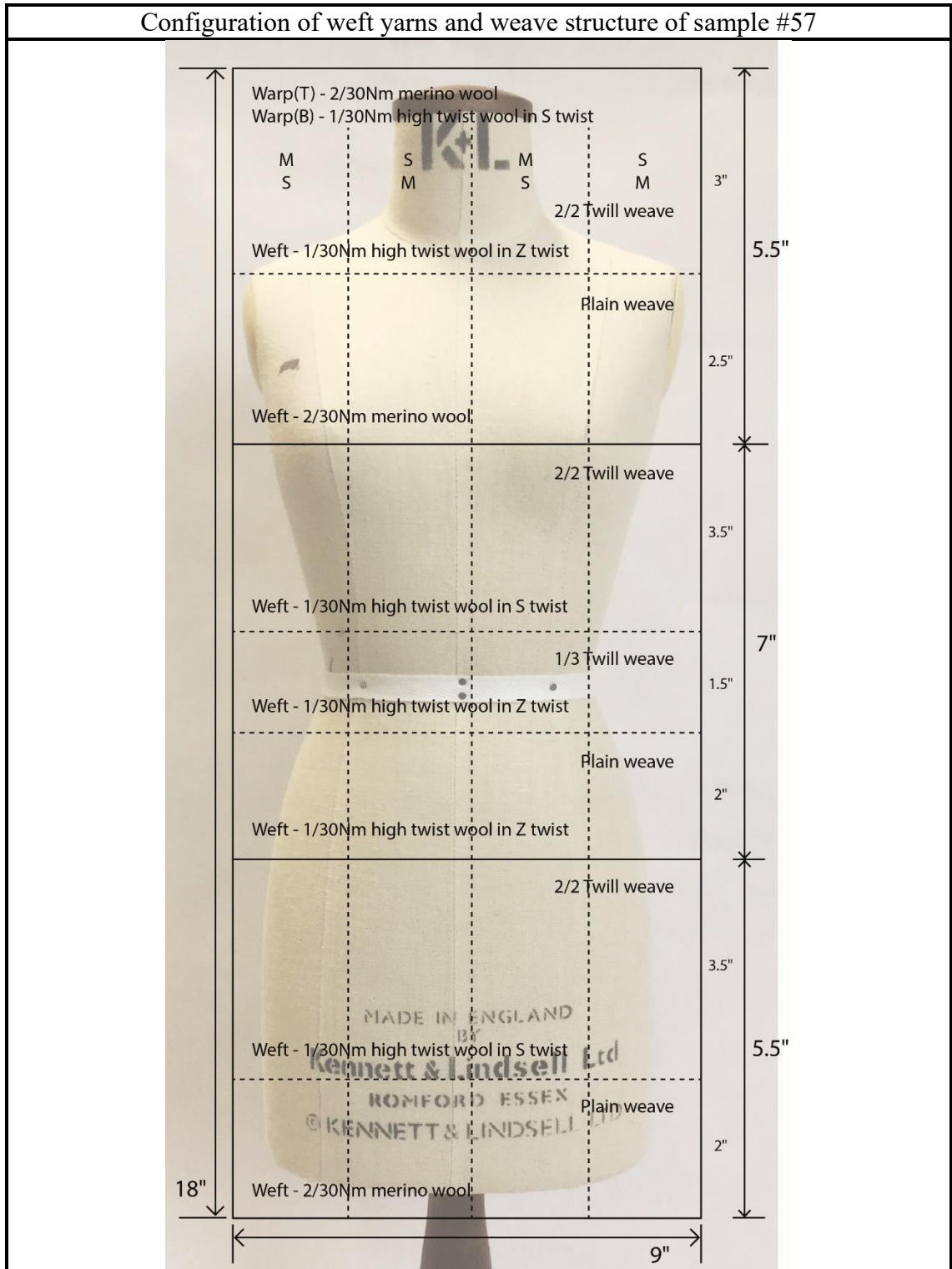
Configuration of weft yarns and weave structure of sample #55



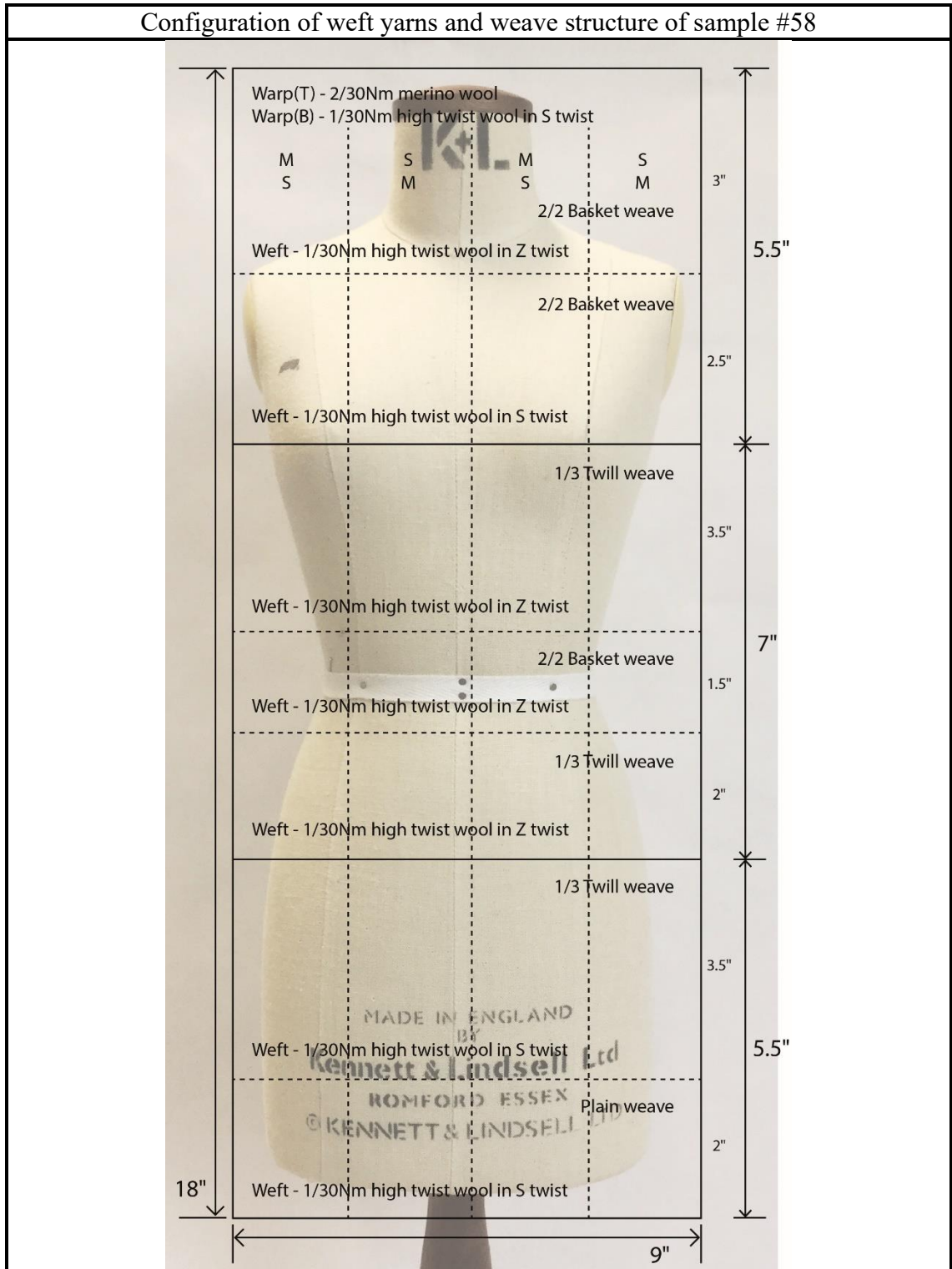
Configuration of weft yarns and weave structure of sample #56



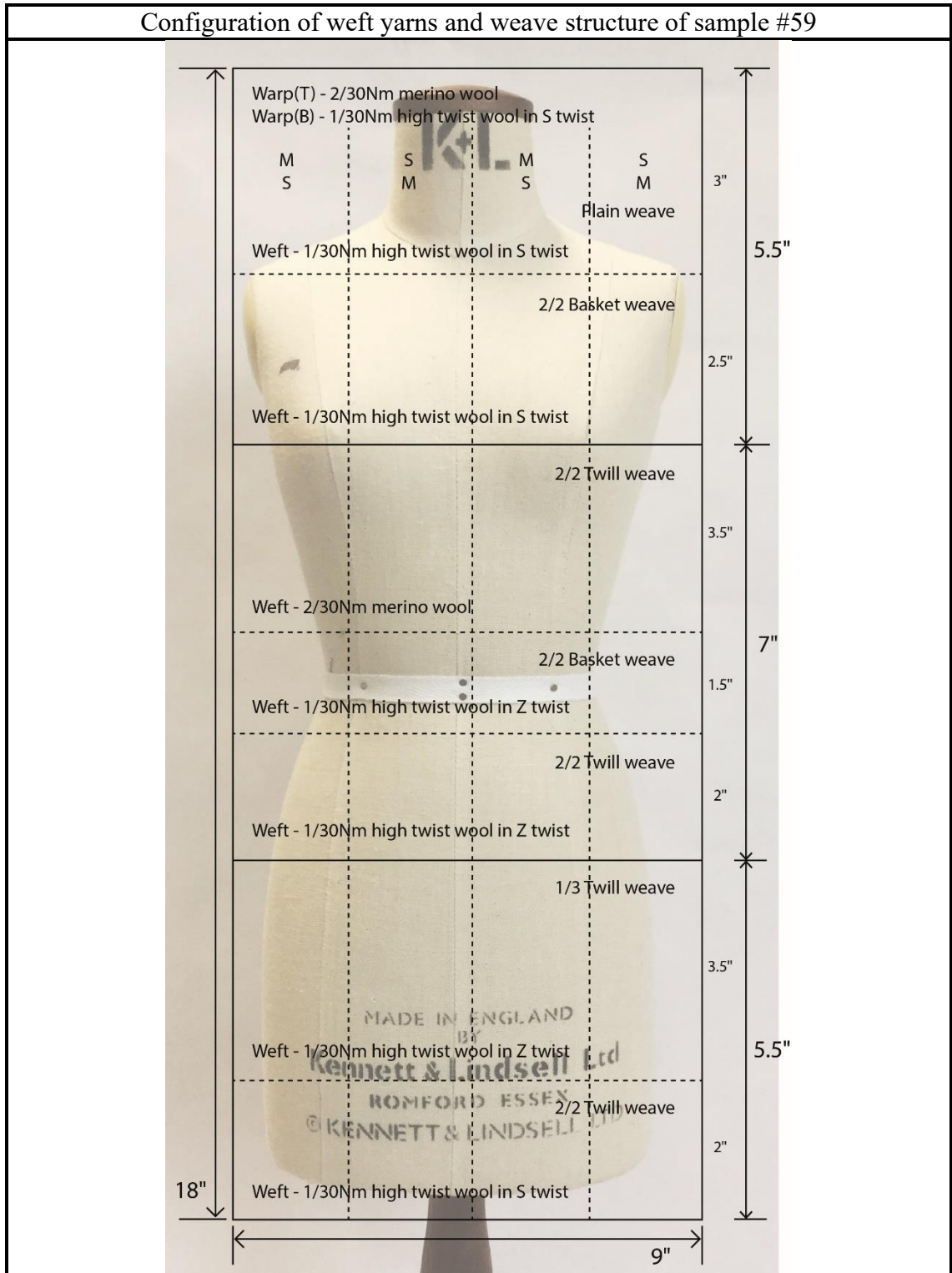
Configuration of weft yarns and weave structure of sample #57



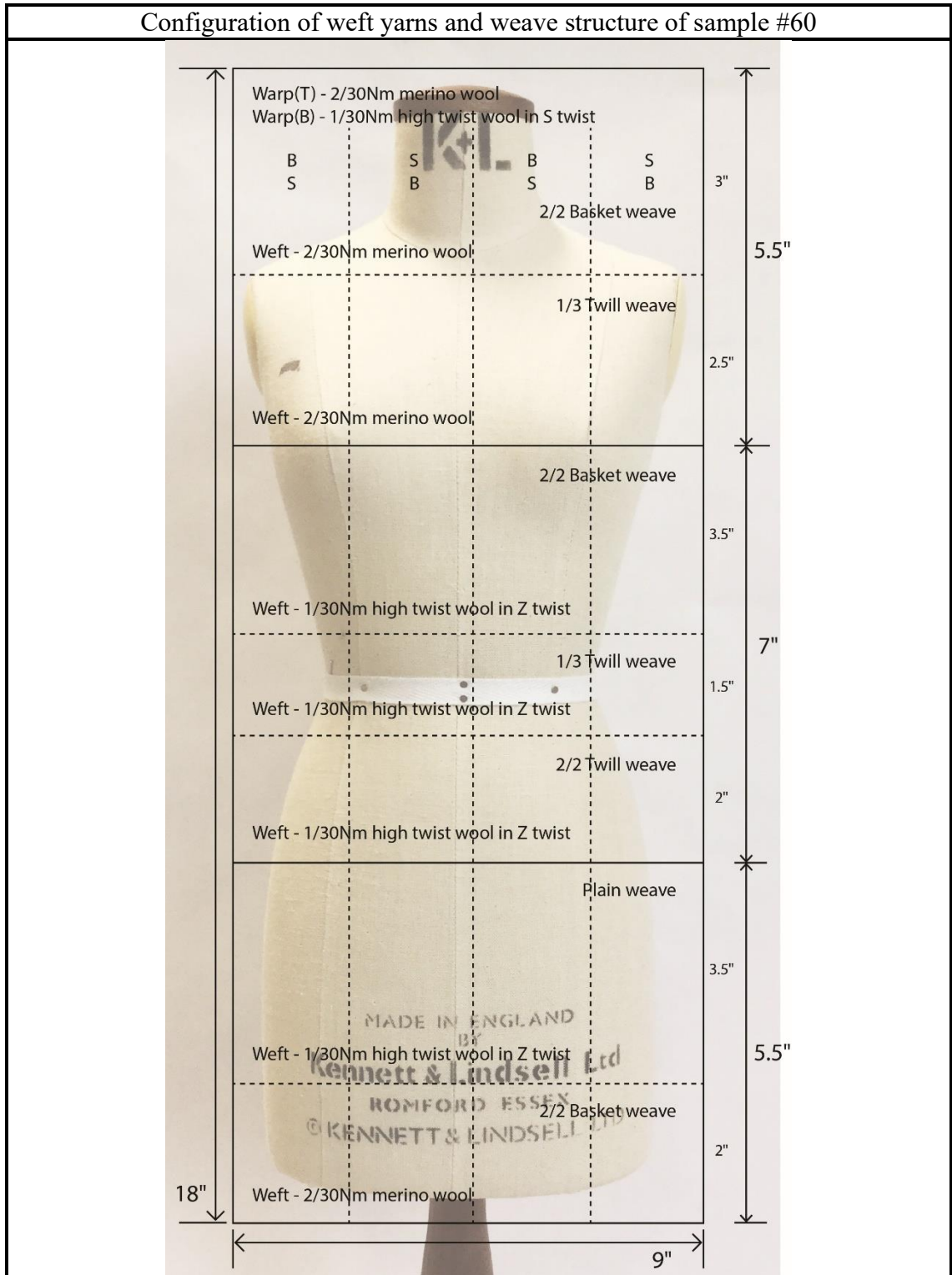
Configuration of weft yarns and weave structure of sample #58



Configuration of weft yarns and weave structure of sample #59



Configuration of weft yarns and weave structure of sample #60



















Appendix C: The data analysis of shapeable woven textiles in tubular construction





A datasheet of the first set of weaving trials in shapeable woven textiles in tubular construction

No.	Weave Structure	Warp Yarn	Weft Yarn	EPI	Width/Length Off Loom In(cm)		Width/Length After Finishing In(cm)		Shrinkage (%) W-Loss/L-Loss/Overall %
46	Plain	2/30Nm merino wool	2/30Nm merino wool	32	8.5*5.5 (21.5*14)	17.7 (45)	8.1*4.9 (20.5*12.5)	16.1 (41)	5% / 11% / 15%
			1/30Nm high twist wool Z		8.5*6.9 (21.5*17.5)		5.3*6.3 (13.5*16)		37% / 9% / 43%
			2/30Nm merino wool		8.5*5.3 (21.5*13.5)		8.1*4.9 (20.5*12.5)		5% / 7% / 12%
47	Plain		1/30Nm high twist wool S		8.5*5.5 (21.5*14)	17.3 (44)	6.3*5.1 (16*13)	16.1 (41)	26% / 7% / 31%
			1/30Nm high twist wool Z		8.5*6.7 (21.5*17)		4.7*6.3 (12*16)		44% / 6% / 47%
			1/30Nm high twist wool S		8.5*5.1 (21.5*13)		6.7*4.7 (17*12)		21% / 8% / 27%
48	2/2 Twill		1/30Nm high twist wool S		8.3*5.3 (21*13.5)	17.5 (44.5)	6.7*5.1 (17*13)	16.5 (42)	19% / 4% / 22%
	Plain		1/30Nm high twist wool Z		8.1*6.9 (20.5*17.5)		6.1*6.5 (15.5*16.5)		24% / 3% / 27%
			2/30Nm merino wool		8.7*5.3 (22*13.5)		8.3*4.9 (21*12.5)		5% / 7% / 12%
49	2/2 Basket		2/30Nm merino wool		8.1*5.5 (20.5*14)	18.3 (46.5)	7.5*5.2 (19*13.3)	17.2 (43.8)	7% / 5% / 12%
	1/3 Twill	1/30Nm high twist wool Z	7.9*7.3 (20*18.5)	6.1*6.9 (15.5*17.5)	23% / 5% / 27%				
	2/2 Basket	1/30Nm high twist wool S	8.1*5.5 (20.5*14)	6.5*5.1 (16.5*13)	20% / 7% / 25%				
50	2/2 Basket	1/30Nm high twist wool S	8.1*5.3 (20.5*13.5)	17.7 (45)	5.9*5.1 (15*13)	16.7 (42.5)	27% / 4% / 30%		
		1/30Nm high twist wool Z	8.1*6.9 (20.5*17.5)		4.9*6.5 (12.5*16.5)		39% / 6% / 43%		
	1/3 Twill	1/30Nm high twist wool S	8.1*5.5 (20.5*14)		5.5*5.1 (14*13)		32% / 7% / 37%		

An analysis of shapeable woven samples from the first set of weaving trials

No.	Samples off the loom		Samples after the finishing		Comments
	T	B	T	B	
46					1/30Nm high-twist wool yarn in Z twist used for the weft in the middle part of the sample. The middle part of the sample showed regular wavy pleats and rib pattern in the vertical direction, and had 43% of shrinkage. When compared to the sample #2 (weave sett at 28epi) that the same warp, weft yarn and structure were used, it had less shrinkage due to the higher weave sett at 32epi.
47					Both parts (A and C) using high twist wool yarn in S twist for the weft showed irregular wavy pleats in the vertical direction. For the middle part (B), high twist wool yarn in Z twist was used for the weft and it showed similar effects as the sample #46 but it had 4% more overall shrinkage.

No.	Samples off the loom		Samples after the finishing		Comments
	T	B	T	B	
48					The part (A) using high twist wool yarn in S twist for the weft showed irregular vertical lines on the surface. For the part B, high twist wool yarn in Z twist was used for the weft and showed irregular wrinkle patterns on the surface.
49					The middle part using high twist wool yarn in Z twist for the weft showed unclear vertical pleats with horizontal lines in between pleat patterns. The part (C) using high twist wool yarn in S twist with 2/2 Basket weave structure showed irregular bold pleat patterns on the surface.









No.	Samples off the loom		Samples after the finishing		Comments
	T	B	T	B	
50					The part (A) using 2/2 Basket weave and high twist wool yarn in S twist for the weft showed irregular vertical pleats on the surface. The part (B) also showed irregular vertical pleats but the pattern was slightly unclear and had vertical wave effect. The part (C) using high twist wool yarn in S twist for the weft with 1/3 Twill weave showed regular vertical pleats pattern on the surface.









A datasheet of the second set of weaving trials in shapeable woven textiles in tubular construction





No.	Weave Structure	Warp Yarn	Weft Yarn	EPI	Width/Length Off Loom In(cm)		Width/Length After Finishing In(cm)		Shrinkage (%) W-Loss/L-Loss/ Overall %	
51	Plain	Top 2/30Nm merino wool	1/30Nm high twist wool Z	32	8.5*5.5 (21.5*14)	17.7 (45)	3.9*4.9/3 (10*12.5/7.5)	15.9/ 9.6 (40.5/ 24.5)	T	53% / 11% / 58%
			1/30Nm high twist wool S		8.5*6.7 (21.5*17)		6.1*6.7/3.7 (15.5*15.5/9.5)		B	53% / 46% / 75%
			2/30Nm merino wool		8.5*5.5 (21.5*14)		3.9*4.9/3 (16.5*12.5/7.5)		T	28% / 9% / 34%
									B	28% / 44% / 60%
52	2/2 Twill	Bottom 1/30Nm high twist wool Z	1/30Nm high twist wool S	32	8.3*5.3 (21*13.5)	17.5 (44.5)	3.9*4.9/3.1 (10*12.5/8)	15.9/ 11 (40.5/ 28)	T	23% / 11% / 31%
	Plain		1/30Nm high twist wool Z + 2/30Nm merino wool		8.3*6.9 (21*17.5)		3.9*6.7/5.3 (10*15.5/13.5)		B	23% / 46% / 59%
			1/30Nm high twist wool S + 1/30Nm high twist wool Z		8.5*5.3 (21.5*13.5)		3.5*4.9/2.6 (9*12.5/6.5)		T	52% / 7% / 56%
									B	52% / 41% / 72%
53	2/2 Twill	Bottom 1/30Nm high twist wool Z	1/30Nm high twist wool Z + 1/30Nm high twist wool S	32	8.3*5.7 (21*14.5)	18.1 (46)	3*5.3/4.7 (7.5*13.5/12)	16.7/ 13.6 (42.5/ 34.5)	T	52% / 11% / 58%
	1/3 Twill		1/30Nm high twist wool S + 1/30Nm high twist wool Z		8.5*7 (21.5*17.75)		3*6.5/5.5 (7.5*16.5/14)		B	52% / 23% / 63%
			2/30Nm merino wool + 1/30Nm high twist wool S		8.3*5.4 (21*13.75)		3.7*4.9/3.3 (9.5*12.5/8.5)		T	58% / 7% / 61%
									B	58% / 52% / 80%
	2/2 Twill							T	64% / 7% / 67%	
								B	24% / 17% / 70%	
								T	65% / 7% / 68%	
								B	65% / 21% / 72%	
								T	55% / 7% / 58%	
								B	55% / 37% / 72%	

54	2/2 Twill		2/30Nm merino wool + 1/30Nm high twist wool Z		8.1*5.3 (20.5*13.5)	17.7 (45)	3.3*4.7/4.3 (8.5*12/11)	15.7/ 12.8 (40/ 32.5)	T	59% / 9% / 62%			
	2/2 Basket		1/30Nm high twist wool S + 1/30Nm high twist wool Z		8.1*7.3 (20.5*18.5)		3.3*6.1/5.1 (8.5*15.5/13)		B	59% / 17% / 66%			
			1/3 Twill		1/30Nm high twist wool S + 2/30Nm merino wool		8.1*5.3 (20.5*13.5)		3.5*4.9/3.3 (9*12.5/8.5)	T	59% / 16% / 65%		
55	2/2 Basket				2/30Nm merino wool + 1/30Nm high twist wool S				8.3*5.3 (21*13.5)	17.9 (45.5)	4.3*5.1/3.5 (11*13/9)	16.9/ 13.2 (43/ 33.5)	B
			2/30Nm merino wool + 1/30Nm high twist wool Z		8.1*7.1 (20.5*18)				3.7*6.7/6.1 (9.5*17/15.5)		B		56% / 37% / 72%
			2/30Nm merino wool + 1/30Nm high twist wool S		8.1*5.5 (20.5*14)				4.5*5.1/3.5 (11.5*13/9)		T		48% / 4% / 50%
					B	48% / 33% / 65%							
					T	54% / 6% / 56%							
			B	54% / 14% / 60%									
			T	44% / 21% / 56%									
			B	44% / 45% / 69%									

An analysis of shapeable woven samples from the second set of weaving trials

No.	Samples off the loom		Samples after the finishing		Comments
	T	B	T	B	
51					<p>The part (A) on the top layer showed regular vertical wave patterns while the part (A) on the bottom layer showed dramatic shrink effect causing vertical and horizontal wavy pleats and rib pattern on the surface. The part (B) on the bottom layer showed strong vertical pleats with horizontal wave patterns in between pleats. The last part (C) on the bottom layer showed a moderate wave pattern in the horizontal direction on the surface.</p>
52					<p>The area using high twist wool yarn in S twist for the weft with 2/2 Twill weave structure showed bold pleats and rib pattern in vertical direction with spiral wave pattern.</p> <p>The areas using high twist wool yarn in Z twist for the weft with showed vertical fine pleat patterns on the surface.</p>

No.	Samples off the loom		Samples after the finishing		Comments
	T	B	T	B	
53					The areas using 2/2 Twill weave and high twist wool yarn in Z twist for the weft showed stronger and bolder pleat patterns when compared to the parts of sample #52 using the same weft yarn with plain weave structure.
54					The areas using 1/3 Twill weave and high twist wool yarn in S twist for the weft showed strong vertical pleats with spiral wave pattern. The surface effects were more clear and tight than parts of the sample #52 due to the weave structure.

No.	Samples off the loom		Samples after the finishing		Comments
	T	B	T	B	
55					<p>The areas using 2/2 Basket weave and merino wool yarn for the weft showed horizontal pleat patterns with vertical wave effect of the surface.</p> <p>The areas using 2/2 Basket weave and high twist wool yarn in S twist for the weft also showed strong vertical pleats with spiral wave pattern, however, the effects were rougher and more unclear than parts of the sample #54 due to the weave structure.</p>









A datasheet of the third set of weaving trials in shapeable woven textiles in tubular construction.









No.	Weave Structure	Warp Yarn	Weft Yarn	EPI	Width/Length Off Loom In(cm)		Width/Length After Finishing In(cm)		Shrinkage (%) W-Loss/L-Loss/ Overall %		
56	Plain	Top 2/30Nm merino wool	1/30Nm high twist wool Z	32	17.2 (43.8)		3.9*2.6/1.8 (10*6.5/4.5)	15/ 12.5 (38/ 31.8)	T	52% / 11% / 58%	
									B	52% / 38% / 71%	
			2/30Nm merino wool							T	52% / 17% / 60%
									B	52% / 25% / 64%	
			1/30Nm high twist wool S							T	62% / 6% / 64%
									B	62% / 12% / 66%	
			1/30Nm high twist wool Z							T	67% / 8% / 69%
									B	67% / 21% / 74%	
			1/30Nm high twist wool Z							T	64% / 15% / 70%
									B	64% / 15% / 70%	
56	Plain	Bottom 1/30Nm high twist wool S	2/30Nm merino wool	32	17.2 (43.8)		3.7*3/2.5 (9.5*7.5/6.3)	15/ 12.5 (38/ 31.8)	T	55% / 12% / 60%	
									B	55% / 26% / 66%	
			1/30Nm high twist wool S							T	50% / 20% / 60%
									B	50% / 60% / 80%	
			1/30Nm high twist wool Z							T	48% / 7% / 51%
									B	48% / 20% / 58%	
			2/2 Twill							T	48% / 8% / 52%
									B	48% / 17% / 56%	
			Plain							T	59% / 6% / 61%
									B	59% / 6% / 61%	
57	2/2 Twill	1/30Nm high twist wool S	1/30Nm high twist wool Z	17.3 (44)		4.1*2.8/2.4 (10.5*7/6)	16.1/ 13.8 (41/ 35)	T	55% / 5% / 57%		
								B	55% / 19% / 64%		
			1/30Nm high twist wool Z						T	55% / 5% / 57%	
								B	55% / 19% / 64%		
57	1/3 Twill	1/30Nm high twist wool Z	1/30Nm high twist wool Z	17.3 (44)		3.3*3.1/3.1 (8.5*8/8)	16.1/ 13.8 (41/ 35)	T	59% / 6% / 61%		
								B	59% / 6% / 61%		
			1/30Nm high twist wool S						T	55% / 5% / 57%	
								B	55% / 19% / 64%		
57	2/2 Twill	1/30Nm high twist wool S	1/30Nm high twist wool Z	17.3 (44)		4.6*2.2/2 (11*5.5/5)	16.1/ 13.8 (41/ 35)	T	48% / 8% / 52%		
								B	48% / 17% / 56%		
			1/30Nm high twist wool S						T	59% / 6% / 61%	
								B	59% / 6% / 61%		
57	1/3 Twill	1/30Nm high twist wool Z	1/30Nm high twist wool Z	17.3 (44)		7.9*1.5 (20*3.7)	16.1/ 13.8 (41/ 35)	T	55% / 5% / 57%		
								B	55% / 19% / 64%		
			1/30Nm high twist wool Z						T	55% / 5% / 57%	
								B	55% / 19% / 64%		





58	Plain	1/30Nm high twist wool Z	8.1*2 (20.5*5)	17.1 (43.5)	3.1*1.8/1.6 (8*4.5/4)	15.7/ 13.8 (39.8/ 35)	T	61% / 10% / 65%
							B	61% / 20% / 69%
							T	55% / 6% / 58%
	2/2 Twill	1/30Nm high twist wool S	7.9*3.3 (20*8.5)	3.5*3.1/2.8 (9*8/7)	B	55% / 18% / 63%		
					T	42% / 10% / 48%		
	Plain	2/30Nm merino wool	8.9*2 (20.8*5)	4.7*1.8/0.8 (12*4.5/2)	B	42% / 60% / 77%		
					T	50% / 7% / 53%		
	2/2 Basket	1/30Nm high twist wool Z	7.9*3 (20*7.5)	17.1 (43.5)	3.9*2.8/2.4 (10*7/6)	15.7/ 13.8 (39.8/ 35)	B	50% / 20% / 60%
							T	57% / 13% / 63%
							B	57% / 13% / 63%
							T	60% / 10% / 64%
							B	60% / 16% / 66%
							T	57% / 13% / 63%
							B	57% / 21% / 66%
							T	60% / 6% / 63%
1/3 Twill	1/30Nm high twist wool Z	7.9*1.5 (20*3.7)	17.1 (43.5)	3.3*1.3/1.2 (8.5*3.3/3)	15.7/ 13.8 (39.8/ 35)	B	60% / 17% / 67%	
						T	59% / 12% / 63%	
						B	59% / 18% / 66%	
1/3 Twill	1/30Nm high twist wool Z	7.9*1.8 (20*4.5)	17.1 (43.5)	3.1*1.8/1.6 (8*4.5/4)	15.7/ 13.8 (39.8/ 35)	T	47% / 10% / 52%	
						B	47% / 50% / 73%	
1/3 Twill	1/30Nm high twist wool S	8.1*3.3 (20.5*8.5)	17.1 (43.5)	3.3*3/2.8 (8.5*7.5/7)	15.7/ 13.8 (39.8/ 35)	T	48% / 12% / 54%	
						B	48% / 53% / 75%	
Plain	1/30Nm high twist wool S	8.1*1.9 (20.7*4.7)	17.3 (44)	4.3*1.8/1 (11*4.5/2.5)	15.4/ 13.4 (39/ 34)	T	61% / 8% / 65%	
						B	61% / 8% / 65%	
						T	50% / 18% / 59%	
2/2 Basket	1/30Nm high twist wool S	8.3*2.9 (21*7.3)	17.3 (44)	4.3*2.6/1.4 (11*6.5/3.5)	15.4/ 13.4 (39/ 34)	B	48% / 53% / 75%	
						T	61% / 8% / 65%	
2/2 Twill	2/30Nm merino wool	8.3*3.3 (21*8.5)	17.3 (44)	3.1*2.2/2.2 (8*5.5/5.5)	15.4/ 13.4 (39/ 34)	T	50% / 18% / 59%	
						B	50% / 24% / 62%	
2/2 Twill	2/30Nm merino wool	8.3*3.3 (21*8.5)	17.3 (44)	4.1*2.8/2.6 (10.5*7/6.5)	15.4/ 13.4 (39/ 34)	T	50% / 18% / 59%	
						B	50% / 24% / 62%	

	2/2 Basket		1/30Nm high twist wool Z		8.1*1.5 (20.5*3.7)		3.3*1.4/1.4 (8.5*3.5/3.5)		T	59% / 8% / 62%
									B	59% / 8% / 62%
	2/2 Twill		1/30Nm high twist wool Z		8.3*2 (21*5)		3.1*1.8/1.8 (8*4.5/4.5)		T	62% / 10% / 66%
									B	62% / 10% / 66%
	1/3 Twill		1/30Nm high twist wool Z	8.1*3.3 (20.5*8.5)		3*3/2.8 (7.5*7.5/7)		T	63% / 12% / 68%	
								B	63% / 18% / 70%	
	2/2 Basket		1/30Nm high twist wool S	8.1*2 (20.5*5)		3.9*1.8/1.4 (10*4.5/3.5)		T	51% / 10% / 56%	
								B	51% / 30% / 66%	
60	2/2 Basket		2/30Nm merino wool		8.1*3 (20.5*7.5)	17.5 (44.5)	6.3*2.4/2.2 (16*6/5.5)	15.6/ 14 (39.5/ 35.5)	T	22% / 20% / 38%
									B	22% / 27% / 43%
	1/3 Twill		2/30Nm merino wool		8.1*2.4 (20.5*6)		5.5*2.2/1.6 (14*5.5/4)		T	32% / 8% / 37%
									B	32% / 33% / 54%
	2/2 Basket		1/30Nm high twist wool Z		8.3*3.5 (21*9)		3.7*3.1/3.1 (9.5*8/8)		T	53% / 6% / 55%
									B	53% / 6% / 55%
	1/3 Twill		1/30Nm high twist wool Z		8.1*1.4 (20*3.5)		3.1*1.1/1.1 (8*3/3)		T	60% / 14% / 66%
									B	60% / 14% / 66%
	2/2 Twill		1/30Nm high twist wool Z	8.1*2 (20.5*5)		3.1*1.8/1.8 (8*4.5/4.5)		T	61% / 6% / 63%	
								B	61% / 6% / 63%	
	Plain		1/30Nm high twist wool Z	8.3*3.3 (21*8.5)		3.3*3.1/2.6 (8.5*8/6.5)		T	60% / 6% / 62%	
								B	60% / 24% / 69%	
	2/2 Basket		2/30Nm merino wool	8.1*2 (20*5)		4.3*1.8/1.6 (11*4.5/4)		T	48% / 10% / 53%	
								B	48% / 20% / 58%	

An analysis of shapeable woven samples from the third set of weaving trials

No.	Samples off the loom		Samples after the finishing		Comments
	T	B	T	B	
56					<p>The area using high twist wool yarn in S twist for both the warp and weft showed regular vertical pleats. The area using S high-twist for the weft intersected with merino wool yarn showed irregular curly wave pattern in vertical direction.</p> <p>The area using high twist wool yarn in Z twist for the weft intersected with high twist wool yarn in S twist showed vertical curly pleats with a horizontal wave pattern on the surface.</p>
57					<p>The area using 2/2 Twill weave and high twist wool yarn in S twist for both the warp and weft showed stronger and bolder vertical pleats than sample #56 due to the weave structure.</p>


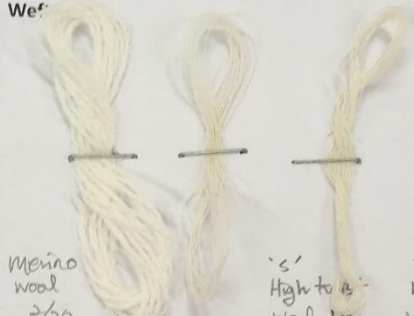
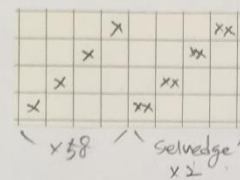
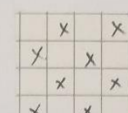
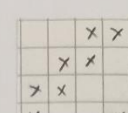
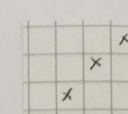
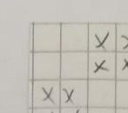
No.	Samples off the loom		Samples after the finishing		Comments
	T	B	T	B	
58					The areas using 2/2 Basket weave and both high twist wool yarn in S and Z twist for the weft intersected with merino yarn had twill weave effects on the surface resulting from a high degree of shrinkage.
59					When merino wool was applied between areas with high shrinkage, it was observed that the sample had dynamic shapes, which could be applied to the garment for the decorative purpose.

No.	Samples off the loom		Samples after the finishing		Comments
	T	B	T	B	
60					It was also observed that the sample had dynamic shapes when merino wool was applied to each side of an area with a high shrinkage degree. It could also be applied to the sleeve part for the decorative purpose.

Appendix D: Technical preparation sheets


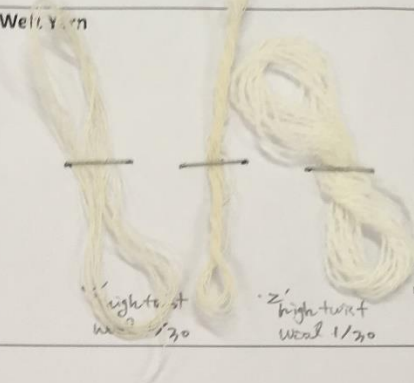
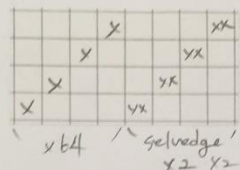
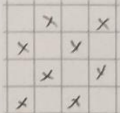

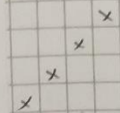
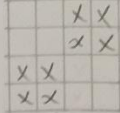
Technical preparation sheet for the first set of shapeable weaving trials in a single layer

Sampling - #1 Sep, 2015

Selected Warp Yarn  <p style="text-align: right; margin-right: 20px;">Merino wool 2/30</p>	Weft  <p style="margin-right: 20px;">Merino wool 2/30</p> <p style="margin-right: 20px;">'S' high twist wool 1/30</p> <p style="margin-right: 20px;">'Z' high twist wool 1/30</p>
Threading Plan & Shaft  <p style="margin-left: 100px;">4 shafts</p> <p style="text-align: right; margin-right: 20px;">* 60 needles for each shaft</p>	
Warp EPI - 28 epi	Weft PPI - Depends on structure,
Total Width - 8 inches (about 20cm)	Peg Plan  <p style="margin-left: 20px;">plain</p>
Total Ends - 210 ends inc 16 selvedges	 <p style="margin-left: 20px;">Twill 2/2</p>
Bundles - Total 18 ea each bundles - 14 ends selvedges - 8 ends x 2.	 <p style="margin-left: 20px;">Twill 1/3</p>
Reed Allocation * 26 reed, 2 EPD 4 EPD for selvedge	 <p style="margin-left: 20px;">Basketed 2/2, 2/3</p>
Beam requirement 1 Beam	* floating Selvedge
Total Length 1 sample is 8 inches Total 15 samples - 120 inches + waste = 160 inches	

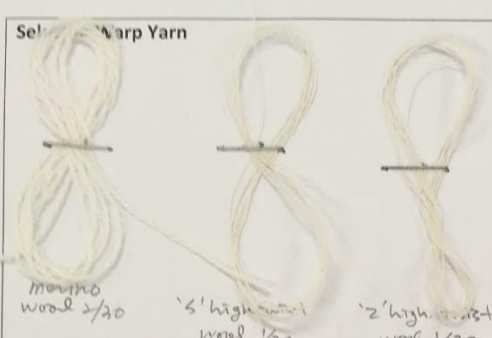
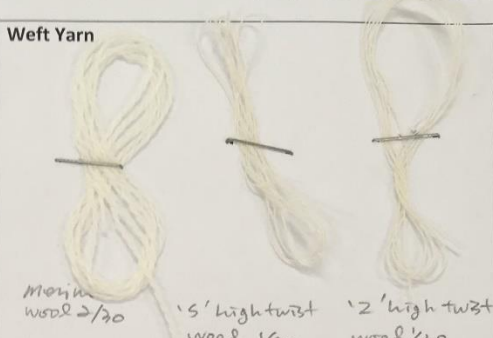
Technical preparation sheet for the second set of shapeable weaving trials in a single layer

Sampling - #2 Sep, 2015

<p>Selected Warp Yarn</p>  <p>5' high twist wool 1/30</p>	<p>Weft Yarn</p>  <p>1' high twist wool 1/30 2' high twist wool 1/30 Merino wool 2/30</p>
<p>Threading Plan & Shaft</p>  <p>4 shafts.</p> <p style="text-align: right;">* 60 needles for each shaft.</p>	
<p>Warp EPI - 32 epi</p>	<p>Weft PPI - Various, 32 to</p>
<p>Total Width - 8 inches (about 20cm)</p> <p>Total Ends - 288 ends inc 32 selvedges</p>	<p>Peg Plan</p>  <p>plain</p>  <p>Twill 2/2</p>  <p>Twill 1/3</p>  <p>Basket 2/2, 2/3</p> <p style="text-align: right;">* floating selvedge</p>
<p>Bundles - Total 18 ea</p> <p>each bundles - 16 ends</p>	
<p>Reed Allocation</p> <p># 30 reed 2 EPD 4 EPD for selvedge.</p>	
<p>Beam requirement</p> <p>1 Beam</p>	
<p>Total Length</p> <p>1 sample is 8 inches Total 15 samples - 120 inches + waste = 160 inches</p>	

Technical preparation sheet for the last set of shapeable weaving trials in a single layer

Sampling - #4 Oct. 2015

<p>Warp Yarn</p>  <p>Merino wool 2/30 'S' high twist wool 1/30 'Z' high twist wool 1/30</p>	<p>Weft Yarn</p>  <p>Merino wool 2/30 'S' high twist wool 1/30 'Z' high twist wool 1/30</p>																																																																																											
<p>Threading Plan & Shaft</p> <p style="text-align: center;"> 1 5 W 'S' 'Z' W 'S' 'Z' W 'S' 'Z' 5 1 16 16 32 32 16 32 32 16 32 32 16 </p> <table border="1" style="margin-left: auto; margin-right: auto; text-align: center;"> <tr><td></td><td></td><td>x</td><td></td><td></td><td></td><td>xx</td><td></td><td></td><td></td><td></td></tr> <tr><td></td><td></td><td>x</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr> <tr><td></td><td></td><td>x</td><td></td><td></td><td></td><td>xx</td><td></td><td></td><td></td><td></td></tr> <tr><td></td><td></td><td>x</td><td></td><td></td><td></td><td>xx</td><td></td><td></td><td></td><td></td></tr> </table> <p style="text-align: center;">4 shaft</p> <p style="text-align: right;">x 60 needles for each shaft.</p>				x				xx							x											x				xx							x				xx																																																			
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<p>Warp EPI - 32 for high twist yarn 1/30 16 for wool 2/30</p>	<p>Weft PPI - Various 16, 32 to.</p>																																																																																											
<p>Total Width - 9 inches (about 23 cm)</p> <p>Total Ends - 272 ends inc 32 selvages</p>	<p>Peg Plan</p> <table border="1" style="margin-bottom: 10px;"> <tr><td></td><td>x</td><td></td><td>x</td></tr> <tr><td>x</td><td></td><td>y</td><td></td></tr> <tr><td></td><td>x</td><td></td><td>x</td></tr> <tr><td>x</td><td></td><td>x</td><td></td></tr> </table> <p>plain</p> <table border="1" style="margin-bottom: 10px;"> <tr><td></td><td></td><td></td><td>x</td><td>x</td></tr> <tr><td></td><td></td><td></td><td>x</td><td>x</td></tr> <tr><td></td><td></td><td></td><td></td><td></td></tr> <tr><td></td><td></td><td></td><td>x</td><td></td></tr> <tr><td></td><td></td><td></td><td>x</td><td></td></tr> </table> <p>Twill 2/2</p> <table border="1" style="margin-bottom: 10px;"> <tr><td></td><td></td><td></td><td></td><td>x</td></tr> <tr><td></td><td></td><td></td><td></td><td>x</td></tr> <tr><td></td><td></td><td></td><td></td><td></td></tr> <tr><td></td><td></td><td></td><td></td><td></td></tr> <tr><td></td><td></td><td></td><td></td><td></td></tr> </table> <p>Twill 1/3</p> <table border="1"> <tr><td></td><td></td><td></td><td>x</td><td>x</td></tr> <tr><td></td><td></td><td></td><td>x</td><td>x</td></tr> <tr><td></td><td></td><td></td><td></td><td></td></tr> <tr><td></td><td></td><td></td><td></td><td></td></tr> <tr><td></td><td></td><td></td><td></td><td></td></tr> </table> <p>Basket 2/2, 2/3</p>		x		x	x		y			x		x	x		x					x	x				x	x									x					x						x					x																			x	x				x	x															
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<p>Bundles - Total 20 ea</p> <p>① 1-16, ④ 4-16, ⑦ 7-16, ⑩ 10-16, ⑬ 13-16, ⑯ 16-16, ⑲ 19-16, ⑳ 20-16 ② 2-8, ⑤ 5-16, ⑧ 8-8, ⑪ 11-16, ⑭ 14-8, ⑰ 17-16, ⑳ 20-16 ③ 3-8, ⑥ 6-16, ⑨ 9-8, ⑫ 12-16, ⑱ 15-8, ⑳ 18-16</p>																																																																																												
<p>Reed Allocation</p> <p>#70 reed 1EPD - wool 2/30 2EPD - high twist 1/30 4EPD - selvages</p>																																																																																												
<p>Beam requirement</p> <p>1 Beam</p>																																																																																												
<p>Total Length</p> <p>1 samples for 9 inches. Total 5 samples - 45 inches + waste - 85 inches.</p>																																																																																												

Appendix E: Ethics Approval Form for the Questionnaire



School of Textiles and Design Research Ethical Guidelines

In keeping with directives from the European Union and from the UK Government, universities are required to put in place ethics procedures and guidelines for research. In addition, research councils ask for formal ethics approval of proposals in some of their funded programmes.

Heriot-Watt University has established a University Ethics Committee to guide schools, monitor procedures and ensure appropriate ethical issues are being considered. The committee has asked schools to submit ethical approval procedures relevant to their research activities. At the School of Textiles and Design, Ethical Approval must be sought using this form. The Director of Research approves most requests on presentation of the form (with supporting documents where applicable). In a limited number of cases granting of approval may have to be referred to the School Research Committee (or part thereof). Where there are more serious concerns applications will be referred to the University's Ethics Committee.

This note outlines the context and provides a standard protocol for ethics approval for research proposals.

General Ethical Principles

- No field of human activity can be considered exempt from ethical concerns. Increased accountability has led to systems of research governance to ensure that research methods and information are open to public scrutiny and can be seen to be subject to the highest ethical standards.
- Research should conform to generally accepted moral and scientific principles. There are:
 - a) Obligations to society:- for example, conforming with responsible, moral and legal practice; maintenance of high scientific standards and impartial assessment and dissemination of findings.
 - b) Obligations to funders and employers:- the relationship between researchers, funders, and employer should be clear and balanced without compromise to morality, the law or professional integrity.
 - c) Obligations to colleagues:- the maintenance of standards and appropriate professional behaviour with methods, procedures and findings open to review.
- Breaches of these principles include areas of research misconduct such as fabrication, falsification and plagiarism.
- The well-being of all involved in research is of central concern in ethical considerations. All staff are therefore obliged to comply with health and safety guidelines and to carry out a risk assessment of the research whatever its nature (for example, laboratory work, field work, testing of participants).

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Ethical principles for research involving human participants

One major obligation on the part of researchers which is not included in the above list is to the participants who are involved in research. Social researchers must strive to protect participants from undue harm arising as a consequence of their participation in research. This requires that their participation should be voluntary, and as fully informed as possible. At the same time, no group should be disadvantaged by routinely being excluded from consideration. Participants should also be aware of their entitlement to refuse to participate at any stage for whatever reason, and to withdraw data just supplied. Special considerations should be given to studies requiring informed consent from vulnerable participants. Such groups include children, those with an intellectual disability and those in a dependent relationship to the researcher or commissioning body (for example, students in the University or patients in a hospital).

a) For interviews / focus groups:

- All participants must be fully informed of the nature of the research and give informed consent prior to interview.
- Participants must be given a plain language statement of the nature and purpose of the research.
- It is generally preferable not to identify individual participants but, if the identification of participants is necessary, participants must be informed of this, and of safeguards to ensure that this information is restricted to the researcher or a specific research group.
- No interview should be recorded without the permission of the participant.
- Interviews by telephone must meet the same conditions as face-to-face interviews.
- Written parental consent is required for interviews with participants under age 18 (16 in Scotland), unless such interviews take place in the presence of a parent or guardian or in an institutional setting where the institutional consent has been given.

b) Questionnaires: All written questionnaires must have an opening statement informing the participant of the nature and purpose of the research. If a questionnaire contains any questions likely to cause offence to the respondent, this should be clearly indicated on the front cover, so that the participant may decide not to read on. Completion of the forms shall indicate evidence of informed consent. Please provide a copy of your proposed questionnaire.

c) Observational methods: Where behaviour patterns are observed without the participants' knowledge, researchers should take care not to infringe the privacy of an individual or group. Where practical, an attempt should be made to obtain consent *post hoc*. Cultural variations in what constitutes public and private space should be acknowledged.

d) Photography: Photographing human participants in publicly accessible spaces is a legitimate research tool. However; if prejudicial to the participants' interests or reputation, identifying features of the participant must be obscured.

e) Experimental or field testing of participants: Ethical requirements for this situation are the same as for those applying to participant interviews.

f) Withholding information from participants: If it is essential to the design of an experiment, questionnaire or interview that some information about its purpose is withheld from participants (e.g. because this knowledge would influence their behaviour), then full information must be provided when participants are debriefed and they must be given the opportunity to withdraw their data. Experiments of this kind should not be conducted if it is likely that participants will react to debriefing with discomfort, anger or objections.

More detailed reference documents are available which provide useful further guidance on these issues, notably, the Social Research Association's *Ethical Guidelines*, <http://the-sra.org.uk/wp-content/uploads/ethics03.pdf> and the British Psychological Society ethical code at [http://www.bps.org.uk/system/files/documents/code of ethics and conduct.pdf](http://www.bps.org.uk/system/files/documents/code_of_ethics_and_conduct.pdf)

School of Textiles and Design
Protocol for Ethics Approval

1. **Title of research:**

From the Loom to wear: shapeable tubular textiles for seamless fashion

2. Purpose of study: The purpose of study is how woven textiles can reduce fabric wastage and enhance sustainability in garment making by integrating natural elastane fibres while improving product lifespan. The study will explore how 2D woven fabrics from the loom could be transformed into 3D fashion, in particular by using a shapeable tubular weaving technique.

3. Is ethical approval required by another body linked to the research?
N/A

If YES please attach copies of the approval given to the other body, and confirmation that no changes have been made to the protocol since approval was granted

4. Is permission required from another body to use data or research materials?
N/A

If YES please attach copies

5. Does the research involve the use of human subjects:
Questionnaire

If YES what is the nature of the research e.g. focus group, questionnaire, etc

If NO please go to Q.13

N.B. The researcher should have considered the use of secondary data sources and should be clear that the aims of research cannot be met without new primary research involving people.

6. Is written consent to be obtained?
Yes, see attached.

If YES please attach a copy of the consent and information form or indicate when it will be supplied.

If NO please justify.

-
7. How long will a subject have to decide whether to take part in the study.

It is voluntary participation on questionnaire; *immediately.*

If less than 1 day, please comment.

(Note that it is common in the case of face to face interviews not to give significant advanced notice. This is acceptable in view of maximising the response rates and reliability of some survey based research.)

8. Will any of the subjects be from one of the following vulnerable groups?:

N/A

- Children under 18 (16 in Scotland)
- People with learning difficulties
- Patients in hospital
- Other vulnerable groups (e.g. mental illness, dementia)

9. If any 'yes' box in question 8 is ticked, what special arrangements have been made to deal with issues of consent for the subjects (e.g. consent from parents, professional carer, relevant institution, etc).

10. Are there any potential physical, psychological or disclosure dangers that can be anticipated from involvement in the research?

N/A

If yes, please give details.

11. What steps will be taken to safeguard the confidentiality and anonymity of subjects? Participants will be clearly informed of the nature of the study, and their ability to remain anonymous.

12. Does the study design involve actively deceiving participants?

No

If yes, briefly describe the nature of the deception and explain why it is necessary

13. Does the research project comply with the requirements of current Data Protection legislation (for example, data storage and security.), including in relation to the use and (non) disclosure of secondary data sets?

Yes

14. Is your risk assessment of the health and safety implications for staff of the research High/Medium/Low or negligible: Negligible

If medium or high please ensure that the health and safety officer in the School is informed.

Please sign the following:

I as a Principal Investigator have checked the above for accuracy and am satisfied the information provided is a true reflection of the intended study.

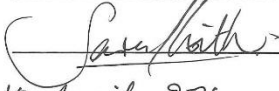
Name (please print) Kang Hyun An

Signature 

Date 9 April 2018

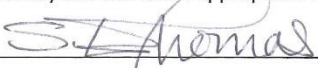
My Supervisor is:

Name (please print) Sara Keith

Signature 

Date 10 April 2018

I am satisfied that the researcher has properly considered the ethical implications of the intended study and has taken appropriate action.

 (Ethics Officer)

Date 17th April 2018

Appendix F: Plain Language Statement for the Questionnaire



Plain Language Statement

I am Kang Hyun An, a PhD student of Heriot Watt University in the School of Textiles and Design, in Scotland.

I am doing research with regard to sustainable textile design for seamless fashion.

I would like to ask you to take part in this research work by questionnaire. The questionnaire will approximately take 5 minutes.


This research has received ethics approval.

Participants' information is confidential and will anonymise all of your answers, unless you wish to be recognised and it is appropriate. You have the right to withdraw without giving a reason and prior to the publication of the research September in 2019.

Contact for further information:

Researcher: Kang Hyun An

Contact details: ka15@hw.ac.uk

Signature: -----

Date: 9, April 2018

Supervisor: Sara Keith

Contact details: s.a.keith@hw.ac.uk

Signature: -----

Date: 10 April 2018

School of Textiles – Heriot-Watt University 09.04.2018

Appendix G: A form of Questionnaire



From the Loom to Wear: shapeable tubular textiles for seamless fashion

Thank you very much for agreeing to participate in this questionnaire.
Your feedback is important for my research on sustainable textile design, which is part of my PhD research.

Please give your opinion by filling in the simple questionnaire about displayed works in the exhibition.
Your information is confidential and your answers will be anonymous, unless you wish to be recognised.
All data will be collected and stored in accordance with the UK Data Protection Act, 1998.
You have the right to withdraw without giving a reason and prior the publication of the research before 2019.

1. Please give your personal information:

Gender: Male Female Prefer not to answer
Age: under 21 22-30 31-40 41-50 51-60 over 60
Education level: Less than a high school diploma High school degree or equivalent
Some college level Associate degree
Bachelor's degree Master's degree Doctorate
Post Code:

2. Do you consider sustainability (environmental) issues when you purchase your clothes?

Always Very often Sometimes Rarely Never

3. Do you understand the design concept behind this exhibition? (such as seamless woven garments with multi-wearability for sustainable textiles)

Fully understand Mostly Moderately Slightly Not at all

4. How would you rate shapeable tubular weaving for Seamless Garments displayed in the exhibition, based on its design?

Excellent Good Average Poor Very poor

5. Do you believe that multi wearability in the Seamless Woven Garments (which can be worn as a scarf, a shawl and a dress or a jacket) would encourage you to wear them often and keep them longer?

Strongly Agree Agree Undecided Disagree Strongly Disagree

6. Would you consider purchasing a stretchable woven garment made with wool fibres (such as garments displayed here), rather than purchasing a similar garment made from synthetic fibres?

Definitely Probably Possibly Probably Not Definitely Not

7. Do you have suggestions to improve this collection?

Further enquiries: Kang Hyun An, Ka15@hw.ac.uk

Appendix H: Ethics Approval Form for a Focus Group Discussion



School of Textiles and Design Research Ethical Guidelines

In keeping with directives from the European Union and from the UK Government, universities are required to put in place ethics procedures and guidelines for research. In addition, research councils ask for formal ethics approval of proposals in some of their funded programmes.

Heriot-Watt University has established a University Ethics Committee to guide schools, monitor procedures and ensure appropriate ethical issues are being considered. The committee has asked schools to submit ethical approval procedures relevant to their research activities. At the School of Textiles and Design, Ethical Approval must be sought using this form. The Director of Research approves most requests on presentation of the form (with supporting documents where applicable). In a limited number of cases granting of approval may have to be referred to the School Research Committee (or part thereof). Where there are more serious concerns applications will be referred to the University's Ethics Committee.

This note outlines the context and provides a standard protocol for ethics approval for research proposals.

General Ethical Principles

- No field of human activity can be considered exempt from ethical concerns. Increased accountability has led to systems of research governance to ensure that research methods and information are open to public scrutiny and can be seen to be subject to the highest ethical standards.
- Research should conform to generally accepted moral and scientific principles. There are:
 - a) Obligations to society:- for example, conforming with responsible, moral and legal practice; maintenance of high scientific standards and impartial assessment and dissemination of findings.
 - b) Obligations to funders and employers:- the relationship between researchers, funders, and employer should be clear and balanced without compromise to morality, the law or professional integrity.
 - c) Obligations to colleagues:- the maintenance of standards and appropriate professional behaviour with methods, procedures and findings open to review.
- Breaches of these principles include areas of research misconduct such as fabrication, falsification and plagiarism.
- The well-being of all involved in research is of central concern in ethical considerations. All staff are therefore obliged to comply with health and safety guidelines and to carry out a risk assessment of the research whatever its nature (for example, laboratory work, field work, testing of participants).

Ethical principles for research involving human participants

One major obligation on the part of researchers which is not included in the above list is to the participants who are involved in research. Social researchers must strive to protect participants from undue harm arising as a consequence of their participation in research. This requires that their participation should be voluntary, and as fully informed as possible. At the same time, no group should be disadvantaged by routinely being excluded from consideration. Participants should also be aware of their entitlement to refuse to participate at any stage for whatever reason, and to withdraw data just supplied. Special considerations should be given to studies requiring informed consent from vulnerable participants. Such groups include children, those with an intellectual disability and those in a dependent relationship to the researcher or commissioning body (for example, students in the University or patients in a hospital).

a) For interviews / focus groups:

- All participants must be fully informed of the nature of the research and give informed consent prior to interview.
- Participants must be given a plain language statement of the nature and purpose of the research.
- It is generally preferable not to identify individual participants but, if the identification of participants is necessary, participants must be informed of this, and of safeguards to ensure that this information is restricted to the researcher or a specific research group.
- No interview should be recorded without the permission of the participant.
- Interviews by telephone must meet the same conditions as face-to-face interviews.
- Written parental consent is required for interviews with participants under age 18 (16 in Scotland), unless such interviews take place in the presence of a parent or guardian or in an institutional setting where the institutional consent has been given.

b) Questionnaires: All written questionnaires must have an opening statement informing the participant of the nature and purpose of the research. If a questionnaire contains any questions likely to cause offence to the respondent, this should be clearly indicated on the front cover, so that the participant may decide not to read on. Completion of the forms shall indicate evidence of informed consent. Please provide a copy of your proposed questionnaire.

c) Observational methods: Where behaviour patterns are observed without the participants' knowledge, researchers should take care not to infringe the privacy of an individual or group. Where practical, an attempt should be made to obtain consent *post hoc*. Cultural variations in what constitutes public and private space should be acknowledged.

d) Photography: Photographing human participants in publicly accessible spaces is a legitimate research tool. However; if prejudicial to the participants' interests or reputation, identifying features of the participant must be obscured.

e) Experimental or field testing of participants: Ethical requirements for this situation are the same as for those applying to participant interviews.

f) Withholding information from participants: If it is essential to the design of an experiment, questionnaire or interview that some information about its purpose is withheld from participants (e.g. because this knowledge would influence their behaviour), then full information must be provided when participants are debriefed and they must be given the opportunity to withdraw their data. Experiments of this kind should not be conducted if it is likely that participants will react to debriefing with discomfort, anger or objections.

More detailed reference documents are available which provide useful further guidance on these issues, notably, the Social Research Association's *Ethical Guidelines*, <http://the-sra.org.uk/wp-content/uploads/ethics03.pdf> and the British Psychological Society ethical code at http://www.bps.org.uk/system/files/documents/code_of_ethics_and_conduct.pdf

School of Textiles and Design
Protocol for Ethics Approval

1. **Title of research:**

From the Loom to wear: shapeable tubular textiles for seamless fashion

2. Purpose of study: The purpose of the study is how woven textiles can minimise fabric wastage and enhance sustainability in garment making by integrating natural elastane fibres while improving product versatility. The study will explore how 2D woven fabrics from the loom could be transformed into 3D fashion, in particular by using a shapeable tubular weaving technique.

3. Is ethical approval required by another body linked to the research?
N/A

If YES please attach copies of the approval given to the other body, and confirmation that no changes have been made to the protocol since approval was granted

4. Is permission required from another body to use data or research materials?
N/A

If YES please attach copies

5. Does the research involve the use of human subjects:
Focus group discussion

If YES what is the nature of the research e.g. focus group, questionnaire, etc

If NO please go to Q.13

N.B. The researcher should have considered the use of secondary data sources and should be clear that the aims of research cannot be met without new primary research involving people.

6. Is written consent to be obtained?
Yes, see attached.

If YES please attach a copy of the consent and information form or indicate when it will be supplied.

If NO please justify.

7. How long will a subject have to decide whether to take part in the study.
3days

If less than 1 day, please comment.

(Note that it is common in the case of face to face interviews not to give significant advanced notice. This is acceptable in view of maximising the response rates and reliability of some survey based research.)

8. Will any of the subjects be from one of the following vulnerable groups?:
N/A
- Children under 18 (16 in Scotland)
 - People with learning difficulties
 - Patients in hospital
 - Other vulnerable groups (e.g. mental illness, dementia)

9. If any 'yes' box in question 8 is ticked, what special arrangements have been made to deal with issues of consent for the subjects (e.g. consent from parents, professional carer, relevant institution, etc).

10. Are there any potential physical, psychological or disclosure dangers that can be anticipated from involvement in the research?
N/A

If yes, please give details.

11. What steps will be taken to safeguard the confidentiality and anonymity of subjects? Participants will be clearly informed of the nature of the study, and their ability to remain anonymous.

12. Does the study design involve actively deceiving participants?
N/A

If yes, briefly describe the nature of the deception and explain why it is necessary

13. Does the research project comply with the requirements of current Data Protection legislation (for example, data storage and security.), including in relation to the use and (non) disclosure of secondary data sets?
Yes, password protection of h-drive on a university system which gets backed up regularly.

School of Textiles – Heriot-Watt University 06.08.2018

14. Is your risk assessment of the health and safety implications for staff of the research High/Medium/Low or negligible: Negligible

If medium or high please ensure that the health and safety officer in the School is informed.

Please sign the following:

I as a Principal Investigator have checked the above for accuracy and am satisfied the information provided is a true reflection of the intended study.

Name (please print) Kang Hyun An

Signature 

Date 06/08/2018


My Supervisor is:

Name (please print) Sara Keith

Signature 

Date 8 August 2018

I am satisfied that the researcher has properly considered the ethical implications of the intended study and has taken appropriate action.

 (Ethics Officer)

Date 21.08.2018

Appendix I: Plain Language Statement for a Focus Group Discussion



Plain Language Statement

I am Kang Hyun An, a PhD student at Heriot-Watt University in the School of Textiles and Design, in Scotland.

I am doing research with regard to sustainable textile design for seamless fashion.

I would like to invite you to take part in this research work by focus group. The focus group will take approximately 1 hour and 30 minutes. This research has received ethics approval.

Participants' information is confidential and will anonymise all of your answers unless you wish to be recognised and it is appropriate. You have the right to withdraw without giving a reason and prior to the publication of the research in September 2019.

Contact for further information:

Researcher: Kang Hyun An


Contact details: ka15@hw.ac.uk

Signature: -----

Date: *06/08/2018*-----

Supervisor: Sara Keith

Contact details: s.a.keith@hw.ac.uk

Signature: -----

Date: *8 August 2018*-----

School of Textiles – Heriot-Watt University 06.08.2018

Appendix J: Informed Consent Form



Informed Consent Form

You are invited to participate in a research project.

This work is being carried out as part of the PhD research of Kang Hyun An from the School of Textiles and Design at Heriot-Watt University, Scotland. I am exploring the sustainable textile design for seamless fashion.

The focus group will be semi-structured, and I will take note and video and sound recording.

(Participants will not be identified in the publication of any photographs, and an event of using such images their faces will be blurred.)

This research has received ethics approval.

The length of the focus group will take approximately 2 hours. You will be under no obligation to answer any of the questions.

Your information is confidential, and your answers will be anonymous unless you wish to be recognised. All data will be collected and stored in accordance with the UK Data Protection Act, 1998. You have the right to withdraw without giving a reason and prior the publication of the research before 2019.

Participant

I have been fully informed as to what this research will entail, and am aware of my right to withdraw at any time. I hereby fully and freely consent to participate in the interview, which has been fully explained to me.

Participant Signed _____

Contact details _____

Postcode _____

Date 29 Aug 2018

Contact for further information:

Researcher: Kang Hyun An, ka15@hw.ac.uk

Supervisor contact details: Sara Keith, s.a.keith@hw.ac.uk

School of Textiles – Heriot-Watt University 28.08.2018

Appendix K: Exhibition Poster

From the Loom to Wear

Shapeable tubular textiles for seamless fashion

A.K. Kang Hyun An

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Sat 7 April - Sun 3 June 2018

Catwalk

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References

Acar, S., Meriç, D. and Kurtuldu, E. (2019) 'Pleat Effects With Alternative Materials and Finishing Methods', *Journal of Textile & Apparel/Tekstil ve Konfeksiyon*, 29(1).

Alex James: Slowing Down Fast Fashion (2016) Directed by Akers, B. [DVD]. Germany: Journeyman Pictures(Accessed: 10 September 2017).

Allwood, J. M., Laursen, S. E., Malvido De Rodriguez, C. and Bocken, N. (2006) *Well dressed? The present and future sustainability of clothing and textiles in the United Kingdom*. Cambridge, United Kingdom: University of Cambridge, Sustainable Manufacturing Group, Institute for Manufacturing.

Anderson, K. (2004) *SEAMLESS TEXTILES WITH INHERENT SHAPE*. PhD thesis. North Carolina State University.

Anderson, K. and Seyam, A. (2004) 'Developing seamless shaped woven medical products', *Journal of Medical Engineering & Technology*, 28(3), pp. 110-116.

Archer, B. (1995) 'The nature of research', *Co-Design Journal*, 2(11), pp. 6-13.

Ashenhurst, T. R. (1884) *A Treatise on Textile Calculations and the Structure of Fabrics*. Bradford: J. Broadbent and CO.

Barbour, R. S. (2007) *Doing focus groups*. London: SAGE.

Barnes, L. and Lea-Greenwood, G. (2010) 'Fast fashion in the retail store environment', *International Journal of Retail & Distribution Management*, 38(10), pp. 760-772.

Behera, B. K. and Hari, P. K. (2010) 'Shrinkage in woven fabrics', in Behera, B. K. and Hari, P. K. (eds.) *Woven Textile Structure*. North America: Woodhead Publishing Limited (Chapter 5).

Bhattacharya, S. S. and Koranne, M. (2012) 'Novel method of weaving three-dimensional shapes', *International Journal of Clothing Science and Technology*, 24(1), pp. 56-63.

Bocken, N. M. P., de Pauw, I. C., Bakker, C. A. and van der Grinten, B. (2016) 'Product design and business model strategies for a circular economy', *Journal of Industrial and Production Engineering*, 33(5), pp. 2168-1015.

Bolton, A. (2016) *Manus x machina : fashion in an age of technology*. Edited by Cope, N. A. and Metropolitan Museum of Art. New York, N.Y.: New York, N.Y. : Metropolitan Museum of Art.

Bourque, L. B. and Fielder, E. P. (1995) *How to conduct self-administered and mail surveys*. Thousand Oaks, London, New Delhi: SAGE Publications.

Brace, I. (2008) *Questionnaire design: how to plan, structure and write survey material for effective market research*. 2nd edn. London: Kogan Page.

Browne, M. A., Crump, P., Niven, S. J., Teuten, E., Tonkin, A., Galloway, T. and Thompson, R. (2011) 'Accumulation of Microplastic on Shorelines Worldwide: Sources and Sinks', *Environmental science & technology*, 45(21), pp. 9175-9179.

Bryman, A. (2016) *Social research methods*. 5th edn. Oxford: Oxford University Press.

Bye, E. (2010) 'A Direction for Clothing and Textile Design Research', *Clothing and Textiles Research Journal*, 28(3), pp. 205-217.

Campaign for Wool (2013) *About Wool*. [Online]. Available at: <http://www.campaignforwool.org/about-wool/> (Accessed: 18 Sep 2017).

Candy, L. and Edmonds, E. (2017) 'Practice-Based Research in the Creative Arts: Foundations and Futures from the Front Line', *Leonardo*, 51(1), pp. 63-69.

Chapman, J. (2005) *Emotionally Durable Design: Objects, Experiences and Empathy*. United Kingdom: Earthscan Publications Ltd.

Chapman, J. (2014) *Prospect, Seed and Active: Advancing Design for Sustainability in Fashion: Routledge handbook of sustainability and fashion*. Edited by Fletcher, K. and Tham, M. United Kingdom: Routledge.

Christys' London (2018) *Our Heritage*. Online: Christys' London, [Figure]. Available at: <https://www.christys-hats.com/our-heritage>.

Corscadden, K. W., Biggs, J. N. and Stiles, D. K. (2014) 'Sheep's wool insulation: A sustainable alternative use for a renewable resource?', *Resources, Conservation & Recycling*, 86, pp. 9-15.

Cross, N. (2007) 'From a Design Science to a Design Discipline: Understanding Designerly Ways of Knowing and Thinking', in Michel, R. (ed.) *Design Research Now: Essays and Selected Projects*. Basel: Birkhäuser Basel, pp. 41-54.

Crouch, C. and Pearce, J. (2012) *Doing research in design* London: Berg.

DEFRA (2007) 'SUSTAINABLE CLOTHING ROADMAP BRIEFING NOTE - Sustainability Impacts of Clothing and Current Interventions', *Department for Environment, Food and Rural Affairs*, pp. 1-14.

DEFRA (2010) *Sustainable Clothing Action Plan*. [Online]. Available at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/69193/pb13206-clothing-action-plan-100216.pdf (Accessed: 14 December 2015).

Design press (2018) '하나의 오브제가 된 스카프 (Scarf that became an object)', *Design People*, 9 May 2018 [Blog]. Available at: <http://blog.naver.com/PostView.nhn?blogId=designpress2016&logNo=221271575216&categoryNo=7&parentCategoryNo=0> (Accessed: 10 June 2018).

Desveaux, D. (1998) *Fortuny* United Kingdom: Thames and Hudson.

Dixon, A. (2007) *Handweaver's Pattern Book: An Illustrated Reference to Over 600 Fabric Weaves*. London: Bloomsbury Publishing PLC.

Dombek-Keith, K. and Loker, S. (2011) 'Sustainable clothing care by design', in Gwilt, A. and Rissanen, T. (eds.) *Shaping sustainable fashion: changing the way we make and use clothes*. United Kingdom: Earthscan Ltd.

Durling, D. (2002) 'Discourses on research and the PhD in Design', *Quality Assurance in Education*, 10(2), pp. 79-85.

Durrant, A. c., Vines, J., Wallace, J. and Yee, J. S. R. (2017) 'Research Through Design: Twenty-First Century Makers and Materialities', *Design Issues*, 33(3), pp. 3-10.

Earley, R. (2017) 'Circular Design Futures', *Design Journal*, 20(4), pp. 421-434.

Earley, R. and Goldsworthy, K. (2017) *PLATE: Product Lifetimes And The Environmen*. Amsterdam, Netherlands, 8-10 November 2017. Delft University of Technology and IOS Press. doi: DOI: 10.3233/978-1-61499-820-4-127.

Eden, C. and Ackermann, F. (2018) 'Theory into practice, practice to theory: Action research in method development', *European Journal of Operational Research*, 271(3), pp. 1145-1155.

Ekstrom, K. M. and Salomonson, N. (2014) 'Reuse and recycling of clothing and textiles-a network approach', *Journal of Macromarketing*, 34(3), pp. 383-399.

Fangueiro, R. and Soutinho, F. (2011) 'Textile structures', in Fangueiro, R. (ed.) *Fibrous and Composite Materials for Civil Engineering Applications*. Cambridge, UK, Philadelphia, PA: Cambridge, UK, Philadelphia, PA : Woodhead Publishing : Published in association with the Textile Institute, pp. 62-91 (Chapter 3).

Farrer, J. (2011) 'Remediation: discussing fashion textiles sustainability', in Gwilt, A. and Rissanen, T. (eds.) *Shaping sustainable fashion: changing the way we make and use clothes*. United Kingdom: Earthscan Ltd.

Field, A. (2008) *Collapse Weave: Creating Three-Dimensional Cloth*. United States: Trafalgar Square Publishing.

Fletcher, K. (2008) *Sustainable fashion and textiles: Design journeys*. London: Earthscan Publications.

Frayling, C. (1993) 'Research in art and design', *Royal College of Art Research Papers*, 1, pp. 1-5.

Friedman, K. (2002) 'Conclusion: Towards an integrative design discipline', in Squires, S. and Byrne, B. (eds.) *Creating breakthrough ideas: the collaboration of anthropologists and designers in the product development industry*. Westport: Conn: Bergin & Garvey, pp. 199-214.

Friends of Light (2016) *Hand-woven Jacket*. Online: Friends of Light, [Figure]. Available at: <https://www.friendsoflight.net/>.

Gill, A. A. (2012) *Practical Basketry*. Project Gutenberg Available at: <http://www.gutenberg.org/ebooks/38681> (Downloaded: 13 June 2018).

Gillham, B. (2008) *Developing a questionnaire*. 2nd edn. London: Continuum.

Gilligan, E. G. (2004) *Woollen and Worsted Woven Fabric Design*. Oxford: Elsevier B.V. United Kingdom of Great Britain & Northern Ireland.

Goldsworthy, K. (2012) *Laser-finishing: a new process for designing recyclability in synthetic textiles*. PhD thesis. University of the Arts London.

Gong, R. H. (2011) 'Developments in 3D nonwovens', in Chen, X. (ed.) *Advances in 3D Textiles*. Amsterdam, Netherlands: Woodhead Publishing, pp. 264-286 (Chapter 11).

Gray, C. (1996) 'Inquiry through practice: developing appropriate research strategies.', *'No guru, no method?'*. *International Conference on Art and Design Research*. UIAH, Helsinki, 4-6 September 1996. Research Institute, University of Art and Design Helsinki, pp. 1-28.

Gray, C. and Malins, J. (2004) *Visualizing research: a guide to the research process in art and design*. Aldershot: Ashgate.

Grossiord, S. (2019) 'DELPHOS' DRESS, MARIANO FORTUNY. [Online]. Available at: <http://www.palaisgalliera.paris.fr/en/work/delphos-dress-mariano-fortuny> (Accessed: 8 May 2019).

Gullingsrud, A. (2017) *Fashion fibers: Designing for Sustainability*. New York: Fairchild Books.

Guo, W. (2014) *BODITECTURE - CONVERTIBLE FASHION CONSTRUCTION | CONVERTIBLE DRESS FROM DAY TO NIGHT FROM WORK TO DATE FROM LONG TO SHORT | MULTI-WAY DRESS*. Online: Boditecture, [Figure]. Available at: <http://www.boditecture.com/fw2012/release31.shtml>.

Gwilt, A. (2014) *A Practical Guide to Sustainable Fashion*. United Kingdom: Fairchild Books.

Herpen, I. V. (2010) *Crystallization | Behind the scenes*. Online: Iris van Herpen, [Figure]. Available at: <http://www.irisvanherpen.com/behind-the-scenes/crystallization>.

Herpen, I. V. (2017) *Ludi Naturae | Behind the scenes* Online: Iris van Herpen, [Figure]. Available at: <http://www.irisvanherpen.com/behind-the-scenes>.

Herpen, I. V. (2018) *Biography*. [Online]. Available at: <http://www.irisvanherpen.com/about> (Accessed: 8 June 2018).

Hishinuma, Y. (2005) *Exhibited "3D-KNIT" at AXIS Gallery, Tokyo*. Online: Yoshiki Hishinuma, [Figure]. Available at: <http://www.yoshikihishinuma.co.jp/works.html>.

Ireland, C. (2003) 'Qualitative Methods: From Boring to Brilliant', in Laurel, B. (ed.) *Design Research: Methods and Perspectives*. Cambridge, Massachusetts, London, England: The MIT Press, pp. 63-69.

Issey Miyake (2016) *MAKING THINGS | ISSEY MIYAKE | BRANDS*. Online: Issey Miyake Inc, [Figure]. Available at: <https://www.isseymiyake.com/en/brands/isseymiyake/making>.

IWTO (2016) *Guidelines for conducting a life cycle assessment of the environmental performance of wool textiles*. [Online]. Available at: https://www.iwto.org/sites/default/files/files/iwto_resource/file/IWTO%20Guidelines%20for%20Wool%20LCA.pdf (Accessed: 8 March 2019).

IWTO (2019) *Wool Life Cycle Assessment*. [Online]. Available at: https://www.iwto.org/sites/default/files/files/iwto_resource/file/Wool%20Life%20Cycle%20Assessment.pdf (Accessed: 8 March 2019).

Johnston, C. (2015) 'The importance of colour in textiles and clothing for an ageing population', in *Textile-Led Design for the Active Ageing Population*. Cambridge, Waltham, Kidlington: Woodhead Publishing, pp. 39-45.

Jonas, W. (2015) 'A cybernetic model of design research', in Rodgers, P. A. and Yee, J. (eds.) *The Routledge Companion to Design Research*. Oxon: Routledge, pp. 23-37 (Chapter 2).

Joung, H.-M. (2014) 'Fast-fashion consumers' post-purchase behaviours', *International Journal of Retail & Distribution Management*, 42(8), pp. 688-697.

Kawamura, Y. (2011) *Doing research in fashion and dress : an introduction to qualitative methods*. New York, Oxford: Berg.

Kearley, S. (2014) *Woven textiles: a designers guide*. Marlborough: The Crowood Press Ltd.

Kemmis, S. (2009) 'Action research as a practice-based practice', *Educational Action Research*, 17(3), pp. 463-474.

Kemmis, S. and McTaggart, R. (2005) 'Participatory Action Research: Communicative Action and the Public Sphere', in *The Sage handbook of qualitative research, 3rd ed.* Thousand Oaks, CA: Sage Publications Ltd, pp. 559-603 (Chapter 10).

Kemmis, S., McTaggart, R. and Nixon, R. (2014) *The action research planner: doing critical participatory action research*. Singapore Springer.

Kerr, J. and Landry, J. (2017) *PULSE OF THE*

FASHION INDUSTRY. Available at: https://globalfashionagenda.com/wp-content/uploads/2017/05/Pulse-of-the-Fashion-Industry_2017.pdf (Accessed: 12 June 2018).

King, J. A. (2012) 'Colour trends and selection in fashion design ', in *Colour Design*. Cambridge, Philadelphia, Vardaan House, Woodhead Publishing, pp. 535-550.

Klee, K. d. (2016) *Friends of Light: Handwoven jackets from New York*. [Online]. Available at: <http://www.designindaba.com/articles/point-view/friends-light-handwoven-jackets-new-york> (Accessed: 10 September 2017).

Klepp, I. G. and Laitala, K. (2014) *Consumption Studies: Routledge handbook of sustainability and fashion*. Edited by Fletcher, K. and Tham, M. United Kingdom: Routledge.

Koo, H. S., Dunne, L. and Bye, E. (2013) 'Design functions in transformable garments for sustainability', *International Journal of Fashion Design, Technology and Education*, 7(1), pp. 10-20.

Krueger, R. A. (1994) *Focus groups: a practical guide for applied research*. 2nd edn. London: Sage.

Laitala, K., Klepp, I. G. and Henry, B. (2017) *Product Lifetimes And The Environment*. Delft University of Technology. Delft University of Technology and IOS Press. doi: 10.3233/978-1-61499-820-4-202.

Laitala, K., Klepp, I. G. and Henry, B. (2018) 'Does Use Matter? Comparison of Environmental Impacts of Clothing Based on Fiber Type', *Sustainability*, 10(7), pp. 1-25.

Landahl, K. (2015) *The myth of the silhouette : on form thinking in knitwear design / by Karin Landahl*. PhD thesis. Boras : University of Boras.

Larsen, J. L. and Freudenheim, B. (1986) *Interlacing : the elemental fabric / by Jack Lenor Larsen with Betty Freudenheim*. Tokyo, New York, San Francisco: Kodansha International.

Lau, C. K. (2011) 'Exhibition Review: Hussein Chalayan: From Fashion and Back', *Fashion Theory*, 15(1), pp. 93-98.

Lee, R. (2010) *Three-dimensional textiles with coils, loops, knots and nets*. London: Batsford.

Lewin, K. (1946) 'Action research and minority problems', *Journal of social issues*, 2(4), pp. 34-46.

Lin, V. (2001) 'Issey Miyake: A-POC', *Graphis*, 57(333), pp. 72-137.

Ma, Y. J. and Koo, H. (2016a) *INTERNATIONAL TEXTILE AND APPAREL ASSOCIATION (ITAA) ANNUAL CONFERENCE PROCEEDINGS*. Vancouver, British Columbia 8-11 November. Iowa State University Digital Repository.

Ma, Y. J. and Koo, H. (2016b) 'Preferences on transformable dresses for sustainability', *Research Journal of Textile and Apparel*, 20(4), pp. 166-181.

Maggioni, S. and Muston, F. (2018) *Buyers' Briefing S/S 19: Womenswear Details*. [Online]. Available at: https://www.wgsn.com/content/board_viewer/#/78251/page/3 (Accessed: 25 June 2018).

Manonik (2014) *Three-dimensional pattern weaving*. Online: Manonik, [Figure]. Available at: <http://www.manonik.com/about/>.

Matthews, J. (2011) *Textiles in three dimensions: an investigation into processes employing laser technology to from-led three-dimensional textiles*. PhD thesis. Loughborough University.

McDonough, W. and Braungart, M. (2002) *Cradle to cradle : remaking the way we make things*. New York: North Point Press.

McHattie, L.-S. and Ballie, J. (2018) 'Material Futures: Design-led Approaches to Crafting Conversations in the Circular Economy', *Journal of Textile Design Research and Practice*, 6(2), pp. 184-200.

McQuillan, H. (2019) 'Waste, so What?: A reflection on waste and the role of designers in a circular economy', *Nordic Design Research Journal*, No 8, pp. 1-9.

Milton, A. and Rodgers, P. (2013) *Research methods for product design*. Edited by Rodgers, P. London: Laurence King.

Miyake and Fujiwara (2002) *A-POC making / Issey Miyake and Dai Fujiwara*. Germany: Vitra Design Museum.

Miyake, I., Fujiwara, D., Miyake, I., Fujiwara, D. and Kries, M. (2002) *Issey Miyake & Dai Fujiwara: [the Exhibition A-Poc Making is shown at Vitra-Design-Museum Berlin, June 1 - July 1, 2001]*. Germany: Vitra Design Museum GmbH.

Moon, K. K.-L., Youn, C., Chang, J. M. T. and Yeung, A. W.-h. (2013) 'Product design scenarios for energy saving: A case study of fashion apparel', *International Journal of Production Economics*, 146(2), pp. 392–401.

Moreno, M., Rios, C., Rowe, Z. and Charnley, F. (2016) 'A Conceptual Framework for Circular Design', *Sustainability*, 8(9), p. 937.

Morgan, L., Kane, F., Tyrer, J. and Shen, J. (2018) 'Laser Shibori: A Digital Moulding Technique Supporting Circular Textile Design in Three Dimensions', *Journal of Textile Design Research and Practice*, 6(1), pp. 5-22.

Mullins, W. G. (2009) *Felt*. New York, USA: Berg

Mäkelä, M. (2007) 'Knowing through making: The role of the artefact in practice-led research', *Knowledge, Technology & Policy*, 20(3), pp. 157-163.

Nakamichi, T. (2012) *Pattern Magic: Stretch Fabrics*. United Kingdom: Laurence King Publishing.

Ng, F. M. C. (2004) 'A Review of the Development of Basketry, Braiding, Crochet, and Felting towards the Creation of Seamless Fashion', *Research Journal of Textile and Apparel*, 8(2), pp. 65-75.

NG, F. M. C., Hu, J., Szeto, Y.-C. and Wang, X. (2007) 'Integrated Design of Seamless Fashion in Woven Textile with Multilayer', *Research Journal of Textile and Apparel*, 11(2), pp. 67-74.

Ng, M. C. F., Xueqin, W., Jinlian, H. and Szeto, Y.-c. (2010) 'Shapeable Stretch Textiles via Compound Weaves for Seamless Woven Fashion', 80, pp. 1191-1200.

Oxford English Dictionary, (2018a) Online: @OxfordWords [Online]. Available at: <https://en.oxforddictionaries.com/definition/convertible>.

Oxford English Dictionary, (2018b) Online: @OxfordWords [Online]. Available at: <https://en.oxforddictionaries.com/definition/transform>.

Oxford English Dictionary, (2018c) Online: @OxfordWords [Online]. Available at: <https://en.oxforddictionaries.com/definition/versatile>.

Paget, N. (2017) *Transformable*. [Online]. Available at: https://www.wgsn.com/content/board_viewer/#/70392/page/1 (Accessed: 25 June 2018).

Piper, A. and Townsend, K. (2016) 'Crafting the Composite Garment: The role of hand weaving in digital creation', *Journal of Textile Design Research and Practice*, pp. 1-24.

Pirc, U., Vidmar, M., Mozer, A. and Kržan, A. (2016) 'Emissions of microplastic fibers from microfiber fleece during domestic washing', *Environmental Science and Pollution Research*, 23(21), pp. 22206-22211.

Rathinamoorthy, R. (2019) 'Circular fashion', in Muthu, S. S. (ed.) *Circular economy in textiles and apparel*. Duxford: Duxford : Woodhead Pub. (Chapter 2).

Refinity (2009) *Fragment textiles*. Online: Refinity, [Figure]. Available at: <http://en.refinity.eu/fragment-textiles.html>.

Richards, A. (2012) *Weaving Textiles That Shape Themselves*. United Kingdom: The Crowood Press Ltd.

RMIT Gallery (2010) *The Endless Garment: The New Craft of Machine Knitting*. [Exhibition]. Available at: <https://rmitgallery.com/exhibitions/the-endless-garment/> (Accessed: 15 June 2018).

Rodie, J. B. (2012) 'Merino Wool: Performance For All Seasons', *Textile World*, 162(2), p. 46.

Ross, A. (2018) *Outerwear: S/S 19 Category Update*. [Online]. Available at: https://www.wgsn.com/content/board_viewer/#/78455/page/8 (Accessed: 25 June 2018).

Schleunig, S., Wilson, M. and Zijpp, S. (2018) *Iris van Herpen: Transforming Fashion*. [Exhibition]. Available at: <https://www.rom.on.ca/en/iris> (Accessed: 6 July 2018).

Schofield, S. and Kilfoyle, S. (2014) *ENTANGLED: FIBER TO FELT TO FASHION*. [Exhibition]. Available at: <https://www.kent.edu/museum/entangled-fiber-felt-fashion> (Accessed: 5 May 2018).

Selby, M. (2012) *Contemporary weaving patterns*. London: A & C Black Publishers.

Seyam, A.-F., Saleh, S., Sharkas, M. and Abouhashish, H. (2014) 'Shaped Seamless Woven Garments', *Research Journal of Textile and Apparel*, 18(2), pp. 96-107.

Shima Seiki (2018) *Company-History*. [Online]. Available at: <http://www.shimaseiki.com/company/history/> (Accessed: 14 June 2018).

Silverman, D. (2013) *Doing qualitative research: a practical handbook / David Silverman*. 4th edn. London: Sage.

Simpson, W. S. (2002) 'Wool production and fibre marketing', in Simpson, W. S. and Crawshaw, G. H. (eds.) *Wool : science and technology*. North America: Woodhead Publishing Ltd and CRC Press LLC.

Stappers, P. J. (2007) 'Doing design as a part of doing research', *Design research now*, pp. 81-91.

Sustainable Apparel Coalition (2019) *The Higg Index / Sustainable Apparel Coalition*. [Online]. Available at: <https://apparelcoalition.org/the-higg-index/> (Accessed: 12 March 2019).

Swann, C. (2002) 'Action Research and the Practice of Design', *Design Issues*, 18(1), pp. 49-61.

Taylor, J. and Townsend, K. (2014) 'Reprogramming the hand: Bridging the craft skills gap in 3D/digital fashion knitwear design', *Craft Research*, 5(2), pp. 155-174.

Tellier-Loumagne, F. (2005) *The art of knitting : inspirational stitches, textures and surfaces* London: Thames and Hudson.

Tellier-Loumagne, F. (2008) *The art of felt : inspirational designs, textures and surfaces*. London: Thames and Hudson.

Tobler-Rohr, M. I. (2011) *Handbook of sustainable textile production*. Philadelphia: In association with the Textile Institute.

Turley, D. B., Horne, M., Blackburn, R. S., Stott, E., Laybourn, S. R., Copeland, J. E. and Harwood, J. (2009) *The role and business case for existing and emerging fibres in sustainable clothing: final report to the Department for Environment, Food and Rural Affairs (DEFRA)*. London, UK. Available at: http://randd.defra.gov.uk/Document.aspx?Document=EV0420_9092_FRP.pdf (Accessed: 12 March 2019).

Udale, J. (2014) *Fashion knitwear / by Jenny Udale*. London: London: Laurence King.

UK Trade & Investment (2014) *Armadillo Merino wins contracts to supply t-shirts to NASA - GOV.UK*. [Online]. Available at: <https://www.gov.uk/government/news/armadillo-merino-wins-contracts-to-supply-t-shirts-to-nasa> (Accessed: 10 September 2017).

Uğur, S. (2013) *Wearing embodied emotions: A practice based design research on wearable technology*. Milan, Italy: Springer.

Vera, D., M. (2018) *Zephora top*. [Online]. Available at: <https://www.denissemvera.com/collections/all/products/zephora-top> (Accessed: 13 June 2018).

Vezzoli, C. and Manzini, E. (2008) *Design for Environmental Sustainability*. London: Springer.

Violette, R. (2011) *Hussein Chalayan / edited by Robert Violette*. New York, N.Y.: New York, N.Y. : Rizzoli.

Virtanen, M., Manskinen, K. and Eerola, S. (2017) 'Circular Material Library. An Innovative Tool to Design Circular Economy', *The Design Journal*, 20(sup1), pp. 1611-1619.

Vuletich, C. (2015) *Transitional Textiles: A Crafts Based Exploration of Fashion Textile Design Practice and Values for New Roles in a Sustainable Industry*. PhD thesis. University of the Arts, London.

Wada (2002) *Memory on cloth : Shibori now / by Yoshiko Iwamoto Wada*. Tokyo: Kodansha International.

Wada, Y. I., Rice, K. M. and Barton, J. (2011) *Shibori : the inventive art of Japanese shaped resist dyeing : tradition techniques innovation*. US ed. edn. New York: Kodansha USA.

Wang, X. (2010) *Creation of Seamless Woven Fashion via Jacquard Technology*. PhD thesis. The Hong Kong Polytechnic University.

Wang, X., Ng, F. M. C. and Hu, J. (2013) '3D Seamless Woven Fashion Based on New Concept and Technology', *Research Journal of Textile and Apparel*, 17(3), pp. 13-19.

Wang, X., Ng, F. M. C., Hu, J. and Seto, Y.-c. (2009) 'Shapeable Stretch Textiles via Simple Weaves for Seamless Woven Fashion', 79, pp. 1715-1724.

Wilson, A. (2006) 'Marketing research: An integrated approach', *marketing research*, 15(17), pp. 17-18.

WRAP (2012) *Valuing our clothes-The true cost of how we design, use and dispose of clothing in UK*. [Online]. Available at: <http://www.wrap.org.uk/sites/files/wrap/VoC%20FINAL%20online%202012%2007%2011.pdf> (Accessed: 2015/11/16) (Accessed: 16 November 2015).

Yang, S. (2010) *A creative journey developing an integrated high-fashion knitwear development process using computerized seamless v-bed knitting systems*. PhD thesis. Curtin University of Technology.

Zheng, T., Li, S., Jing, S. and Ou, Y. (2013) 'Designing of 3D woven integrated T-joint tube', *Textile Research Journal*, 83(11), pp. 1143-1155.

Zuber-Skerritt, O. (2011) *Action leadership: Towards a participatory paradigm (6)*. Dordrecht: Springer.