CAPTURING LOFT

Capturing Loft: Adding value to New Zealand wool bedding products through textile design innovation

An Exegesis in Partial Fulfilment towards a Master of Design

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This design-led research project was developed in collaboration with the Christchurch-based bedding manufacturing firm FibreTech New Zealand Limited. It explored the potential of an innovative wool-fill product developed by FibreTech. This new wool-fill maximises loft and bulk, both key factors for warmth and comfort in bedding. Loft is an active, three-dimensional feature of bedding, controlled through processes of compression and release. Retaining and managing loft was vital.

The designer provided a holistic approach, using a textile design perspective to explore functionality and aesthetics in relation to the structure of the fill and outer membrane layers of bedding products. Through material sampling the project assessed how FibreTech's new wool product could be layered and bonded with other textiles. The technical processes of needle punching, fusing and stitch bonding were used to explore the loft and compression relationship within the textiles. It was found that ratios of loft and compression could be altered to improve the efficiency of manufacturing; while at the same time optimising functionality and aesthetics.

Using the existing manufacturing process of digital quilting, stitch paths were redesigned to create an innovative range of bedding products for use over and under the body. The resulting textiles revealed a departure from classic bedding construction, with a new focus on controlling the stitch line through computer-aided design (CAD) technology. This hard-edged stitch line was a digital imposition that contrasted with the organic nature of soft, lofted materials. This visual and haptic tension was identified as key design interplay for both overbody and underbody approaches. Strategies were created towards lightweight overbody bedding and engineered shaping of underbody bedding. These new digital quilting strategies captured loft in distinctly different, yet functional ways.

This project provides evidence that a textile designer can be a key contributor in the manufacturing industry, along with other disciplines such as science and engineering to add value to research and development in the New Zealand wool textile manufacturing industry. The design research progressed as a Callaghan Innovation Postgraduate Fellowship project and represents the development of a new aesthetic for wool bedding products.

Key words:

Textile design, wool knops, knoppy web, New Zealand wool, loft, overbody bedding, underbody bedding, sampling, research and development, digital quilting, computer-aided design

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INTRODUCTION

Capturing Loft explored the notion that bedding is constructed using techniques of tension through connection, compression and release. Falling asleep is signified by a release of tension. Nancy (2009) pulls us into the depth of falling asleep, revealing that sleep is both active and inactive:

> *This fall is the fall of a tension, it is a relaxation that is not content with an inferior, limited degree of tension but that sinks down toward an infinitesimal proximity to degree zero: until that underlying closeness to simple inertia that we know in the bodies of sleeping infants, which we sometimes recognize when on the edge of sleep we can feel that we are beginning to stop feeling the basic energy of our bodies. We feel the suspense of feeling. We feel ourselves falling, we feel the fall. (Jean–Luc Nancy (2009) Fall of Sleep p. 3)*

This observation evokes soft, bulky bedding layers that surround the body in sleep. In use the resting body presses, squashes, pulls, tugs and shapes bedding into distortion. Bedding is activated and deactivated by the presence of the body. Even without the body, however, these bulky textiles will still hold three-dimensional form.

This design-led research project was developed in collaboration with FibreTech New Zealand Limited, a Christchurch-based wool manufacturing firm specialising in bedding. FibreTech is involved in research and development of an innovative new wool-fill product. This product is unique because it does not flatten like traditional wool fill. The fill is made of soft wool clusters, referred to as ‘knops’, processed into a wadding form or ‘knoppy web’ (see Figure 1.). Knoppy web can be described as a thick, interconnected, flexible textile layer that holds its shape. Wool is a compelling bedding material because it naturally breathes, regulates humidity, insulates and is hypoallergenic. The invention of this innovative new product provided the catalyst for FibreTech to seek design expertise to explore its potential.

Design research progressed as a Callaghan Innovation Postgraduate Fellowship, providing the project with funding and a travel grant for onsite factory visits in Christchurch. FibreTech provided industry mentoring from Executive Director Peter Sheldon, access to factory machinery and soft wool knop fill in various forms. Like many small New Zealand manufacturing firms, FibreTech had not engaged with a designer before this partnership (Sheldon, P. 2013, personal communication). A similar grant was awarded by Callaghan Innovation for science PhD student Jack Grigg from Lincoln University to research soft wool knops (due for completion in 2015), offering an excellent opportunity for design and science disciplines to work closely together.

The most important components to this industrial collaboration were wool knops and knoppy web, loft, wool as a bedding material, overbody bedding and underbody bedding. Wool knops are small soft spheres of New Zealand wool, produced using nonwoven processes at FibreTech’s Christchurch factory. These knops make excellent bulk fill when clustered together. While they originally only existed in loose form, research and development initiatives have resulted in the development of a new knop product – a stable wadding or ‘knoppy web’ with the soft wool knops arranged in a thick sheet formation. The new development involves nonwoven processes and introducing a small percentage of a specific renewable fibre into the product. The aim of this development was to overcome drawbacks in wool bedding that include fibre migration, poor bulk, poor washability and poor recovery from compression. Initial testing by Grigg (2013) suggests marked improvement in these areas. The application of design to retain loft and prevent unnecessary flattening of wool bedding was central throughout this project.

I am a designer and researcher with a BDes (Hons) in textile design. My previous research had explored the intimate space of the home interior through phenomenological inquiry, linking design decisions directly to stories and material culture. *Capturing Loft* was different because it departed from narrative. During this project I had to consider manufacturing, performance criteria and testing results, which expanded my own skills as a designer. Textile form was found through iterative and experiential research, drawing inspiration from the sampling processes and the nature of the bulky materials used.

I used my own personal reflections while resting in bed or relaxing on the couch to self-evaluate the experience of soft, bulky bedding. Was there really a design project to be found through something as customary as a duvet inner or cushioning? What were my own preconceptions? I observed that these textiles provided a safe and familiar soft cocoon, an encapsulating rapture and warmth that thin, flat materials simply could not offer. These humble textiles were well known within the everyday and very ordinary realm of the bedroom and a place of rest – the bed. Further, bedding was a universal tool of comfort managed individually through the seasonal shifts of different layers of texture and weight. Using the model of layering, this research endeavoured to find out how this new wool-fill product could be applied as a key layer for bedding use.

Figure 1: Types of wool knop fill developed

Image 1. *Single wool knop*

2. *Loose wool knops*

3. *Large wool knop (original development)*

4. *Fine knoppy web (original development)*

5. *Lot 2 - underbody (Grigg, 2013)*

6. *Lot 4 - underbody (Grigg, 2013)*

7. *Lot 5 - overbody (Grigg, 2013)*

8. *Lot 6- overbody (Grigg, 2013)*

Loft is the most significant feature of bulky insulation products and is key to the performance of knoppy web. According to The Textile Institute (2002) 'Loft or Lofty' is a term applied to an "assemblage of fibres to denote a relatively high degree of openness and resilience, or a large volume for a given mass". Other industry resources such as the Association of the Nonwovens Industry (INDA, n.d.) use the term 'Highloft,' with specific dimensional criteria, relating to a ratio of volume to weight. For this project the term 'Loft' will be used rather than 'Highloft'.

As wool knops are made from wool fibre, it is important to establish the benefits and disadvantages of wool as a bedding material. Wool is a protein-based, natural fibre that offers a unique combination of properties resulting in a healthy and safe textile, ideal for the home environment. Properties relevant to bedding include breathability, humidity control, fire resistance, being hypoallergenic, resiliency and insulating qualities. The use of wool in bedding achieves a comfortable micro-climate that promotes better and longer sleep despite variations of climate (International Wool Textile Organisation, 2011; Woolmark Ltd. 2011). Scientific research shows wool regulates body temperature and moisture-humidity (Umbach, 1986 as cited in Woolmark Ltd. 2012) and provides a superior sleeping and resting base that aids pressure on the skin and muscles (Mistiaen et al, 2010). As different sheep breeds produce different types of wool, breeding is of particular importance to the quality and characteristics of wool produced. Soft wool knops use a variety of wool types (mostly mid-micron to coarse types) depending on the end use. Through current market research, it was found that wool-filled bedding was positioned as a 'natural option' generally priced at mid to high range, between feather and down and synthetic 'microfibre' fills. Traditional wool fill, however, has a disadvantage of compacting and felting with washing, losing its lofted, bulky features.

'Overbody' and 'underbody' bedding are terms used in industry to distinguish between bedding products and are used throughout this project. Overbody bedding describes textile products such as blankets, comforters, duvets and quilts that rest on top of the body for insulation. It is sometimes referred to as 'upperbody' bedding. This project will refer to this bedding type as overbody, as this is term used by FibreTech. The criteria for overbody bedding include consideration of warmth, breathability, handle, drape and weight. The knoppy web developed for overbody is made from fine wool knops. It feels lightweight, soft and has a good drape (see Lots 5 and 6).

Underbody bedding, in contrast, describes bedding products that provide a soft base for underneath the body, such as mattress ticking, mattress toppers, underlays and futon layering. The criteria for underbody bedding development include consideration of breathability, comfort and resilience to compression. Underbody can also extend to other end uses where a soft layer is required, such as cushioning and furniture upholstery. The knoppy web developed for underbody is dense and firm, made from larger knops with good recovery from compression (see Lots 2 and 4).

Retaining loft is especially relevant for both overbody and underbody bedding, which require the ability to provide warmth and comfort respectively. Loft can be described as an active feature of a textile product encapsulating air and space. This trapped 'dead space' is significant because it creates an insulating barrier (Johnson & Cohen, 2010). Applying external pressure changes the form of the lofted textile, pushing air out; however, by retaining loft, the textile has the ability to 'move' and bounce back to its original state. This is why the new development of a wool fill that maintains its loft is very significant to the use of wool for bedding. In a compressed state the structure has areas of denseness and holds tension. Air-filled lofted areas and dense compressed areas of the textile can be manipulated and controlled using subsequent nonwoven bonding processes such as needle punching, fusing and stitch bonding to create three-dimensional shaping. This loft, compression and release relationship was a key area of design research for this project.

This project set out to address the following questions:

How can value be added to the 'knoppy web' developed by FibreTech, using a textile design approach for new lofted, three-dimensional, sandwich-structured textiles? How can knoppy web be used in overbody and underbody bedding? Were there unique physical aspects of the new fill that could be discovered?

How can the design process be integrated into existing nonwoven manufacturing processes and industry approaches (such as needle punching, fusing and stitch bonding)? What aesthetics can be achieved by utilising programming of advanced computer quilting software in the design process?

What is 'bedding'? What aspects of existing, well-known bedding systems (underbody and overbody bedding) can be built on or redesigned? What are current and future trends in this area? What are the existing (and potential) materials/fibres used in bedding?

And finally, can textile design research contribute to a New Zealand wool industry research and development project through industry collaboration?

These research questions were investigated through contextual research and materially responsive sampling. Research began by establishing wool as a bedding material, examining opportunities for adding value to New Zealand wool and identifying current bedding manufacturing approaches.
The concept of bonded, multilayered textiles, or 'sandwich-structured textiles', was identified as a key strategy in the creation of bulky bedding products. Research into 'sandwich-structured textiles' showed that although the material selection of outer layers of traditional woven or knit fabric with new nonwoven fill was important, it was the specific way in which these layers were connected that had a considerable aesthetic and functional impact on the new bonded textile. Contemporary design examples showed how bulky textiles and bedding objects could be elevated through design. A patent search was then carried out using keywords – 'wool', 'bedding construction' and 'sandwich-structured' – as a way of investigating recent technological developments in the area. This contextual knowledge informed design decisions through the selection of processes and alternative materials during the sampling to explore the potential of knoppy web.

An iterative and experimental design method was used in *Capturing Loft*. This method involved creating material samples in series and critically evaluating them before further progression. The evaluation process included observations during the production, photographing and using haptic methods such as squashing or draping the textile to gain further insight. The samples were evaluated on the basis of their aesthetic qualities and meeting performance criteria relevant to overbody or underbody bedding use.

This approach was exploratory, yet very reflective. The sampling strategy enabled ideas to be tested and evaluated, after which it was possible to carry out further research into related theory or revisit past samples. Each sampling stage informed the next iteration of speculative design work. Visual workbooks, mood boards and a digital diary (Evernote) were used to record individual samples and technical notes. Responding to the notions of Sir Christopher Frayling (1993), this project could be described as research through design, as opposed to research into or for design. *Capturing Loft* worked through processes and conveyed results through artefacts.

As a collaborative project with industry funding, predetermined objectives were defined through the Callaghan Innovation Fellowship (see Figure 2.). Although these objectives provided linear direction, in practice it was necessary to revisit literature and past samples regularly. This framework provided structure for working with FibreTech onsite with a total of six trips made to Christchurch from Wellington. Industry mentor Peter Sheldon provided industry support during these visits, which involved critiquing recent samples and introducing new developments with knoppy web.

The context of working with an industry partner meant design decisions were negotiated in consideration of commercial viability. Processes of needle punching, stitch bonding and fusing were explored at an early stage through relatively low-tech methods, and creating the textile in this way often involved numerous steps. In contrast, FibreTech was already using industrial quilting in the constructing of bedding. It was therefore decided that intervention through computer-aided design (CAD) controlled quilting, an existing factory process used primarily for securing duvet layers together, was the best direction for further exploration.

Thus instead of adding processes requiring the purchase of additional machinery, an existing process was reviewed, challenged, shifted and refined using the iterative design process. In order to change the existing designs, I had to learn how to programme and operate the Dolphin quilting machine using computer-aided design. Conceptual shifts in the digital quilting design and how the machinery was used influenced the potential products that could be made and further potential uses of the machinery itself.

Important factors changed as the project progressed. The first was the evolution of the knoppy web being developed by FibreTech and Grigg (2013). The second was FibreTech's ongoing considerations of export markets, from the USA to China and Japan. These markets have different climates and cultural expectations relating to bedding use (Kroemer, 2009, p. 307). These were important factors to consider when evaluating samples, as they both involve the material and context for use. It was decided that samples would remain speculative and design-led through materials available at the time. FibreTech supported this approach (*Onsite visit # 1*, March) as it recognised the concept/idea using knoppy web fill produced during this project would form a strong foundation for further developments in future.

Overall, sampling progressed through four iterative stages. Figure 3. gives an outline of sampling stages that will be highlighted in this exegesis.

Figure 2. **Callaghan Innovation Objectives + Onsite visits to FibreTech**

Contextualisation

Objective 1
Scoping of Project

Objective 2
Literature Review

- March - *Onsite visit #1*

Design

Objective 3
Existing Technology

- May - *Onsite visit #2*

Objective 4
Changing and Redirecting Existing Technological Process

- July - *Onsite visit #3*

- August - *Onsite visit #4*

Objective 5
Confluence of Speculative Design and Integrative Technology and Material Processes

- September - *Onsite visit #5*

- October - Peter Sheldon visits Massey in Wellington

- November - *Onsite visit #6*

Review

Objective 6
Analysis + Summary of Findings

Figure 3. **Iterative Sampling Stages**

Stage 1
Low tech experimentation

Experimentation of loft and compression using a variety of nonwoven processes and materials

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Stage 2
Computer aided design CAD controlled quilting sampler

Introduction of digital quilting

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Stage 3
Building blocks

Expansion of knoppy web overbody and underbody directions through digital quilting stitchline

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Stage 4
Speculative overbody and underbody design strategies

Overbody:	Underbody:
Intersect	Verge
Echo	Tension
Undulation	Terrain
Open/closed	

Ongoing design research during sampling

Literature

Original design exploration: colour, tension, graphic/soft, breaking apart the grid through visual workbook and mood board exploration

Market opportunities/trends

Performance testing research

Critique from FibreTech

DESIGN RESEARCH

The wool industry in New Zealand would benefit from the development of wool for bedding. According to Nicol and Saunders of Te Ara Encyclopedia of New Zealand (2012) 68 per cent of New Zealand wool is used for interior textiles, with bedding accounting for less than 6 per cent of these products.

> *Wool has been a less important export earner for New Zealand since the 1990s. As a percentage of total exports, wool fell from 26 per cent in 1920 to 1.6 per cent in 2011. Sheep farmers have switched their focus from wool to sheepmeat as meat prices have risen, relative to total export prices, and wool prices have fallen. (Statistics New Zealand, 2011)*

As Statistics New Zealand suggests, the importance of wool as an export product has declined. Years ago the felted wool blanket gave way to the comforter (sometimes referred to as a duvet) because of the latter's superior loft. Two popular fill choices used in these bedding products are not always ideal such as synthetic fill, which is affordable but does not breathe, and feather and down fill, despite having high loft, is expensive and highly allergenic. The unique qualities of knoppy web provided the opportunity to revisit wool for overbody and underbody bedding and offer more opportunities to expand export market for New Zealand wool beyond carpets and rugs.

Over recent years there has been a renewed push to add value to the New Zealand wool clip. This trend has implications for research involved with wool, as more integrated, partnership-based relationships between woolgrowers and the market are developed. The merino wool sector of the New Zealand wool clip is performing well for end use in apparel, however, this sector accounts for less than ten per cent of the total New Zealand wool (Faulkner, 2012). Over ninety per cent of New Zealand wool is mid-micron and coarse wool. This wool remains underperforming in price and underrepresented due to the disestablishment of the Wool Board in the early 2000s.

The value of mid-micron and course wool as a strong, resilient, bulky material has not yet been fully realised. Various types of wool, depending on overbody or underbody requirements, are used in the production of soft wool knops. Mid-micron wool is the common type of wool used in overbody bedding due to its excellent combination of resilience and softness (Sheldon, personal communication, 2013), while coarser grades of wool are suitable for underbody due its capacity to recover from compression. This shows a relationship between the characteristics of the product and type of wool required for optimum performance. Two recent wool-use initiatives will be discussed: Wool Research Organisation's recent collaboration with F212, a New York-based marketing firm, and The Campaign for Wool. These initiatives articulate the benefits of wool as a resilient and practical natural resource with a diverse range of end uses.

Three reports from the Wool Industry Network (2007), Wool Taskforce (2010), Conforte, Dunlop and Garnevska (2011) all recognise the need to add value to what can be described as this 'struggling' mid-micron and coarse wool sector, which dominates New Zealand wool production. These reports highlight the intense competition from synthetic alternatives and the need to push demand for wool products. Farmer Hamish de Latour, of the Hawkes Bay, was recently featured on television series Country Calendar stating, "Nobody on this farm is allowed to wear polar fleece… I can't believe they've been allowed to even call it fleece. The synthetic industry has done us for dinner and we've sat there and let them get away with it." (Edmond, 2013). De Latour is part of Elder's Wool 'Just Shorn' branding campaign and involved with the export market promotion of wool carpeting. Opportunities for adding value to mid-micron and coarse wool include promoting partnership models for a more direct path to market; diversification of the end use outside carpeting and rugs; exploiting the inherent properties of particular wool types; and investing in research and development.

Sandra Faulkner's report Hello New Zealand Wool – This is the Future Speaking (2012) highlights a fragmented New Zealand wool industry. Faulkner is a Gisborne-based woolgrower and was awarded the Nuffield Fellowship to research challenges facing New Zealand wool industry. She sets out a case for amalgamation among woolgrowers to secure their future earning potential and to better promote the New Zealand wool 'brand' internationally:

> *Merino New Zealand have proven that creating an energetic, proactive environment for their growers improves the value gained by them from the fine wool industry. Unfortunately [Merino New Zealand] only act on behalf of 8% of the total clip – albeit 25% of the income. (p. 9)*

Due to low returns for wool at auction, the majority of sheep farmers view shearing as a by-product of meat production as an animal health maintenance cost. Faulkner argues it is imperative that farmers retain ownership of the wool through the processing stage, with a pathway to retail – adding value and traceability, and maintaining quality control. Recent initiatives by Wools of New Zealand (Laneve) and another New Zealand firm, Elders Wool (Just Shorn), have used similar strategies to promote wool as a sustainable luxury fibre for carpets and rugs. These parallel campaigns show a fractured 'strong' wool industry competing against itself, instead of working together for mutual benefit to increase global New Zealand wool demand. Faulkner suggests wool industry representation could provide funding for advocacy and market access, extension and information transfer, administration and governance capabilities. It could also provide funding for Campaign for Wool, research and development that would promote industry-wide benefits. Overall, the report argues that the New Zealand wool industry will have to undergo immense change from a passive approach to a more hands-on approach in order to add value to wool exports; however, Faulkner does not identify the role design can play in research and development.

F212 Wool Research collaboration for finding alternative uses for wool

New York-based marketing company Fahrenheit 212 (F212) was contracted by Wool Research Organisation New Zealand in 2011 to propose new product directions for wool, based on innovations developed in New Zealand. These directions would provide alternatives to carpeting and rug end use. The four product directions identified were beauty care applications, active apparel applications, bedding and infant textiles. Due to commercial sensitivity there has only been a small amount published to date about the outcomes of the research, however it can be assumed more will be published about the venture as commercialisation arrangements are reached. F212 information was available onsite at FibreTech (March, 2013) and I was able to view the information but unable to record or photograph it due to confidentiality agreements.

The Campaign for Wool

A recent opportunity for the wool sector has been the International Campaign for Wool. The organisation was launched globally in 2010 by Patron HRH The Prince of Wales and has a strong presence in New Zealand. The Campaign shares the wool 'story' with the wider public and provides resources to the users of wool. Faulkner (2012) acknowledged the efforts of the organisation to promote coarser grades of wool: "In 2013, the focus is on elevating woollen furnishing textiles into the same space as Merino apparel – serviceable and user-friendly and yet luxurious and elite." (p. 20). Although well intentioned, the elevation of wool furnishings did not find traction in New Zealand. It is viewed as a missed opportunity that should be revisited in the future.

At its heart, *Capturing Loft* explores bedding as an ideal end use for a range of New Zealand wool types. It uses textile design to add value through the manufacturing process, highlighting the need to incorporate design into a key strategy for research and development within the New Zealand wool sector.

Market research into the bedding industry showed that fibre type and structure are important to quality and performance of bedding products. Manufacturing firms Billerbeck and Innofa were identified as leaders in their fields and research into these companies offered further insight for overbody and underbody use respectively. Onsite research at FibreTech's factory outlined how bedding is currently produced.

Billerbeck, based in Germany, is a sleep research-led bedding manufacturer. This company used fill fibre-type as the main strategy for distinguishing between products and suitable end uses. Bedding products were separated into 'down' (feather and down), 'natural' (animal hair/wool, cotton) and 'fibre' (man-made/synthetic fibres) indicating the fill used. Billerbeck's product line also provided different weights for different seasons – showing that one material combination could have various end uses dependent on structure. Billerbeck is also heavily involved sleep research, with findings found through their own clinical research centre supporting product development. By taking an active role in the science of sleep and endeavouring to understand how good sleep is achieved, Billerbeck has successfully placed its bedding product within a 'wellbeing' context.

Innofa, a textile manufacturer based in the Netherlands, displays the importance of the outer layer instead of fill-type. This company produces stretch fabric using four-way knit structures to create textiles that curve evenly when quilted. These were applied mainly to mattress ticking, but had started to cross over into other areas such as furniture upholstery, automobile upholstery and medical textiles. Innofa's textured, three-dimensional fabric range showed that outer layers are a significant design opportunity, even for underbody, which is typically covered.

Observation of current bedding production methods at the FibreTech factory was vital in gaining understanding of bedding as a manufactured product. This scoping took place during *Onsite visit #1* in March and *Onsite visit #2* in May. During these visits the existing products, markets, customers, materials, processes and machinery were identified. Processes and machinery will be discussed in further detail in the 'Sampling Journey' section (pg. 18).

According to Peter Sheldon, Executive Director of FibreTech, the company is placed in the "mid to high end" of the bedding market, producing products for a "niche" market not mass market (personal communication, March, 2013). This is due to the use of natural fibres such as wool, possum and alpaca, which are widely available in New Zealand but not else where in the world. Wool knops are also blended with feather and down. In the bedding market, feather and down fill is considered high end and synthetic fill low end based on price point and perceived quality. Wool is an excellent alternative to feather and down due to its low allergenic qualities and insulating properties -- and is also more affordable, placing it in the mid to high section of the market.

FibreTech focuses on the export market and is a 'business to business' company involved in New Zealand's wool processing supply chain. It runs four divisions, as shown in Figure 4:

Figure 4.

FibreTech New Zealand Limited

Woolfill	**Nimbus Bedding**	**Contract Quilting**	**Bias Binding**
Manufacturing of wool into nonwoven fill products often blending wool with other natural fibres such as possum, alpaca and feather and down	A New Zealand bedding brand manufactured onsite for a retailer/ distributor or hospitality industry customer	Quilting using gear and digitally controlled quilting as a service for customers	Manufacturing of bias binding

Nimbus Bedding, Woolfill, Contract Quilting and Bias Binding work together at the Christchurch factory to provide manufacturing capability for the different stages of the bedding production. FibreTech's direct customer, a retailer or an export distributor, is different to the end user. The customer may order finished products such as Nimbus Bedding, components from Woolfill or Bias Binding, or a service from Contract Quilting. The bedding products currently produced by Nimbus Bedding are of a high-quality but traditional or classic in style. The range includes mattress ticking, mattress toppers, duvets, pillows, reversible underlays and futon mattresses. They also produce infant bedding including bassinet mattresses, underlays and blanketing.

I was able to view and handle FibreTech's full range of bedding in person during onsite visits. This haptic experience was very important because it helped to compare and contrast different samples in regards to fabric, fill and fibre type used. It became evident that bedding products involved two or three layers: a fill layer and one or two outer membrane fabrics for encasement, bonded together through quilting.

The fill layers ranged from being loose to a semi-structured sheet formation of varying weights (see Figure 5.). By handling the different fill products, it was found that the knoppy web under development was much more stable than the existing fills used by FibreTech. A range of these fill products were brought back to Wellington to be used for initial sampling.

The outer layers may provide waterproofing, act as a barrier to stop fibre migration or simply provide structural support. The outer fabric used for a majority FibreTech's overbody bedding products is a high thread count white plain or jacquard woven cotton referred to as 'down-proof cotton'. This fibre is soft to touch but has a waxy, dense handle that immediately gives the impression it should be covered by another layer, such as a duvet cover. It was determined that traditional wool fill is treated like feather and down, and uses a high thread count outer fabric to prevent fibres escaping. An elasticised cotton-blend knit fabric was used typically for underbody products with a lightweight polypropylene nonwoven base layer. This showed that the top side, which faces the body, was the focus of underbody outer layers. The reverse side was added for quilting purposes so the fill did not get stuck in the machinery.

During *Onsite visit #2* in May, FibreTech outlined key performance criteria to be observed during the evaluation of samples (see Figure 6.). A new line of inquiry emerged by re-examining the existing materials through the introduction of knoppy web as the internal layer. For overbody, could the outer layers be changed to an open or loose weave or knit instead of down-proof cotton? Potentially this could result in a lighter product with better drape or handle. Could the shell be constructed out of knit merino wool? The resulting product could gain the excellent natural properties of soft and resilient of merino wool currently used in apparel. Could the knoppy web be exposed on one side? Would the wadding be soft enough on the skin? What structural fabric matrix is required through layering? How can colour and pattern be introduced? Quilting, printing, dyeing and texture could be explored but this would mean the idea of an 'inner' would change. For underbody, could an outer layer made of wool further promote performance criteria? Were multiple fill layers of fill required to add bulk? Through material sampling, it was possible to test these queries, determining which areas could be further developed or disregarded.

Figure 5.

Natural fill Products

Loose form:
Loose wool knops
Feather and down

Semi-structured batting:
• Wool knops
• Alpaca and wool knops
• Possum and wool knops

Figure 6.

Key Performance Criteria as Outlined by FibreTech

Overbody:
• Insulation qualities
• Weight (300gsm optimal)
• Drape
• Loft retention

Underbody:
• Support
• Air circulation
• Compression recoverability

Multilayered bedding is a form of 'sandwich-structured textiles', an area of textiles that create new textiles through the connection of layers. The concept of sandwich-structured textiles was important for designing bedding with internal wadding and external outer fabrics because the nonwoven knoppy web was too structurally weak to perform as a bedding product on its own.

'Composite nonwovens', an umbrella term which includes sandwich-structured textiles, forms a broad field of secondary nonwoven production that develops through combination of layers, coatings, blending fibre type, mixing different fibre structures or adding multiple manufacturing processes to enhance properties required for end use application (Das et al, 2012). Batra and Pourdeyhimi (2012) described multi-layered nonwovens as 'Tertiary Nonwovens' or 'Higher Order Structures,' stating:

These structures are the result of combining two or more primary and/or secondary structures, at least one of which is a recognised flexible, fibrous structure, to obtain a new unified/integrated structure. Examples are stitch-bonded structures, SMS, tufted carpets, and scrim reinforced needle punched structures. In most cases, the resulting performance characteristics are not attainable by the component structures themselves. (p.9)

A 'composite nonwoven' design for bedding can be formed through the attachment of traditional textiles to nonwovens (Das et al., 2012). Although the outer membranes of the textile may be woven or knitted, the stitch-bonding process through digital quilting, formed a new sandwich-structure that was influenced by not only what materials were in combination but how it had been connected.

FibreTech's knoppy web falls into a niche area of fill materials. Natural fibres are not generally used in the manufacturing of nonwoven fill. In 1999 for instance, only 2 per cent of worldwide nonwovens were made from natural fibres, with the remaining 98 per cent using manmade fibres, mostly polypropylene and polyester (Wulholst, 2006, p.168). Natural fibres are a compelling option due to their biodegradability and renewability, and as they can be recycled (Das et al. 2012). Their primary drawback compared to continuous man-made fibres is the extra cost of processing the non-uniform raw fibre.

In the sandwich-structure layering system, the knoppy web could provide internal bulk and loft. However, the outer layers required different qualities as they were in contact with the body and skin. To complement the natural qualities of wool, FibreTech requested the use of natural fabrics, rather than synthetics, in the outer layers of any bedding designs (personal communication, May, 2013). Cotton, linen and wool were researched, sampled and selected with an emphasis on the material weave or knit structure, depending on their end use: overbody or underbody.

The three bonding techniques for connecting layers were explored in this project: needle punching, fusing and stitch bonding. The following information (Figure 7.) indicates how the inner and outer layers can be connected through these processes.

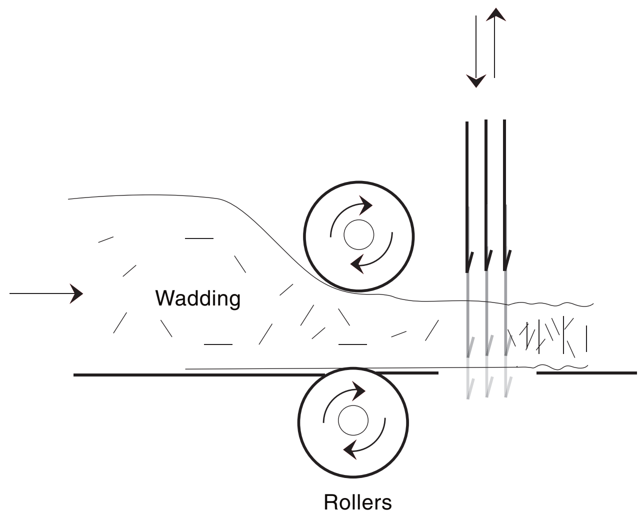
As shown, these processes compress the lofted fill to some extent, resulting in tensioned areas. Through research into sandwich-structured textiles it was found the design approach would have to be sensitive to the loft/compression relationship as it had an impact on both aesthetic and functional qualities of the product, resulting in a new textile that differed from its original component layers.

Design examples using multilayered textiles, from furniture design to homeware design using digital tools, were researched. Three contemporary designer examples, Patricia Urquila, Inga Sempé and Meg Callahan, showed the opportunity of design to transform three-dimensional sandwich-structured textiles (see Appendix 2, page 83). These examples gave strong indication that the structure of lofted, soft textiles can be sensitively altered with purpose.

Figure 7.

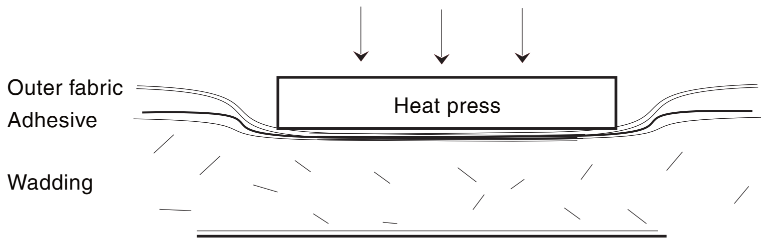
Needle punching

Using multiple barbed needles to agitate fibre and causing entanglement. Needle-loom located at Massey University has been used.



Fusing

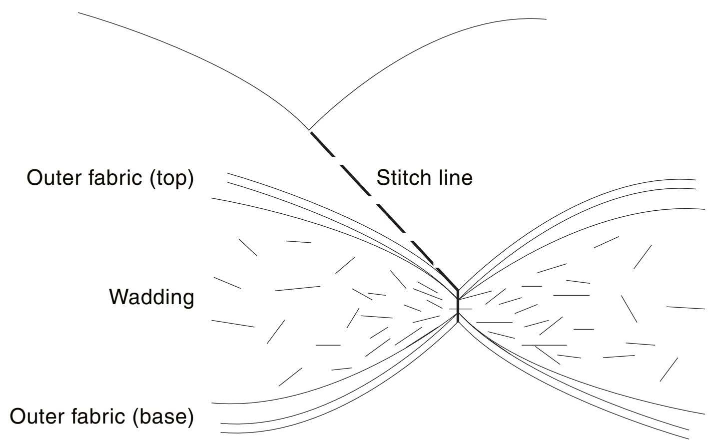
Using thermally activated adhesives to bond materials together.



Stitch bonding

Using thread and sewing techniques to bond multiple layers of material together, or use stitching on a single layer to add strength.

Digital quilting is a form of stitch bonding



A patent search was then carried out to examine technological advancement in the field of soft sandwich-structures that could be applied to bedding using keywords: ‘bedding’, ‘sandwich-structures’ and ‘nonwoven wool’. Patent applications also provided descriptive terminology and excellent background information. A review of key patent applications provided insight into hybridised processes, three-dimensional shaping and combined materials. These inventions were usually presented as a form of equipment or machinery to be used in production.

Batra and Pourdeyhimi (2012) comment, “The technologies employed in the manufacture of nonwoven fabrics, and those used to convert them into economically viable and socially useful products or their components, reveal that the study of such technologies inherently involves many disciplines and branched paths” (p.10). This introduces the importance of technology and emphasises that the skills involved are cross-disciplinary. Patent application Printing and Quilting Method Apparatus (Codos, White, Bowman, 2002) describes an integrated sandwich-structure process to make mattress ticking, which synchronises printing and quilting through a digitally controlled conveyer system. This production method was developed to overcome the challenge of coordinating quilting registration to print pattern, which are typically processed separately.

The patent review also uncovered unusual ways of manipulating layers into three-dimensional shapes. The patent application Nonwoven Spacer Fabrics (Russell et al., 2010) developed voids in filler fabric as a way of creating air pockets through compressed air or hydroentanglements. These voids could then be coated or filled with resin or foam, resulting in a more solid material, depending on the desired end use. This also related to an earlier patent application Nonwoven Fabrics having Raised Portions (William, William and Suehr, 1997), which moulded nonwoven textiles through varied entanglement to create different heights.

Combining materials through layering or blending was also of interest. Multilayer Textile Material (Moretti, 2010), developed a product with transparent, glossy polymer casing quilted to wadding, which allows the viewer or user to see through to the fill layer. The end result looked squashed and unattractive, but one can appreciate the idea of mixing natural fibres with man-made to change the texture from a traditionally opaque loft material to one that was shiny and transparent. The Luxury Fibre Blend for Use in Household Fibrefill Textile Articles patent application (Heilman and Kumm, 2008) also provided a market-savvy concept to blend ‘luxury’ fibres, such as natural fibres, with ‘ordinary’ fibres as a way to add value to synthetic fill.

This patent review showed a wide range of approaches being developed within the field of lofted textiles. These patent applications verified the importance of sandwich-structure layering and the processes involved in making the textile and material selection. These areas related specifically to the lofted, bulky nature of bedding textiles.

Four pivotal stages of sampling emerged (see Figure 8.). Initially the design process began broad in scope and gained focus through an iterative process of sampling and evaluation. Key to sampling was learning how to use the Dolphin digital quilting machine, controlled through computer-aided design or 'CAD' programming.

The first stage used low-tech experiments to gain understanding about lofted textiles. This stage was important because the effect of processes on the material could be observed immediately. A hands-on approach provided an opportunity to make changes quickly and test out a wide variety of options to see if they could be developed further.

An active sampling approach was continued through to Stage 2 when utilising FibreTech's Dolphin digital quilting machine. Involvement in all stages of production ensured a high level of understanding of the behaviour between machinery and material. This included learning CAD software developed for FibreTech, creating new stitch line designs, translation of designs into Dolphin software, selection of alternative outer material, preparing fill, machine set up and onsite operation of the machinery. Samples created during this stage were intended not only to shift the design direction for the stitch line, but also test the capabilities of the Dolphin digital quilting machine.

Stage 3 developed 'building block' samples. These samples represent the separation of overbody and underbody bedding through stitch line and material selection. This was achieved by expanding on the findings of Stage 2 by changing scale, shape, direction and distance of the stitch line incrementally. Key feedback from FibreTech's research and development team also influenced design decisions during this period.

The final stage, Stage 4, outlined speculative overbody and underbody design strategies. These are presented as the 'Findings' of this project and signify different directions for overbody and underbody end use. These strategies take into account the internal knoppy web layer, outer fabric layers and stitch line of digital quilting.

Figure 8.

Four Pivotal Sampling Stages

Stage 1: February - May
Low-tech experimentation

Experimentation of loft and
compression using a variety of nonwoven processes and materials

↓

Stage 2: April - July
Computer aided design CAD controlled quilting sampler

Introduction of digital quilting

↓

Stage 3: August - October
Building blocks

Expansion of knoppy web overbody and underbody directions through digital quilting stitch line

↓

Stage 4: November - December
Speculative overbody and underbody design strategies

Overbody:	Underbody:
Intersect	Verge
Echo	Tension
Undulation	Terrain
Open/closed	

STAGE 1

The journey of sampling started with initial experiments with a range of materials and processes. Beginning with the question 'what is loft and compression?', samples were created using different processes to bond the textile together. Findings from these samples are outlined on page 18. As very limited amounts of the knoppy web fill were available, a variety of existing and found fill materials such as synthetic polyester wadding, carded wool, needle felted wool and 'possumwool' (a nonwoven possum and wool blend) were used.

9. E1.1 E1.2 E1.3

10.

E.1.1 *Tacked-down/ Upholstery*
04/03/2013
Timber, thin polyester wadding, staples
Using staple gun to layer wadding on itself

E.1.2
04/03/2013
Timber, thin polyester wadding, staples
Puckering wadding in the linen weave, creates vertical height

E.1.3
04/03/2013
Timber, thin polyester wadding, linen weave, staples
By changing the distance of pleated wadding, different heights can be achieved.

11. E2.1 E2.2 E2.3

12.

13.

E.2.1 *Tacked-down ridges*
05/03/2013
Timber, thin polyester wadding, polyurethane foam skin, possum/ merino knit, staples
Addition of a firm material to ridges

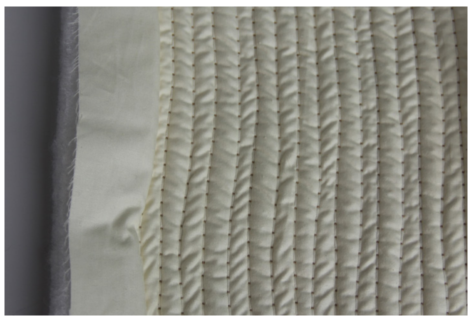
E.2.2
05/03/2013
Timber, thick polyester wadding polyurethane skin foam, possum/ merino knit, staples
Pushing the ridges closer together

E.2.3
05/03/2013
Timber, thin polyester wadding, possum/ merino knit, staples
Stapling to the concave area of timber knot

These images show selected samples from this experimental stage. Some of these concepts were carried through into later work. Different intuitive approaches for layering and attaching were articulated by exploring loft and compression as physical attributes. These were organised into various series, for example, E.3.3 refers to Experiment (E) series three, sample three which focussed on directional hand stiching of lofted wadding.

14.

***E.3.3** Directional hand siticbing*
11/03/2013
Three layers of thin polyester wadding layers, linen thread
Hand stitched experiments, changing the direction of the stitch to see how it compresses



15.

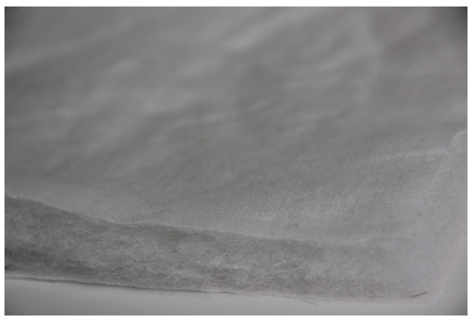
***E.4.5** Three layers*
06/03/2013
Down-proof cotton weave, polyester wadding
Ridges approx 1cm apart. Creates texture on outer layers. Sewn on Industrial machine with zip foot.

16.

***E.5.2** Pockets*
06/03/2013
Felted polyester, thick polyester wadding
Extra wadding added with continuous stitch line creating shapes but they are open. Bobbin a different colour and creates dots.

17.

***E.6.3** Shaping/quilting*
06/03/2013
Down-proof cotton weave, two layers of thin polyester wadding
Sewn shapes with angled parallel lines



18.

***E.7.1** Bonding/fusing*
07/03/2013
Thin polyester wadding, linen, melt fusing
Layers heat bonded together; heat has flattened fill

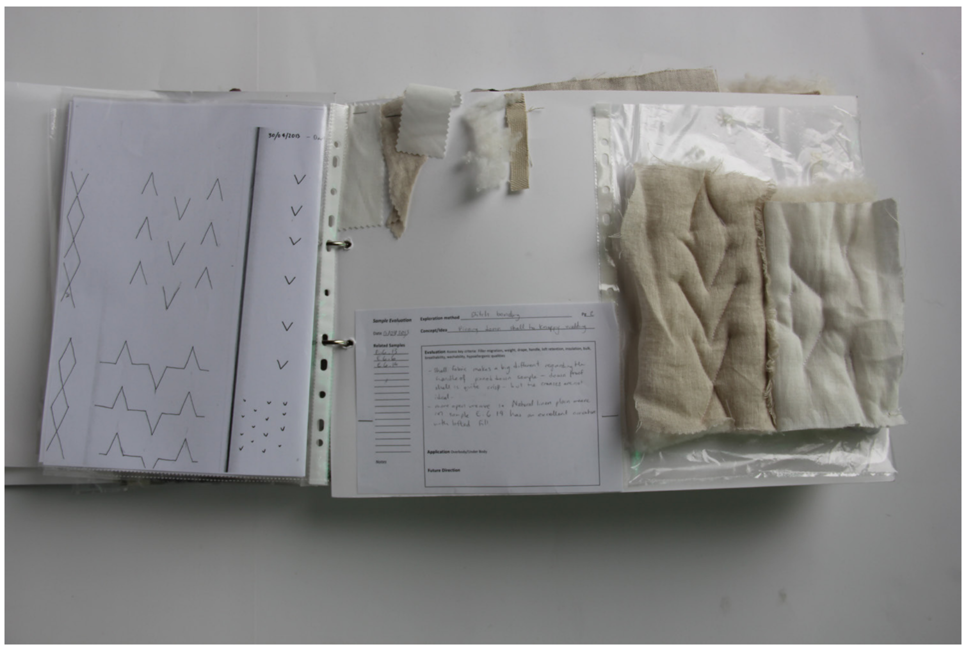
19.

***E.8.2** Linear padding*
07/03/2013
Thin polyester wadding, linen thread, jute webbing
Wadding sitting on top, linen winding around, could this be attached?

Experiments evolved as knoppy web became available. These samples provided physical examples of knoppy web material in combination with other fabrics for the first time. Although samples were hand-made and small in scale, noticeable differences between the knoppy web and existing fills could be seen and experienced through touch.

It was important to be able to refer back to specific samples and this was achieved through technical workbooks. Samples were collated by concept or ‘series’. These were accompanied by related workbook imagery, material swatches and descriptive evaluation notes. Each individual sample was photographed and labeled for quick identification. This information was also digitally filed under the experiment’s code forming a photographic record.

This process of creation and collation of sampling occurred simultaneously with sketching and collecting of visual imagery to develop original design directions.



20-24. *Example from Stitch bonding: Quilting sample book showing Experiments (E)* ***E.6.6, E.6.13, E.6.14*** *that relate to the concept of pinning down alternative outer fabric to knoppy web.*

These early samples first explored form and later introduced knoppy web and alternative outer layers. The following methods of connecting layers were selected for further consideration:

Using a layering system to create different heights and density of wadding, embracing the different qualities of and the diversity available through combination

Using quilting, in a way which departs from classical designs, for example: reducing stitching or pinning down small areas instead of straight, connected lines.

Using quilting as a stitch bonding tool to connect the outer layer fabric to wadding (one or two sided)

Using quilting as a stitch bonding tool to connect an open fabric to wadding

Using quilting as a stitch bonding tool to attach wadding strips to thicker fabric, creating a textured surface.

Using quilting as a stitch bonding tool to connect lighter weight fabric to wadding

Using loose wool knops as fill inside a structure with wadding against outer shell

Possum waste/wool inside wool outer, connecting through needle punching

Wadding used in strips and attached through stitch

Fusing of knops to open, loose fabric using thermal adhesive

Observations about the relationship between outer layers and the fill material also began to be identified:

'Raw' fabrics, such as natural linen and brushed cotton, were aesthetically pleasing when layered with the knoppy web

Open weave fabric (both woven and knit) tended to 'float' on the surface of the wool knops, creating an excellent haptic feel and texture that can be seen underneath.

The 'fine knoppy web' had a particularly good handle that offers itself to being used with only one side of outer fabric

Wool twill felt was ideal for underbody as it is very soft, flexible and you can't feel or see larger knops underneath.

25. Capturing Loft Presentation at Massey University, Critique 2, May 2013

26. Fabric swatches (Wool, linen, cotton) from Technical workbook Stitch bonding 2: quilting

27. Selected fabric and knoppy web swatches collated in textile workbook

STAGE 2

Sampling Stage 2 shifted from manual, low-tech sampling processes to utilising large-scale industrial machinery. FibreTech had two quilting machines onsite: one a manual, punch card multi-needle machine, used for producing mattress ticking on the roll; and one single-needled Dolphin digital quilting machine was used primarily to quilt duvet inners. The digital quilting machine could be described as a combination of a CNC (computer numerically controlled) cutting router machine, sewing machine and embroidery machine with the purpose of sewing bulky textiles. Digital quilting represented a flexible industrial machine that could be reprogrammed using CAD software. This industrial process was selected for further sampling development.

***28.** Multi-needle quilting machine*

***30.** Dolphin digital quilting machine*

***29.** Wave design for mattress ticking*

***31.** Existing digitally quilted duvets by FibreTech, down-proof cotton, classical grid design*

***32.** Existing sample folded to explore drape*

CAD research was a critical area of collaboration and skill development. It took a significant amount of time to learn how to redesign CAD artwork and required regular communication with Peter at FibreTech between April and July. Following *Onsite Visit #2* in May, it was clear that sampling could not progress without proficient understanding of CAD programming specific to the Dolphin digital quilting machine. Use of this technology was pivotal for the project but was complex to learn due to the limitations of the software and limited access to the machinery. CAD artwork towards the first digital quilting trial (Samples 1-9) had to be designed and organised from Wellington prior to *Onsite Visit #3* in July.

Artwork was designed in BrisCAD, a programme similar to well-known AutoCAD, with an added FibreTech plug-in developed for FibreTech's Dolphin quilting machine. This plug-in provided presets relevent to the production of bedding including frame sizes and pre-programmed artwork. The artwork consisted of classic bedding designs and clipart, such as a clown, kiwi and puzzle pieces. The placement and manipulation of these objects was a great way to learn about the software, but it was soon realised that this research would not benefit from developing designs based on pictures. As sampling during Stage 1 had identified the quilted stitch line as a three-dimensional connection tool, CAD programming would be used to test how the stitch affects the textile at the most basic level. This required learning how to create stitch lines from scratch.

Designing for the Dolphin digital quilting machine was characterised by simplicity. This was due to the limitations of the Dolphin software that converted the BrisCAD 'dwg.' files into numeric instructions to quilt the design. Quilting artwork is actually one continuous path from start to back to finish, alternating between a 'stitch line' and 'jump line', see images 33 and 34. On the computer, the stitch line is represented as a red line and jump line as a yellow line. These different line types give instructions to the quilting machine where to stitch (stitch line) and where to back-tack, lift and travel to the next stitch line (jump line). Paths were limited to two line options; 'line' and 'arc' meaning drawings could not be drawn in a fluid method like one would with pen on paper. Instead, imagery was created through plotting, coding or repeating. It was necessary to consider the entire path as all stitch lines were connected through jump lines. The production run time was particularly affected by jump lines, as the new stitch line needed to start and stop with back-tacking which slowed down the machine. This drawing style influenced design decisions away from CAD as I began thinking in 'stitch lines', 'jump lines' and 'paths' in consideration of the direction the quilting machine was travelling in.

An area of considerable concern was that design errors had the potential to cause major damage to the machinery. This was unacceptable as the Dolphin machine was being used in commercial production. Expensive repair costs and lost productivity could jeapordise future sampling. Paths needed to be correctly drawn in CAD so they could be converted into successful A to B instructions for the quilting machine. Errors were mitigated through regular communication with Peter as we worked through individual designs by email. Each converted CAD design was inspected by Peter (this conversion programme was only available at FibreTech), who checked each path connection was correct by simulating the machine's path on the computer. It was decided that each design would have a test run prior to sampling taking place. This meant that each new design had to go through a process that required time and patience.

It was important during this stage to gain the trust of FibreTech staff. If an intial design error occurred during the research, it was resolved quickly and noted down so it was not repeated. These errors were often caused by overlapping lines, an extra small line section or the wrong line type, which caused the conversion program to added extra jumplines or to not recognise areas. Damage could be caused if the machine is given an instruction that does not match and it attempts to jump ahead.

FibreTech also gained insight into their software through this trial and error. By investigating new design possiblities using the CAD software this research tested out the software's limitations and shortfalls. CAD Concepts, FibreTech's software engineering firm was able to assist with serious issues that occurred with the software. Later insights included the revelation that the conversion programme read lines and arcs differently, with arcs read in a direction, and lines not. This specifically affected the ability to mirror objects containing both lines and arcs.

One key aspect of designing for purpose was gaining knowledge about the relationship of the two-dimensional lines drawn using CAD, and the physical effects these stitch lines make on the layers of material in reality. BrisCAD software does not simulate three-dimensional quilting contours. Chapman and Little (2011) comment that prototyping using digital machinery often uses the very same machine used in production, which is the case with the digital quilting machine. This means that sampling directly translates to production. Further, using the term 'digital craft'– the embedding of design and technology – designer and MIT researcher Neri Oxman (2007) argues:

> *Machine execution should not merely be regarded simply as a service tool for materializing design but rather an opportunity to inform the design process as one which integrates machine-logic across all scales of production. Material choice and fabrication methods are not innocent decisions but rather pre-determined factors which guide the design with respect to artefact and process from beginning to end. (pg. 2)*

This indicates the relationship between design and the machine has the potential to be reciprocal, instead of the machine simply being an output mechanism. Janette Matthews' 2011 PhD research investigating three-dimensional laser processes through design research shows a close design/machine relationship resulting in an intuitive understanding of the laser machinery and its parameters with various materials. Textile designer Meg Callahan instead uses multiple digital processes including digital printing, cutting and quilting to recreate traditional patchwork quilts in modern context, showing a confluence of digital design elements (Budds, 2012).

Architect and theorist Rivka Oxman (2012) suggests a 'novel' digital design discourse is emerging, presenting new methodologies for designing and therefore new digital or physical outcomes through engaging with digital technology as a process itself. By understanding how the process works, the designer develops an intuitive relationship about what is being designed in CAD and how it would appear in physical form. Through this understanding, as the designer, I became the interface of line and material.

Samples 1–9 were designed as a sampler to test a wide range of stitch styles (see Figure 10.). Two versions using the same artwork but different material were quilted during *Onsite Visit #3* in July. The first version was quilted using down-proof cotton, with the second introducing a range of fabric (woven and knit) and fibre types (merino, linen, cotton). Each individual sample set out to test different stitch line shapes, directions and spacing to gain further insight into the digital quilting process. The designs departed from the 'default' gridded lines pattern previously used by FibreTech and showed the effect different stitch lines had on sandwich-structured textiles. As knoppy web was unavailable in large quantities, a standard nonwoven wool product from FibreTech was used instead. This worked well because the focus shifted from knoppy web into exploring the latent potential of digital quilting machinery. Knoppy web was re-introduced during Stage 3.

Figure 9.

Digital Quilting Terms

Straight stitch – an interlacing a lock stitch

Large embroidery-machine foot – rounded sewing foot that compresses the bulky textile for sewing

CAD programming - dwg file; BrisCAD with FibreTech plug in, but can be programmed in AutoCAD.

Lines and arcs – Available geometric line styles in CAD software for Dolphin software to read from point A to B.

Stitch line (red) – Line type instructing the machine to back-tack and stitch

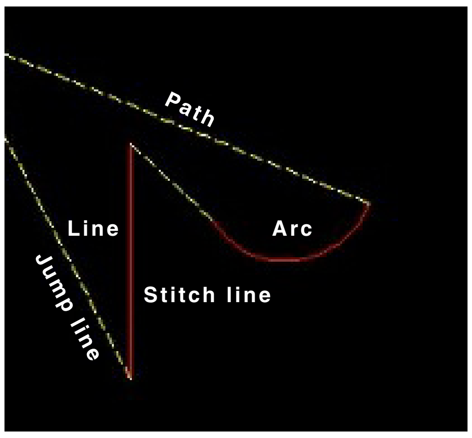
Jump line (yellow) – Line type which instructs the sewing foot to end the back-tack, automatically cut the thread, lift and travel to next 'Stitch Line' to begin stitching.

Path – The continuous and directional line path the quilting machine travels on - alternating between connected Stitch Lines and Jump-lines.

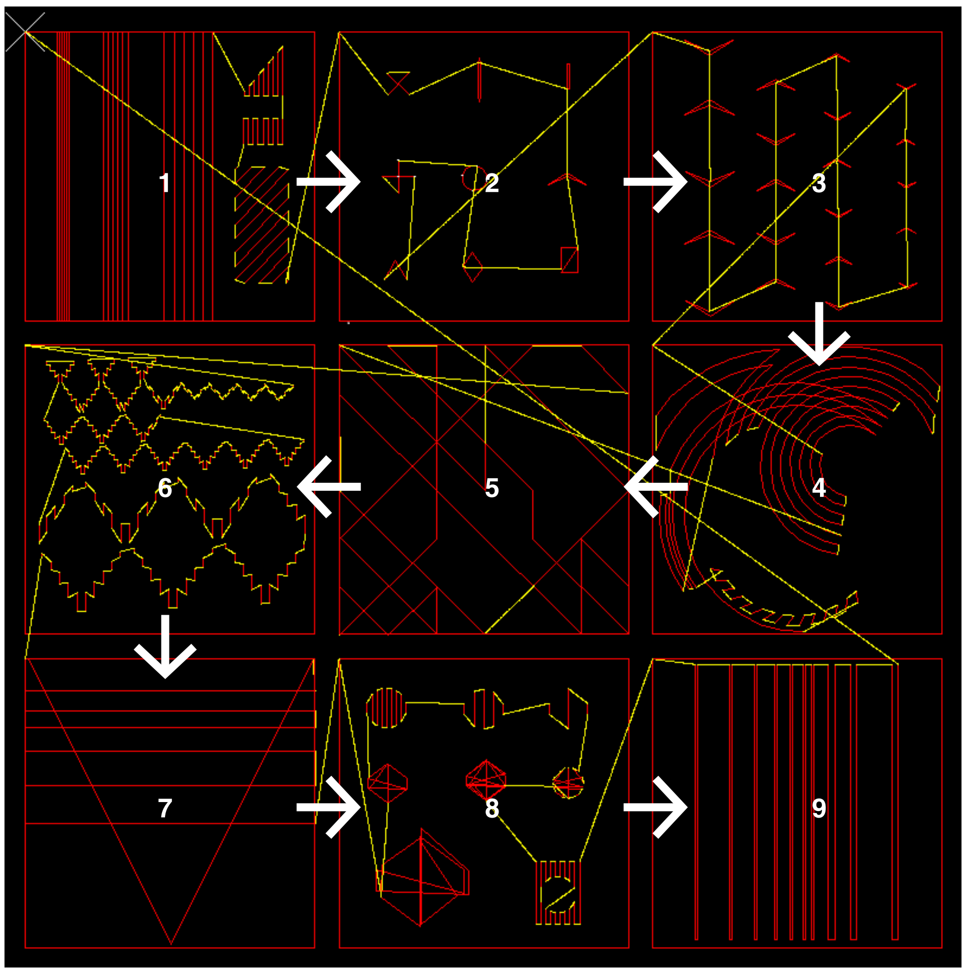
Quilting frame - Material is stretched taut on an aluminium frame that moves back and forth during quilting.

Border – usually 100mm from outer edge to secure even tension.

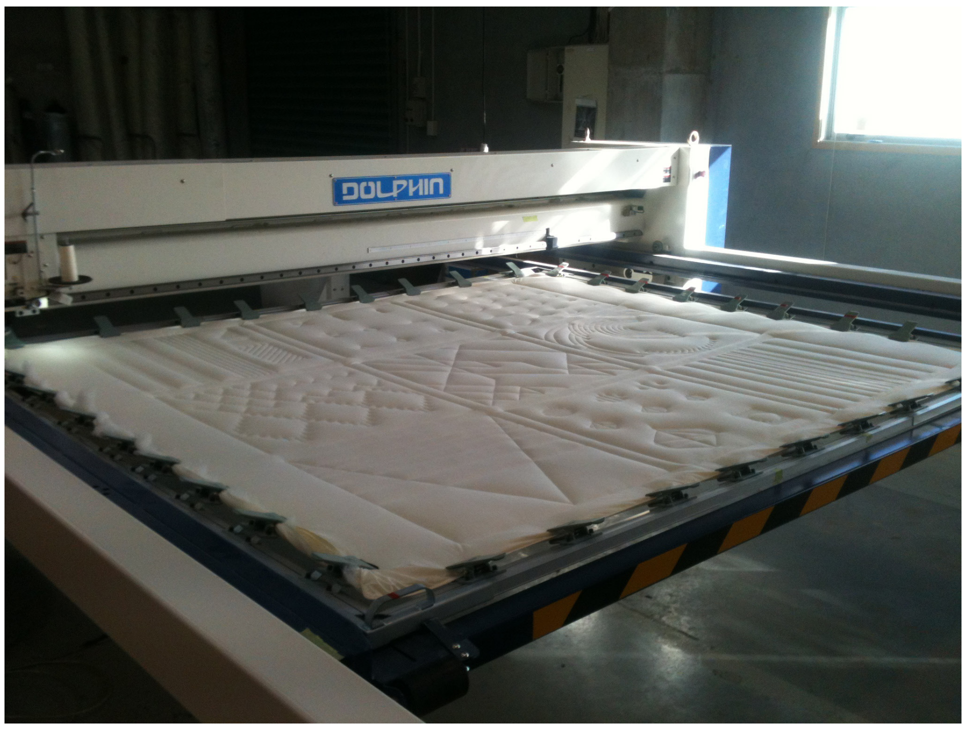
Run time – the production time for quilting the design



33. Designs are based on a combination of connected 'stitch lines and 'jump lines', that direct the 'path' of the quilting machine. stitch lines are restricted to 'lines' and 'arcs'.



34. CAD drawing Samples 1-9 showing stitchlines and jumplines showing order of quilting.



35. Quilted version of Samples 1-9 at FibreTech (July, 2013)

Figure 10.

Sample 1
Varying straight lines at 5mm, 10mm and 20mm spacing with cut out shapes and diagonal lines

Sample 2
Testing out various open and closed pin-down shapes

Sample 3
Dart shape repeated with different spacing and scale.

Sample 4
Testing the arc shape, creating areas of overlap and curved broken lines

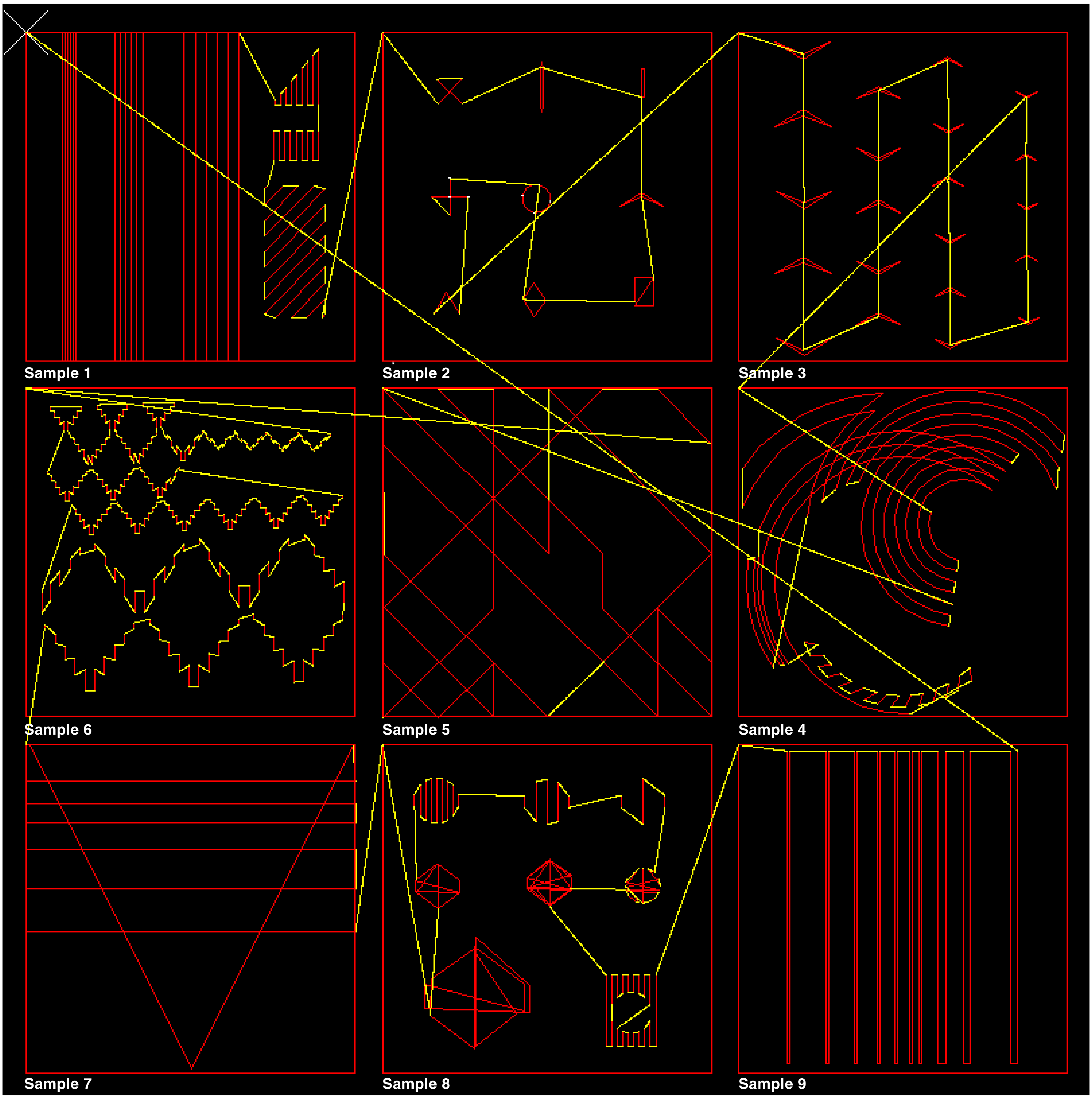
Sample 5
Testing different angles and intersections of lines

Sample 6
Diamond shapes created through the negative space of broken lines

Sample 7
Intersecting lines at different angles

Sample 8
Broken line shapes, shapes created through negative space, changing of scale and density of line and overlapping shapes based on a circle.

Sample 9
Lines of various thickness creating a gradient effect



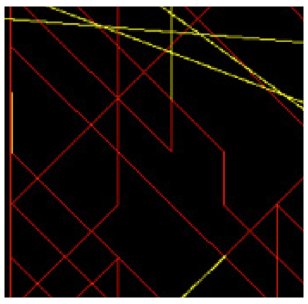
36. CAD drawing Samples 1-9 (600x600mm) detailing design intentions

These findings marked a crucial point for this research project as stitch line use for overbody and underbody bedding began to be defined. Failures for overbody bedding were often found to be helpful for underbody design, for example the manipulation of stitch direction and spacing.

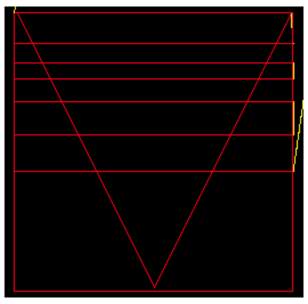
39. Sample 7, down-proof cotton

37. Sample 5, down-proof cotton

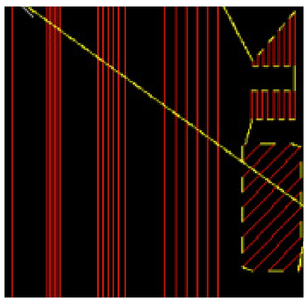
40. Sample 1, down-proof cotton



38. Sample 5 CAD drawing swatch



41.



42.

Isolated Line
It was found that intersecting lines caused the outer fabric layer to buckle, negatively affecting drape by creating stiff areas. This could be avoided by designing the stitch line to run near the edge instead of crossing over. Sample 5 shows examples of both overlapping and avoiding crossover.

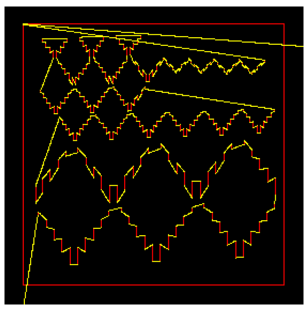
Application: Overbody

Directional drap/edging
The stitch direction and spacing controls the drape movement. This is shown in Sample 7 where hinging creates distinct areas where the fabric wants to fold in on itself, in this case affected by the triangular shape crossing through the straight areas. Sample 1 shows clean edges are possible for intentional folding. Drape direction for overbody should be designed to move around the body, therefore minimal stitching is required. Opportunty to utilise stitch direction for intentional shaping or 'engineered' quilted products as lines quilted close together create hinged areas parallel to stitch direction.

Application: Overbody and Underbody

43. *Sample 6, linen/cotton weave*

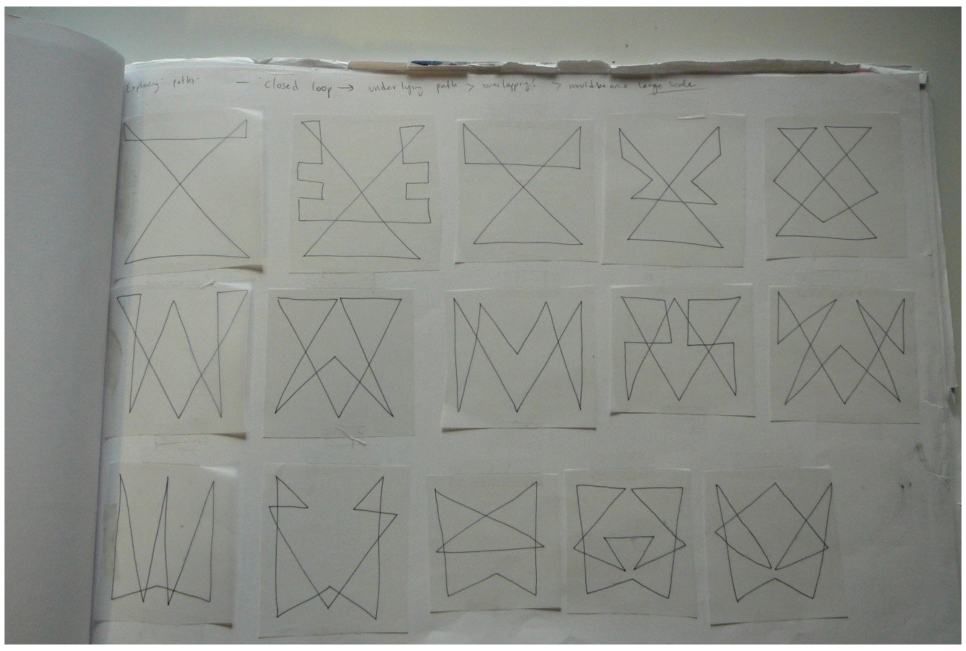
44. *Sample 6, linen/cotton weave (detail)*



45.

Broken line
By breaking up the stitch line, the quilted product maintains loft and drape with an added surface pattern dimension. This textural aesthetic is shown in Sample 6. Breaking up the line takes advantage of the digital quilting machine's ability to automatically back-tack and cut each stitch in the correct position with even tension, which is not possible through manual methods. It was observed that the fabric between the ends of the stitches was taut, but drape was multi-directional. Despite the aesthetic and functional opportunity it was found that quilting a broken line design took an extended time due to the delay with back-tacking. Speed could be improved by scaling up the design so fewer lines were needed, hence faster production.

Application: Overbody



46. *Textile workbook page, pen on paper*

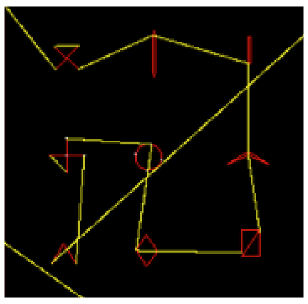
Continuous line
In contrast to 'the broken line', a continuous line has no start/stops, benefiting production speed and efficiency. This approach is challenged through the findings of 'directional drape' and 'isolated line' as it is difficult to create continuous lines for overbody bedding with no crossover areas and also being sensitive to line direction. By analysing the current construction of duvet quilting by FibreTech, it is determined that the first outer line that pins down the layers around the edge is an existing continuous line that lends itself to alteration for more coverage. Underbody on the other hand could benefit by having crossover areas that create rigidity.

Application: Overbody and Underbody

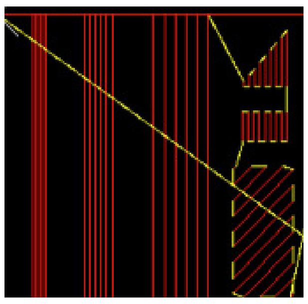
49. Sample 1, down-proof cotton

47. Sample 2, down-proof cotton

50. Sample 1, merino single jersey knit.



48.



51.

Pin-down areas
A focus on securing small areas of the outer fabric to the wadding was explored by testing different isolated shapes. Pin-down shapes created through one continuous line and without sharp corners worked best. For example, the circle shape in Sample 2 took much less time to quilt than the cross shape, but pinned down a similar-sized area. It was also found that the narrow rectangular shape caused the quilting machine to jolt and potentially cause damage; the use of a single line was viewed as the better option, as it negates the necessity for a u-turn.

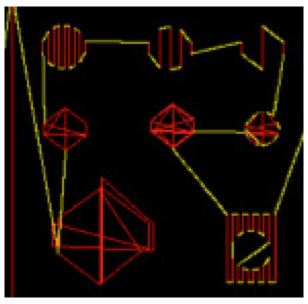
Due to the small scale, pin-down areas are taut but this ridged area only affected a small percentage of the sandwich-structured textile in an unconnected way, which meant that good drape was achieved. It was also found that the outer fabric around a pin-down area was loose and baggy. How the shapes affect this loose fabric can be seen in the 'dart' shape in Sample 3, which shows the effect of scale with positive (stitched) and negative (unstitched) space.

Application: Overbody

Diagonal line
The 45º diagonal stitch line holds tension more evenly with less puckering that than 90º lines, as seen in Samples 1 and 5. The transition from quilted to unquilted areas is also smoother.

Application: Overbody and Underbody

***52.** Sample 8, merino/cotton double jersey knit*

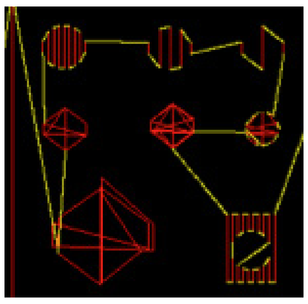


53.

Overlapping
Adds rigidity to the form in that area but also allows areas to pop out dependent on stitch spacing. This can be seen in Sample 8 through the angled shapes.

Application: Underbody

***54.** Sample 8, merino/cotton double jersey knit*



55.

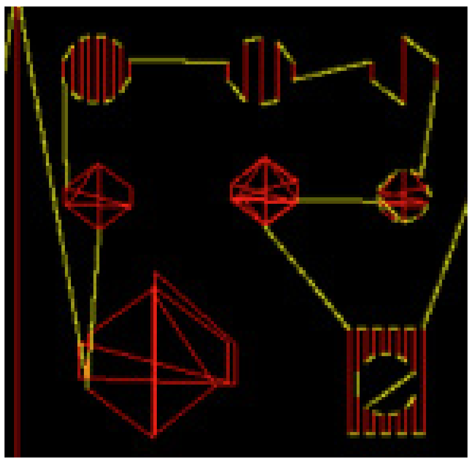
Negative space
It is possible to design in reverse by creating particularly especially soft, lofted sections as shown in Sample 8 with the defined circle shape.

Application: Underbody

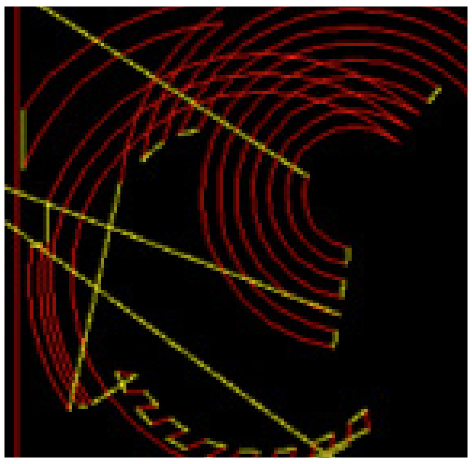
56. Sample 8, merino/cotton double jersey knit

57. Sample 8, merino/cotton double jersey knit (detail)

59. Sample 3, down-proof cotton



58.



60.

Stretch fabric
It was found that fabric with stretch offered a softer curve over the areas of dense stitching. Sample 8 had merino interlock knit as the top layer.

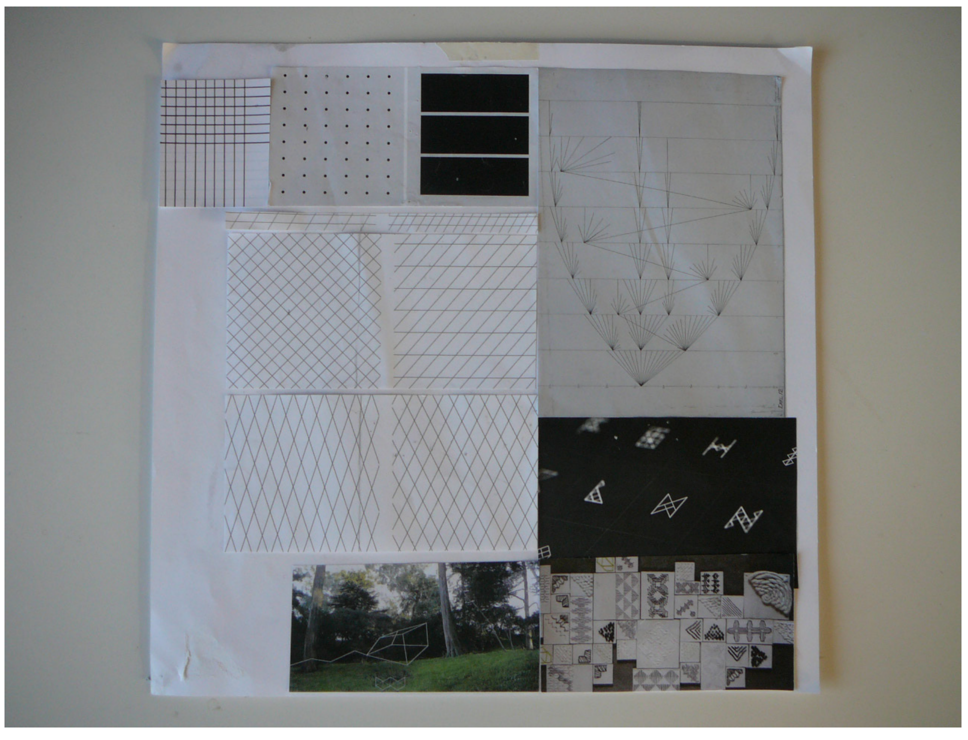
Application: Underbody

Controlling peak height
Contouring can be controlled through stitch spacing. Sample 3 showed stitched 'trough' areas have a 4mm height and an unquilted area has a 25mm height (specific to fill choice). Various heights can be achieved by altering the distance between stitch lines. In this sample it was found a 20mm distance = 7.5mm peak, 30mm distance = 13mm peak and 50mm = 20mm peak.

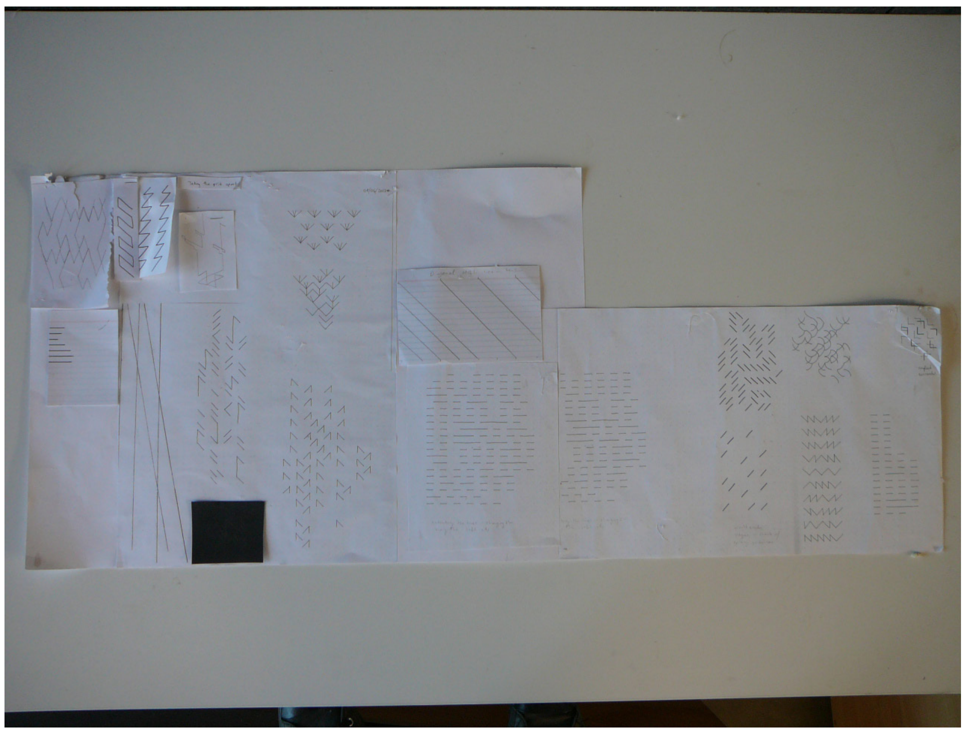
Application: Underbody

During Stages 1 and 2, I began to notice the physicality of layered materials holding space and tension. Was there a unique aesthetic to lofted textiles? A clean, graphic line was observed through the stitch line. This line was the point of connection - but also the same point of compression and release. Loft had been contoured into peaks and troughs that changed the way the textile performed. Through early material experiments, it was found the knoppy web was different to other fill-layers. By departing from classic quilting approaches, what speculative design strategies could be found in response to both quilting and the knoppy web fill?

A juxtaposition between the graphic line of the stitch and the soft wool fill was identified and explored through drawing, string sketches and found imagery collaged into mood boards. These were developed as a response to the 'breaking apart of the grid' and a tension found through quilting. This introduced an organic but controlled visual language that led to further quilting pattern development.

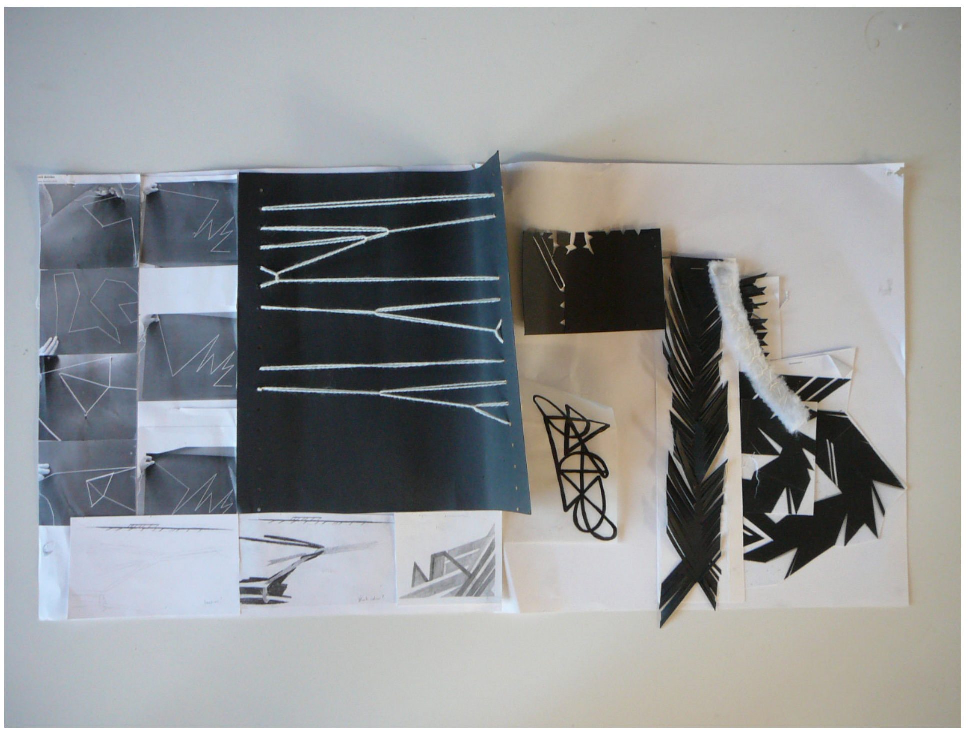


61. Breaking apart the grid



62. Line exploration

63. Continuous lines



64. Exploring tension

STAGE 3

Stage 3 of sampling contributed significantly to *Capturing Loft*. Design work towards thirteen large material swatches, or 'building block' samples, began in August, based on findings from Samples 1–9. The building blocks expanded the use of digital quilting specifically towards overbody and underbody bedding. Understanding of stitch line was achieved through incremental changes to CAD artwork. During this time larger quantities of knoppy web also became available for use with alternative outer fabric layers. Ongoing collaboration with FibreTech's research and development project provided acknowledgement that quilting, although a significant process used in bedding products, had not been explored before. This resulted in a new area of research into performance testing relevant to quilting.

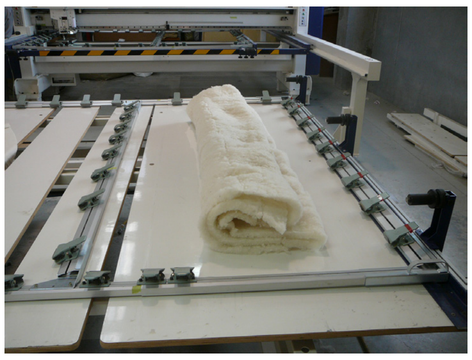
Onsite visit #4 in August and *Onsite visit #5* in September enabled further engagement with the digital quilting process. The following areas were identified as key aspects relevant to building block sampling:

• How tension is created by stretching the material on the quilting frame
• Subsequent spring-back when removed from the frame
• Pushing and distortion of material during quilting
• Effect of quilting direction and curvature
• Effect of quilting spacing
• Automatic stop/starting from jump lines

These areas were used to manipulate quilting design towards meaningful overbody and underbody bedding directions; two end uses with different criteria and structure.

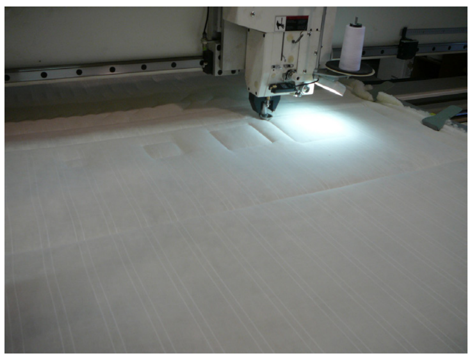
Images 65-70. Quilting Sample 14. The layers are stretched on to the frame. There is a 'deflating' affect when removed from this tension, but some areas remain taut

65. *Dolphin quilting machine control panel.*



66. *Roll of material layers ready to be laid out*

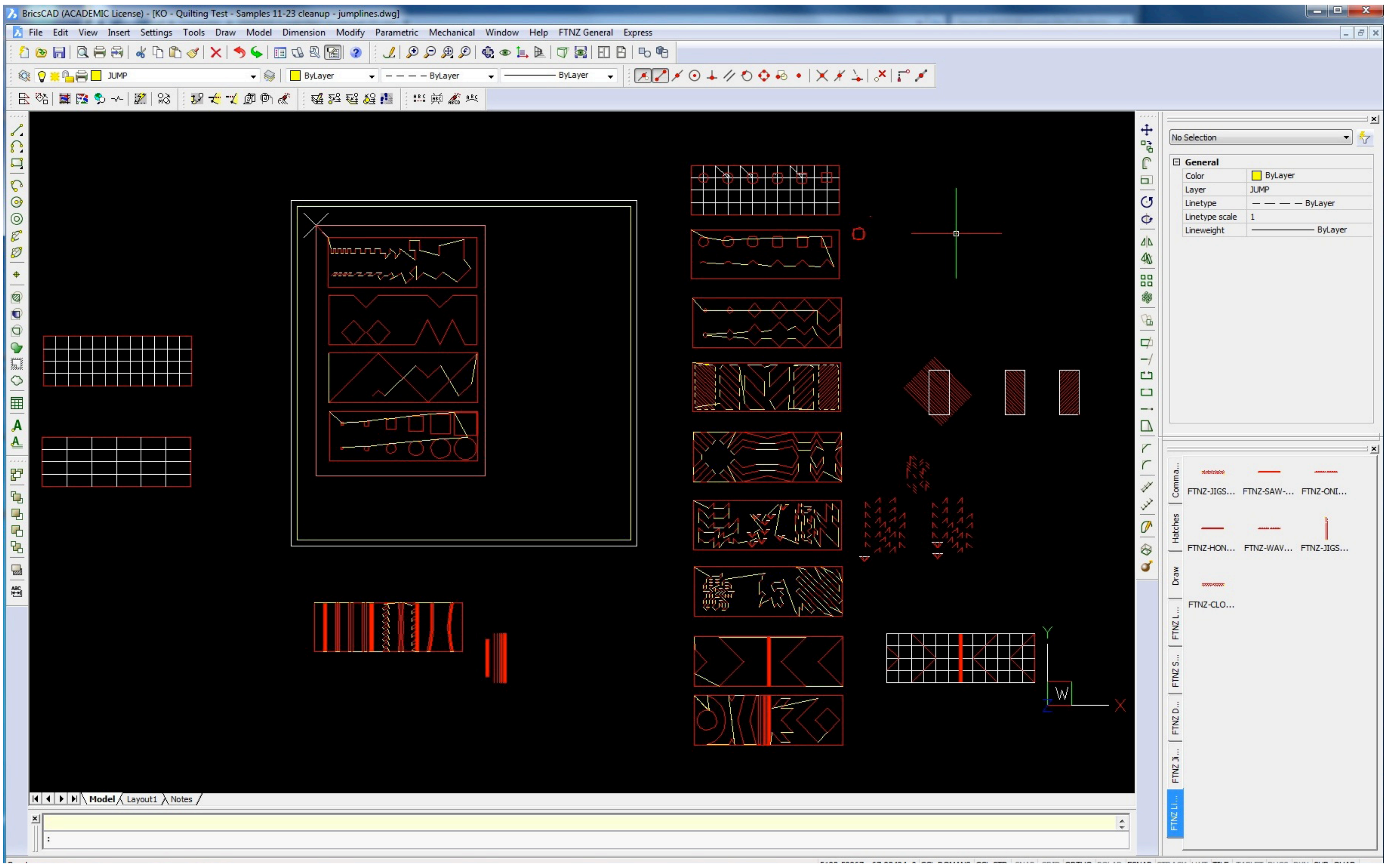
67. *Layers stretched to frame*



68. *Quilting*

69. *Finished sample attached to quilting frame*

70. *Sample 14 removed from frame*



71. CAD working file showing the behind-the-scenes development of building block designs.

Design research into overbody bedding involved designing a new lightweight aesthetic for wool bedding in consideration of outer layers, fill and stitch line. Key recommendations following evaluation are as follows: a curved corner as opposed to a right angle was preferential; diagonal lines hold tension better; the initial quilting border can deviate whilst still remaining functional; and a taut relationship between line ends can be a design feature.

The digital quilting of layers proved a faster production method than the labour-intensive cut-and-sew gusset system required for loose-fill duvets. The design of overbody digital quilting, however, had remained very similar with a repeating, overlapping gridded pattern being used to keep the nonwoven fill in place (*Onsite visit #1*, March, 2013). This common quilting method of pinning down resulted in puckering of the down proof cotton fabric, air gaps in areas of stitch and stiffness occur where quilting crossed over. Some alternative designs previously sampled at FibreTech included scalloping and circle repeats but were not used regularly in production. The technology could be programmed to do much more.

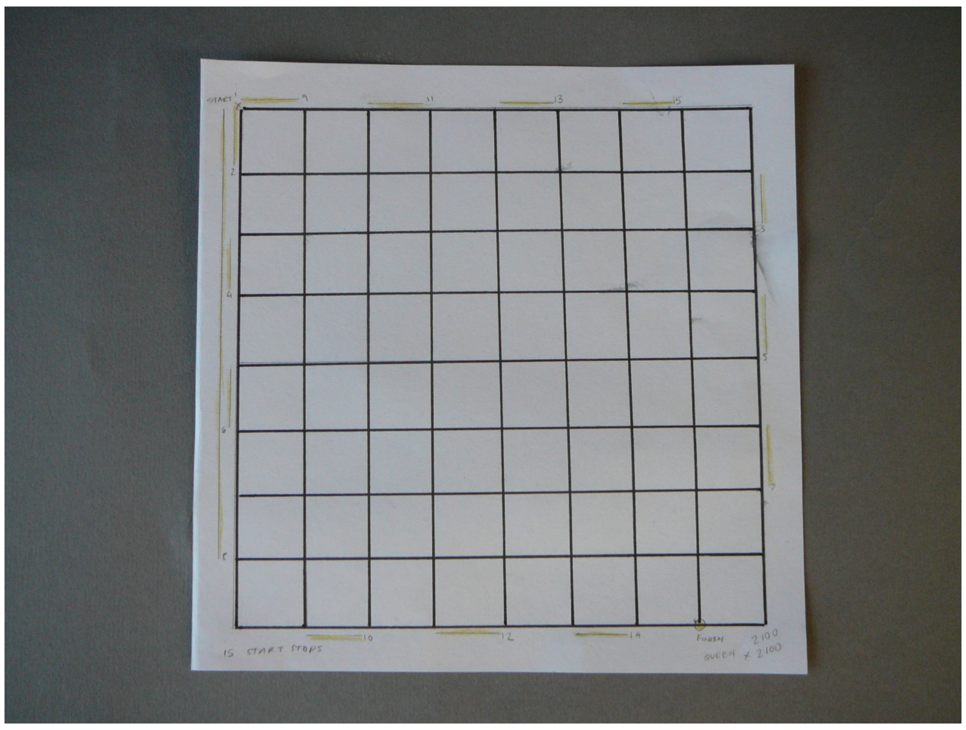
Because trapped air is vital for insulation and start/stop areas determine the run time for quilting production, a minimal approach was taken when designing quilting artwork for overbody. Feedback received from Peter supported minimal quilting as “more quilting means less drape.” (personal communication, May, 2013). From an economical perspective this could also be expanded to: less quilting means faster production. Overbody design needed to be simple but designed in a sensitive way to maintain drape, offer lightweight properties and to sculpt loft. One distinct departure took place however, such as the investigation into three-dimensional texture created through quilting with a broken line. This direction took much longer to quilt but showed new aesthetic possibilities and drape qualities. The prolonged run time meant the continuation of this design direction had to be negotiated with FibreTech.

The design direction of overbody progressed in response to the graphic nature of the digital quilting line, tension through the sewing and ‘breaking apart the grid’. Textile design investigation into texture, line and form for overbody bedding progressed through moodboards. The soft nature of the fill contrasted with the linear graphic stitch achieved through quilting. Visual and material design exploration into lofted, bulky textiles had not been explored by FibreTech.

72. Overbody bedding exploration

73. Mood boards exploring overbody bedding design

74. Existing overbody bedding at FibreTech



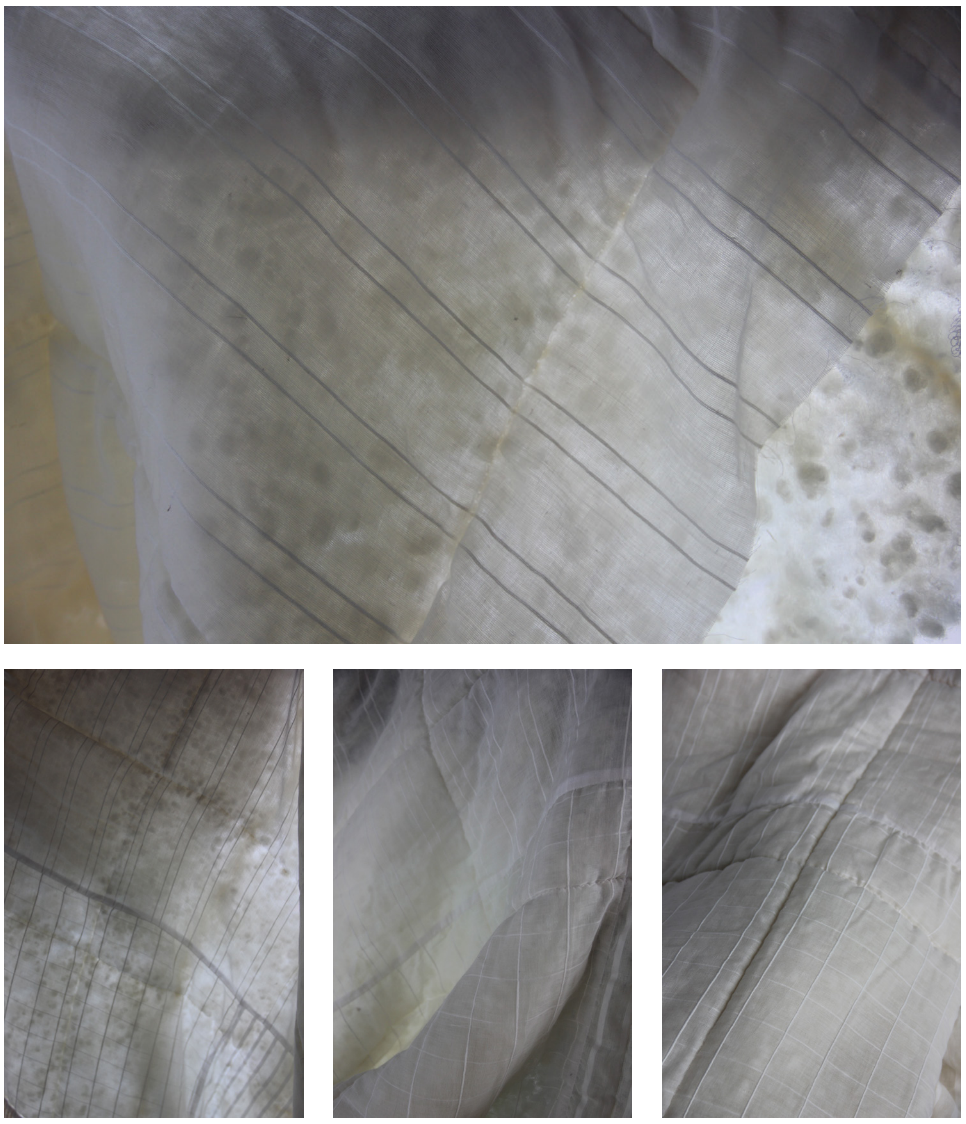
75. Mapping out of gridded quilting path.

Three different lightweight cotton weave fabrics were selected for overbody 'building blocks'. Each of these featured geometric elements – a stripe, grid or pinstripe pattern in the weave. The lightweight fabric was a significant departure from previously used dense, waxy down-proof cotton. Due to the geometric nature of the pattern in each weave, distortions occurred during quilting caused by the sample being stretched on the quilting frame and the pushing/pulling of quilting stitch. This geometric distortion exaggerated the curvature of the fabric stretched over the fill, strongly indicating areas of loft or compression.

Feedback from FibreTech regarding the lightweight outer fabric direction was positive. During *Onsite visit #4* in August, Sample 10 was quilted using FibreTech's existing gridded pattern to test the three lightweight cotton fabric as an outer layer. The result was a semi-transparent look with the knops visible underneath. The sample had a unique textural quality that played with light and shadow. After viewing the lightweight sample, Peter commented:

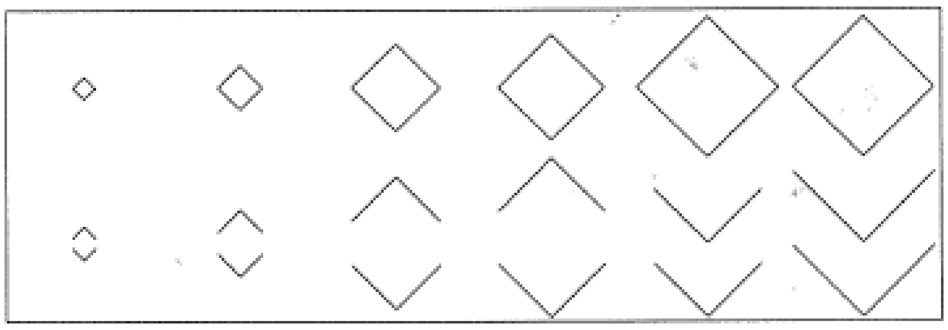
> *Lightness, drape, fashion washability are all key parts of the mix. The fashion part will ensure we get market acceptance. We need something [very] special to inspire the consumer back to wanting to purchase wool based bedding. Knoppy web is the technology now for the X factor.*
> *(Personal communication, August 10, 2013)*

Further samples were created using low-tech methods to test using a diagonal stitch line with the lightweight fabric. One of these smaller samples was taken by Peter overseas on business and received excellent feedback, as it was a notable shift for wool bedding to be viewed as lightweight.

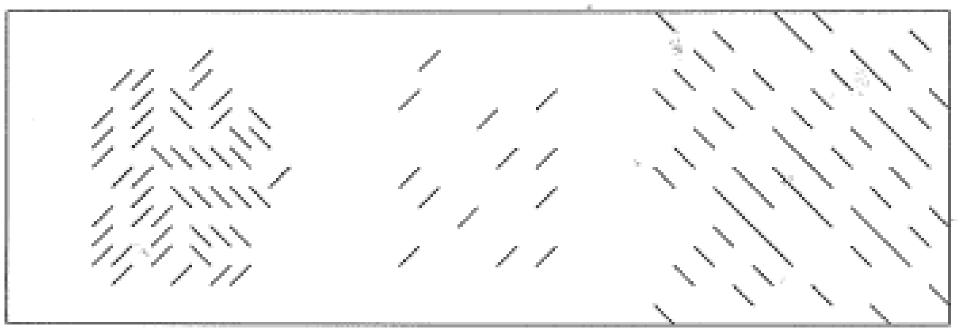


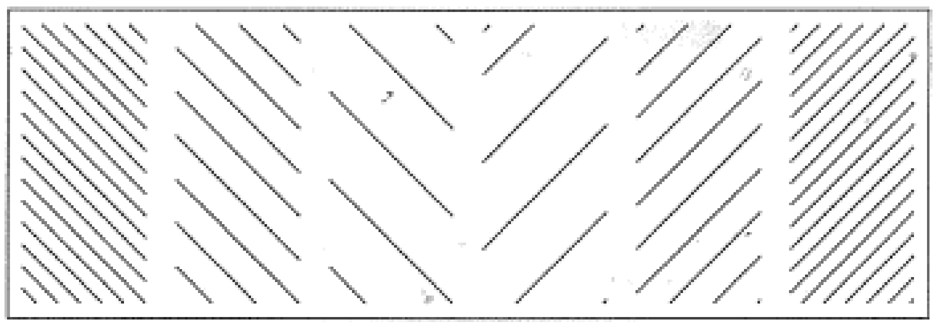
76-79. Sample 10, Knoppy web and lightweight woven cotton

Eight samples were designed to change incrementally in shape, scale, direction or spacing (appendix 1). The impact of these simple changes exposed 'a tipping point' where the sandwich-structured textile started to evolve. Two strong examples included the change of scale and line direction. As a small shape grew, the relationship between positive and negative space changed as well. This affected drape and tension significantly because the textile began to be evenly pinned down. The latter example showed line direction affecting the surrounding unquilted area by creating varying textures through contouring.



80-81. Sample 15, Lot 5, Cotton weave with stripe Showing the gradual scaling up and the ends of broken lines connecting with each other.





82-84. *Sample 20, Lot 6, Cotton weave with double pinstripe. Broken line design connects with the space around stitching.*

85-88. *Sample 17a, Lot 6, Cotton weave with double pinstripe. Although heavily quilted, this combination still felt lightweight..*

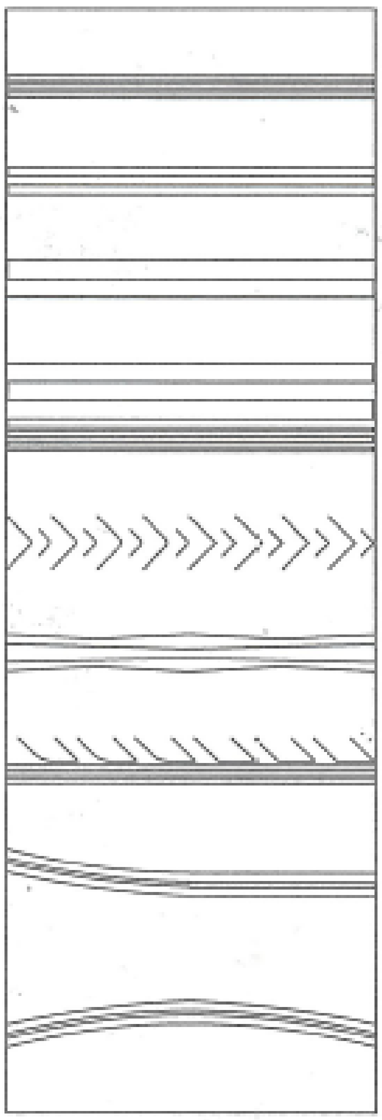
This area of design research found new applications for use under the body beyond bedding – including furniture, medical and infant use – by utilising the digital quilting machinery. Samples 1–9 indicated that small-scale products could be designed by altering line direction and spacing for a specific shape or ergonomic purpose. This introduced the idea of engineered shaping. How could digital quilting be used to construct dense, taut areas, creating shapes that could be easily folded over or cut out? The same considerations for underbody products including comfort, compression recovery and breathability, remained whether for sleep, rest or recovery. Some specific end uses identified include semi-attached furniture padding and removable wheelchair or stroller cushioning.

This tailored approach was not possible using the existing multi-head quilting machine, which quilted a continuous roll with a repeating wave design. Because the stitch line is controlled through manual gears it is both difficult and expensive to alter. FibreTech had trialled this similar wave design using the digital quilting machine (images below), but it had not been used in production. This was surprising because digital quilting offered flexibility to change scale and design very easily.

89-90. Existing underbody bedding design at FibreTech trialled on the digital quilting machine.

***91.** Underbody sample exploration*

***92-93.** Introduction of wool as an outer membrane. Ideally two layers of knoppy web would be used and doubled over for a very soft surface.*



***94.** Stitch line graphic*

***95.** Sample 23, Lot 2, Cotton/polyester/carbon jacquard knit.*
Different line types create hinging for doubling fabric over.

Four underbody building block samples (see Appendix 3) were designed to explore stitch distance and shaping through folding/doubling of layers and dense areas of stitching. It was possible to ‘upholster’ the layers without them being connected to a hard surface. This was found by observing the quilting process of stretching the fabric and fill on the frame and the subsequent stitch bonding lines close together holding this tension. Systematic changes in the stitch spacing showed the effect of quilting affecting handle and aesthetic qualities of the overall sandwich structure. Some important findings were found through failure. For example, Sample 22 showed rigidity through close stitch lines assisted with holding the shape but other areas without this density of stitch line became distorted.

These samples highlighted the importance of appropriate fabric choice for both the fill and quilting process. The cotton jersey knit did not provide the structural integrity required, resulting in unattractive bagging and knops could also be seen and felt. It was decided through this sampling that it was necessary to revisit fabric selection. Clean lines could be achieved quilting with stable outer fabric, but the key was that is still had some stretch through fibre or structure.

96-99. *Sample 22, Lot 4, Cotton Jersey knit. This sample showed distortion after being removed from the frame.*

A pivotal research and development meeting took place during *Onsite visit #5* in September. This meeting offered the opportunity for Jack Grigg and me to present our related research projects to FibreTech's directors and wool scientists, engineers and a wool research representative. A new focus was placed on performance testing, and this changed the trajectory of research. The push from industry to move towards consumer trials was a challenge because key aspects had not been confirmed, such as procurement of outer fabrics and the end use market.

This meeting enabled the research and development team to better understand how the two projects worked together. Grigg presented his research approach and (confidential) knoppy web test results. The wash test results were especially significant, as they showed knoppy web performing much better than traditional wool fill. I presented this design-led research through mood boards and material samples towards overbody and underbody bedding. This approach meant attendees were able to visually see and feel the differences between alternative outer fabrics and quilting design.

Through this meeting it was understood that research by Grigg into the technology of knoppy web fill was the first step and this design research into sandwich-structured textiles a secondary step. This secondary step was a vital part of developing product for overbody and underbody bedding because the outer fabric selection and stitch line affected the look, feel and performance of the knoppy web. Performance testing into this secondary step of product development using knoppy web was needed. Fibre migration, wash testing quilted product and testing of quilting effects on compression were identified as areas for further research. Compression testing on 'building block' Sample 17b was carried out as part of this research at Massey University under the supervision of Dr Janet Webster, in direct response to this meeting (see pg. 60).

Capturing Loft responded to the developing knoppy web fill by taking advantage of its differences to traditional wool fill. For example, it was found that knoppy web held its shape very well when washed and previous rules about pinning down at 25cm intervals were no longer necessary. This opened up a range of design opportunities that also used the machinery more efficiently. "All agreed that we had not utilised design other than in a functional sense in the industry before, and that this was an exciting innovation and opportunity for FibreTech" (Minutes from meeting, September, 2013). Overall this meeting helped clarify the research projects and enabled robust discussion about speculative product directions.

Stage 3 outlined alternatives outer fabric layers to down-proof cotton that would complement the knoppy web for overbody and underbody use.

Complementary overbody fabric
It was possible to introduce lightweight, open weave outer fabrics because the knoppy web no longer required dense down-proof cotton to contain loose wool fibre. The introduction of lightweight cotton, linen and wool created a very different haptic experience of wool bedding. The resulting lightweight bedding product had visually transparent elements, which could be further developed through colour or jacquard weaving for the outer fabric layer (Fabric 1, 2, 3, 4, 9). Mid-weight linen was chosen due to its raw aesthetic qualities, durability and sheen (Fabric 5, 6, 7). Mid-weight wool double-cloth weave (fabric 8) and merino/cotton knit (fabric 7) added a layer of tactility and warmth on the skin, creating a warm outer shell. The following outer layers have been trialled:

Figure 11.

Overbody Material Selection

	Fibre	Outer layer #	Fibre details	Overbody Bedding use	Reason for selection
Outer Layer	Cotton	OB 1, 2, 3	A cellulose fibre produced from the cotton plant	A cellulose fibre produced from the cotton plant	Breathability, washability and soft handle. These qualities are well suited for use with wool fill as the fabric is quick drying, easy care and provides a smooth cool layer, positioning knoppy web as warm without the weight of traditional wool fill. Cotton can also be woven to be very lightweight, but maintain its softness. Cotton has been used as the main fabric that would sit against the skin. Lightweight cotton with a lower thread count is preferred for this project; contrasting with the perceived quality that usually correlates with a high thread count.
	Linen	OB 4, 5, 6	A cellulose fibre produced from flax	Linen has an extensive history of being used in bedding, but has become more exclusive	The 'raw' qualities of linen compliment the knoppy web. As with cotton, it has been selected due to its natural breathability, washability and handle. Linen creases easily, however this is viewed by the designer as an opportunity to give texture to the quilted fabric different to puckering. Combining linen with a man-made fibre can reduce creasing as shown through fabric 6, which is blended with wood pulp derived viscose.
	Wool	OB 7, 8, 9	A protein-based fibre grown on sheep	Wool is not commonly used as an outer fabric layer for bedding	Fine merino wool has become widely used in outdoor apparel and baby wear due to its self-cleaning, breathability and excellent handle. It was difficult to source a lightweight merino knit fabric that was stable enough to be used in the quilting process, however a mid-weight cotton/merino was found. Lightweight wool woven would be ideal, as the stretch would be minimised.
Fill	Knoppy web Lots 5 & 6				Lightweight and smaller wool knops make Lots 5 & 6 the ideal fills to be developed for overbody.

Complementary underbody fabric
It was found that outer fabric needed to be mid to heavy-weight and have an element of stretch through structure or fibre. Kroemer (2009) states,

> *If we like the appearance, the colour and the ambience, we are inclined to feel comfortable. Appealing upholstery, for example, can strongly contribute to the feeling of comfort, especially when it is neither too soft nor too stiff but distributes the body pressure along the contact area, and if it breathes by letting heat and humidity escape as it supports the body. (p.333)*

This passage recognises the importance of both aesthetics and functionality for underbody products. Discussion with Peter at FibreTech (Personal communication, September 2013) determined that the outer fabric for underbody would focus on the top layer only. This was because the base would not touch the body; it would be removed or be folded inside the textile. This top layer needed to be breathable, soft to touch, thick and provide stability for quilting. The following outer layers for underbody were also trialled:

Figure 12.

Underbody Material Selection

	Fibre	Outer layer #	Fibre details	Underbody bedding use	Reason for selection
Outer Layer	Wool	UB 2,3,4,5,6,8	A protein-based fibre grown on sheep	Wool fabric is commonly used for upholstery	Development of wool underbody offered natural stretch qualities, moisture control and softness. Three different structures were explored: a New Zealand-made felted twill and plain weave produced for the upholstery market (fabrics 2, 3 and 4), a lightweight twill weave currently used in apparel (fabric 5) and a brushed merino jersey also used in apparel (fabric 8). The two latter fabric structures were selected because as apparel fabric, they are very comfortable close to the skin.
	Cotton blend	UB 1	Cellulose and synthetic fibres	Cotton blend fabrics are used for mattress ticking	A cotton blend fabric of cotton, polyester and carbon (fabric 5) was provided by FibreTech as an industry standard and is sourced from Bekaert, Australia. The Jacquard knit structure provides a stable, multi directional stretch that quilts well. It was selected as an industry standard. This material was mostly made with breathable cotton and uses a small percentage of polyester and carbon for added resilience and stretch. The polyester fibres were located on the reverse side of fabric.
Fill	Knoppy web Lots 2 & 4				Firmer, thicker and denser for support. Ideally second layer of Lot 5 or 6 would layer be used on the top create a double layer, similar to earlier low-tech experiments. This was attempted during building block trials but the combination was too thick for the current settings of the quilting machine.

Testing weight and thickness of speculative outer layer fabrics outlined particular traits for overbody and underbody (see Appendix 4). These tests took place at Massey University according to the ASTM International (ASTM) testing standards. Results confirmed overbody textiles were both thin and lightweight, whilst underbody textiles were the opposite. These results provide a quantitative point of reference for future selection of outer fabric as product development progresses.

Figure 13.

Overbody (OB) Outer fabric

OB Outer Layer #	Fibre Content	Structure	Thickness (mm)**	Weight (gsm)***
1	Cotton	Plain weave - stripe (warp)	0.2874	62.03
2	Cotton	Plain weave - stripe (warp/weft)	0.4020	51.95
3	Cotton	Plain weave - double pinstripe	0.2472	46.03
4	Linen (flax) - bleached	Plain weave	0.1828	52.07
5	Linen (flax) - natural	Plain weave	0.4348	108.67
6	Linen/viscose - dyed	Plain weave	0.3544	144.00
7	Cotton (50%)/merino (50%)	Jersey, double knit	0.5150	146.40
8	Wool - dyed	Double-cloth weave	0.7546	213.30
9	Wool (89%)/polyester (11%)	Plain weave	0.2838	79.90
10	Polypropylene*	Nonwoven	0.1770	16.60

OB 1 **OB 2** **OB 3** **OB 4** **OB 5** **OB 6**

OB 7 **OB 8** **OB 9** **OB 10**

**Polypropylene nonwoven used for sampling purposes only on reverse side with the possibility of removal and is not deemed appropriate for end-use.*

Figure 14.

Underbody (OB) Outer fabric

UB Outer Layer #	Fibre Content	Structure	Thickness (mm)**	Weight (gsm)***
1	Cotton (71.9%)/polyester (27.7%)/carbon (0.4%)	Jacquard knit	1.6014	383.00
2	Wool	Twill weave, felted	1.6910	390.70
3	Wool	Twill weave, felted	1.0664	350.97
4	Wool	Twill weave, felted	1.4338	353.87
5	Wool	Twill weave	0.5520	186.77
6	Wool (merino)	Jersey knit, single, loop	5.4530	366.66
7	Wool	Jersey knit, single, loop	1.1992	259.83
8	Wool (merino)	Jersey knit, single, fleece	1.4078	372.33

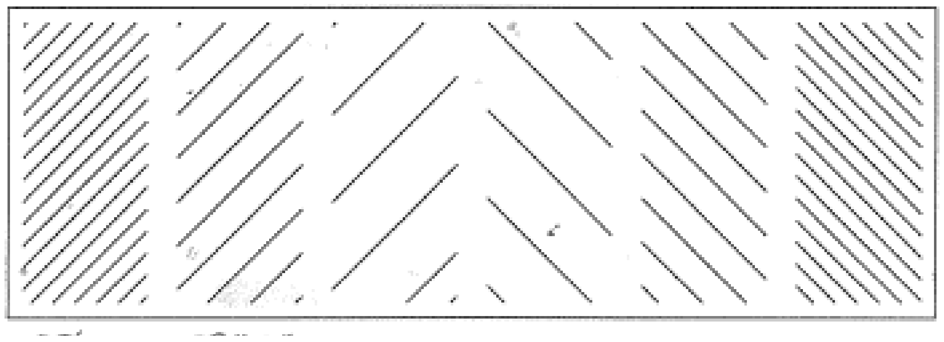
UB 1 **UB 2** **UB 3** **UB 4** **UB 5** **UB 6**

UB 7 **UB 8**

*Testing was carried out at Massey University according to ASTM Standard Test Methods for Thickness of Textile Material D 1776-97 (Reapproved 2007)** and Mass Per Unit Area (Weight of Fabric) D 3776/D776M-09a*** prepared using Standard Practice for Conditioning and Testing Textiles D 1776-08*

Compression testing was carried out to determine how stitch spacing affected the compression of sandwich-structured textiles for underbody bedding (see Appendix 5). These tests were performed at Massey University using a Tensolab machine (15AO model). Sample 17b from the 'building blocks' was developed for testing (see Appendix 3). This sample was a combination of Lot 2 knoppy web, a cotton/polyester/carbon jacquard knit (top) and nonwoven lightweight polypropylene (base) quilted at a 45º angle at increasing distances. Seven samples were tested in total: three samples were single layers and four double-layered.

Tests showed that stitch density affects the initial resting thickness and the modulus of compression occurs. Key observations: Test 6 showed a gradual increase of force under applied load, indicating it is softer than the other doubled samples; test 4 had greatest modulus of compression, indicating it is firmer than the other doubled samples; and tests 2 and 3 performed similarly to one another despite different quilting density. Test 1 shows less initial thickness but has a very similar modulus of compression as testing continued compared to other single-layer tests. In conclusion, these results show that the more quilting in one area the greater modulus of compression.

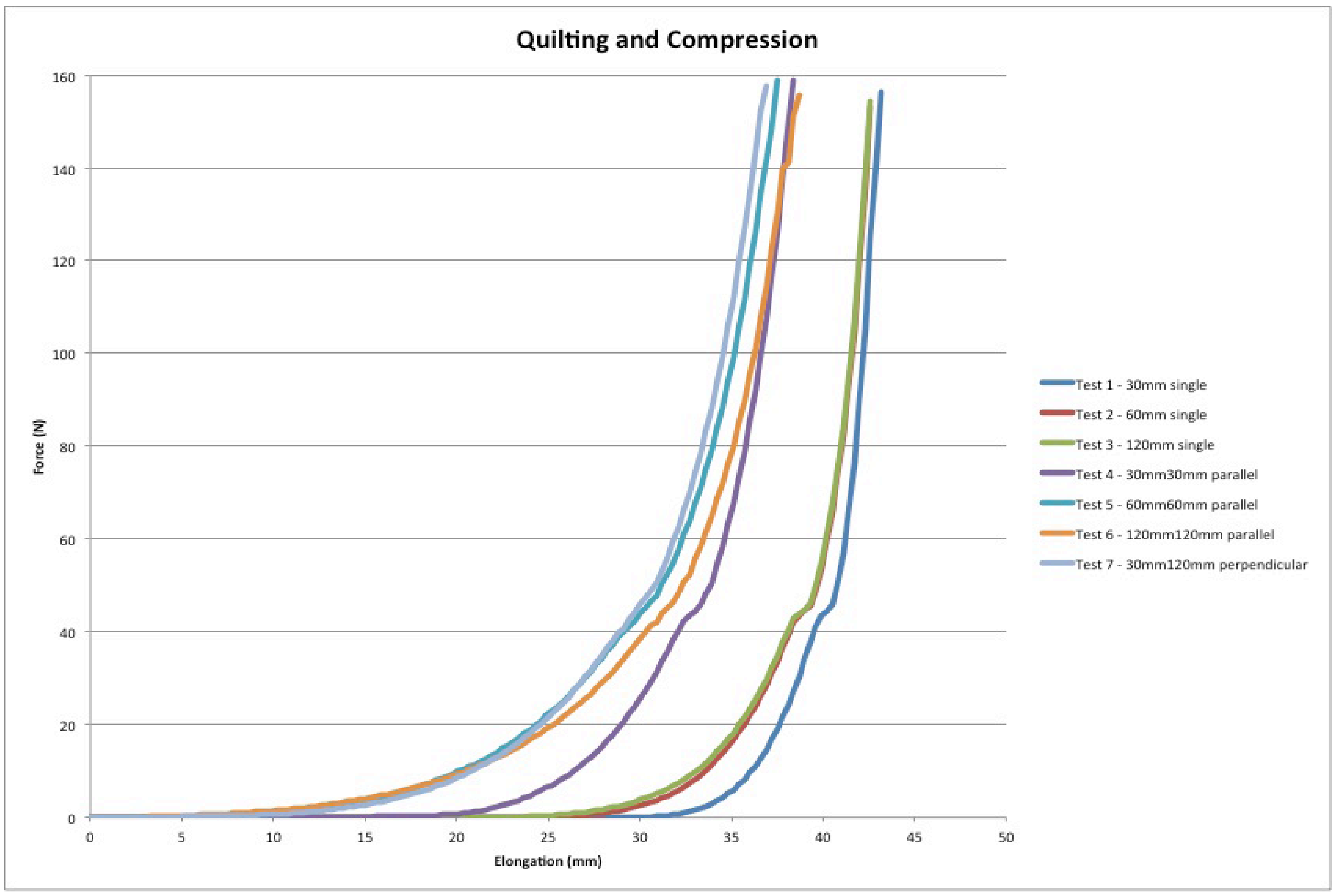


100. *Stitch line graphic*

101. *Building Block Sample 17b, Lot 2 (Cotton/polyester/carbon jacquard knit)*

102. *Single layer samples for tests 1,2,3*

103. *Double-sided samples for tests 4,5,6,7*



104. *Graph. Average test results for Quilting and Compression testing*

105. *Loading Tensolab (modified for compression testing)*

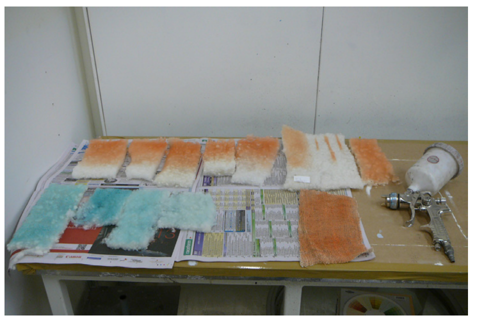
106. *Compression load being applied to sample*

The function of colour shifted significantly as this research progressed. Early in the project, a contemporary colour palette was developed. This colour palette was based on my own understanding of interior design trends and was informed through industry predictions from sources such as WSGN trend forecasting and Viewpoint magazine. Colour was translated into mood boards, workbook studies and material experiments. This followed a typical textile design process. The knoppy web material and 'raw' outer fabric formed inspiration for this colour palette. The following methods for attaining colour, with minimal impact on handle, were considered:

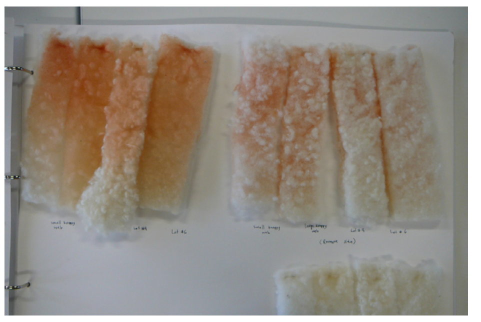
Dyeing: Outer fabric layers, individual knops, knoppy web
Screen-printing: Outer fabric layers with coloured or opaque paste
Spraying: Airbrushing knoppy web with pigment
Thread/yarn: Contrasting quilting thread, coloured yarn in weave, embroidery
Digital printing: Outer fabric layers, wool knop wadding
Layering: Multiple layers of lightweight coloured fabric/netting

However, as sampling developed, I struggled to apply this colour palette effectively to larger samples. These attempts made me realise that adding colour to sandwich-structured textiles was much more complex than I had expected. I was engaging with multiple variables: different layers of fabric, quilting design and colouring methods. It was very difficult to explore colour while simultaneously changing the form of lofted, bulky textiles. It was simply too early to introduce colour because structure was still under development. There were also new colouring techniques such as waterless dyeing and digital printing which could also be investigated. Further research beyond the scope of this project is required to explore the exciting potential of applying colour to knoppy web.

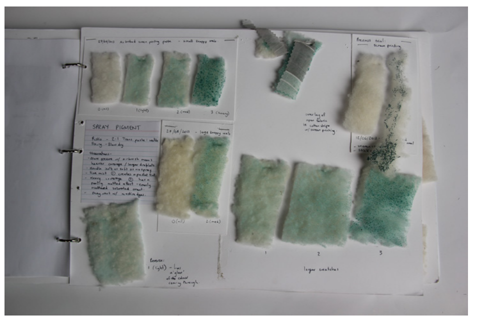
In response to these difficulties, a minimal colour palette was taken forward, with the intention that a specific colour palette could be reintroduced at a later point. Neutral tones and opaque patterns were used to engage with the distorted surface of the quilted textile – maintaining focus on line, form and most importantly loft. It was found that screen-printing on the reverse side of the outer layer of fabric using opaque paste was a successful way to capture opaque/transparent qualities quickly. This could later be translated into woven jacquard pattern. Colouring of the knoppy web layer formed an area of great potential. The knoppy web could be sprayed with pigment, with colour visible through transparent outer layers. This could push the potential of the fill further. Overall, the addition of colour has the ability to differentiate knoppy web as a feature fill material and is viewed as a novel area for future research.



107. Spray pigment on knoppy web (Lots 6 and 4), Massey University 3D workshop



108. Colour shows through reverse side



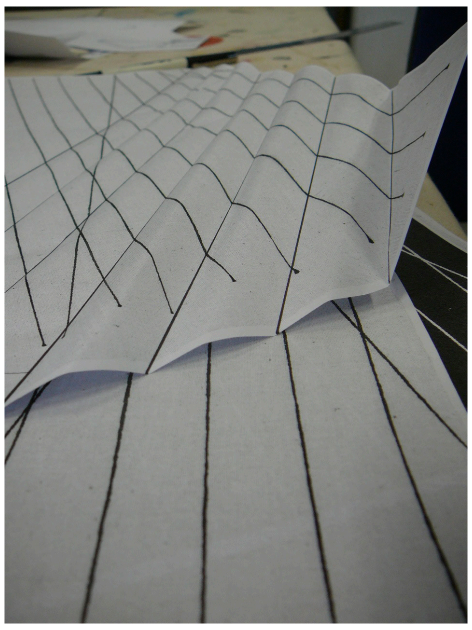
109. Colour variation

110. Colouring multiple layers

111. Colour and texture exploration

112. Colour and texture exploration (detail)

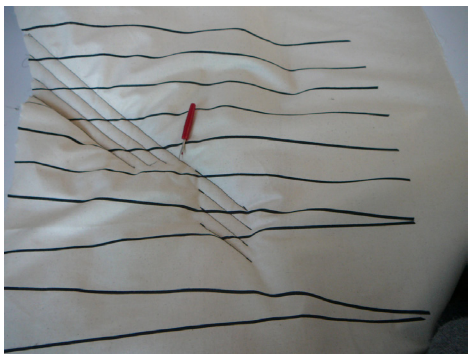
113. Colour palette mood board



Exploring the distortion of line through quilting.

114. *Folding paper with lines to simulate quilting*

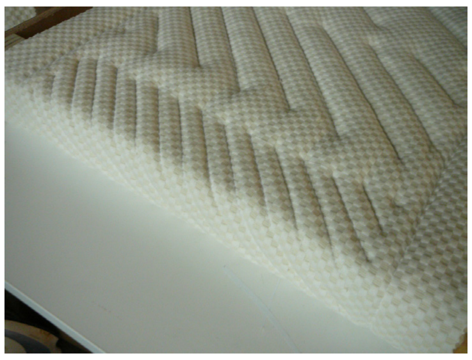
115. *Calico, screen printing, stitching. Overlay of lines*



116. *Unpicking to find distortions*

117. *Return to low tech sampling to work through quilting ideas*

118. *Distorting screen print line*



119. *Sample 17b, October 2013, upholstered to wooden frame. Edging detail*

120. *Sample 23, October 2013. upholstered to wooden frame. Surface detail*

Applying samples to shapes to mock-up use.

121. *Perspex frame, used for creating an edge shape*

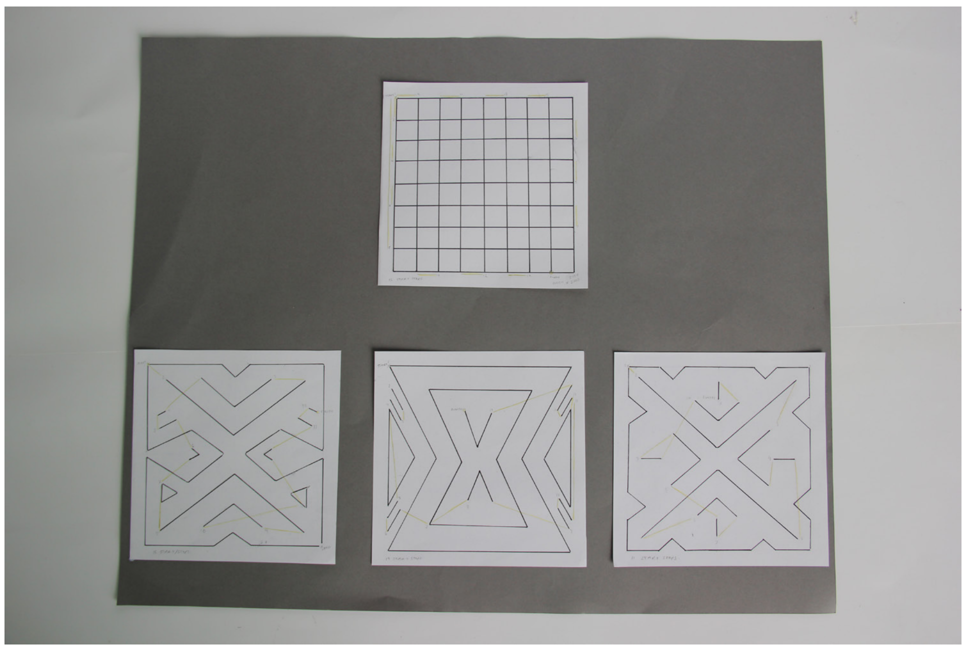
122. *Experimental samples, cutting out stitched and tensioned shapes*

FINDINGS
STAGE 4

During the last stage, the following strategies were identified as offering a new aesthetic for wool bedding through consideration of the outer fabric, knoppy web and digital quilting line path. These samples were carried out during *Onsite visit* #6 in November.

123-126.

Intersect
Distortion of surface pattern and interplay of line from both stitch and graphic print. Transparent and opaque qualities show textural difference, revealing soft fill layer, while retaining a soft handle.



127.

Echo
Through the reverberation of lines and a shifting grid, overall pin-down direction is tilted and splayed apart into open angles, potentially double sided.

128-133.

Undulation
The quilted terrain changes the surface qualities in a structural way through detailed broken lines, resulting in organic geometric sensitivity.

134-137.

Open/closed
Emphasis on continuous quilting line with pin down areas to create positive and negative shaping. Tension changes with both billowing and taut sections. Surface print joins these areas together, responsive to distortion.

138-141.

Verge
Lines relate to an edge or curved form, showing a relationship to three-dimensional shape through directional angles and selected areas of compression.

142-145.

Tension
Attached to frame or an independent shape, the digital quilting machinery is used to reinforce edges, using dense stitching to keep areas taut and tensioned, ready for use.

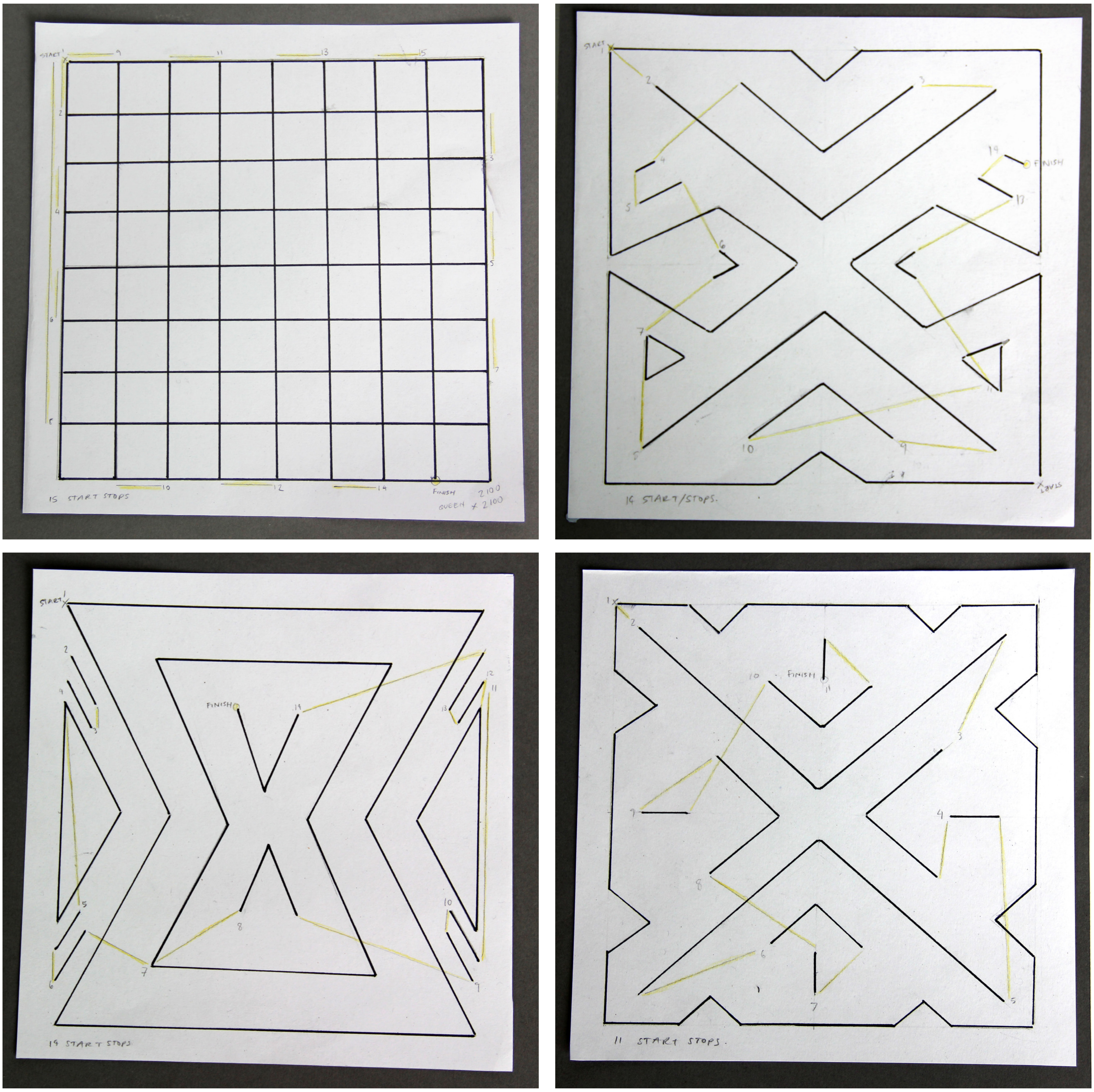
146-149.

Terrain
Using the stitch bonding to sculpt shapes and contoured areas into the surface of the fabric without being restrained to repeat pattern. Could be made to specific shape or scale.

Intersect, Echo, Undulation, Open/closed, Verge, Tension and Terrain are design strategies that can be developed further independently or in combination. For overbody, I recommend that Echo and Open/closed strategies have the greatest potential because they are very efficient (potentially 25% faster than the traditional grid design – See enlarged image), utilising the border outline as part of the design filled in with minimal continuous lines and pin-down areas. For underbody, the biggest opportunity is new market application beyond bedding by quilting shapes for specific small-scale products. My recommendation is to use underbody strategies in combination to develop semi-attached furniture, wheelchair and stroller cushioning.

Pivotal to *Capturing Loft* is the stitch line's effect on lofted bedding textiles. Stitching is a tool of attachment and it became the central strategy of control through loft, compression and release. Stitch line shape, size, direction, spacing and shape had a direct effect on form. The knoppy web fill softened the geometric lines of the quilting, resulting in tension between taut and soft areas. Quilting forms a vital step in the production of bedding and this research proves that quilting design has a tangible effect on the sandwich-structured textile both functionally and aesthetically, therefore, it should not be overlooked.

Value was added to New Zealand wool bedding products by designing for efficiency, bedding function and contemporary aesthetics. It can be assumed the principles of loft, compression and release, realised through this research, can be generalised towards markets beyond bedding.



150. Detail of the Echo design strategy, showing the use of 'isolated lines', 'pin-down areas', 'continuous lines' and 'diagonal lines'. Less starts and stops results in faster production (11 down from 15).

It was important that the sampling journey remained open to new ideas, ready to be translated or changed quickly; or simply ignored or discarded. The sampling process provided a way for ideas to materialise into physical form. Sampling started with insights from previous samples through critical evaluation. In this way the sampling process can be seen as a network, with previous samples forming a point of reference. This process was a combination of structure and unpredictability. This flexible approach seemed to work well as part of a wider research and development project. By gaining experiential knowledge about how the digital quilting process can be used, I gained insight into a wide range of material and end use potentiality.

My initial preconceptions of bedding as a banal area of textile design shifted significantly during this project. It was necessary to bracket these preconceptions early in the project so I could recognise hidden design opportunities. Bulky, multilayered bedding objects were interesting to design for two reasons; firstly, bedding was an intimate object with a close relationship with the body and secondly, bedding had specific physical properties as a multilayered object. The latter was explored through the understanding of sandwich-structured textiles. This definition was important because it helped me recognise although the selection of layers was important; how they were connected was just as significant. Loft, compression and release were three key physical qualities involved throughout the design process.

Designing for bulky textiles was quite challenging. It was found that a typical textile approach did not translate readily due to the aesthetics of stitch bonding. This meant it was necessary to explore the visual language that was associated with the compression and loft relationship. It was acknowledged that quilted textiles create their own three-dimensional aesthetic, with a memory of being stretched taut and released. There is a connection with tension. This relationship was explored through surface pattern design strategies including string experiments and drawing. These experiments helped me understand 'tension' as a design feature.

Through design trend research it was acknowledged that colour is very important to textile design. Although adding colour was explored, it was eventually found that the relationship between line and form was more significant to this project. The area of colour needed extensive research beyond the scope of this project. It was also very difficult to add colour before form had been determined. Through a neutral colour palette however, line, form and distortion became highlighted. It was decided that colour could be inserted when form issues are resolved.

Another area of reflection is designing for a production method and how that production method became embedded in the artefact. This research showed by shifting an existing factory manufacturing process, novel ways of using the machinery could be achieved. This process was aided by close involvement with the machinery used in production. Instead of drawing the designs, having them digitised and quilted by someone else and sent back to the studio in Wellington, I became integral to the process. This gave me a new perspective as a designer. Through observations, small nuances were recognised that effected future designs. This research also showed that the quilting machine could be used in very different ways. Often designs that failed for overbody could be translated into underbody; for example creating rigid areas for over body was not ideal, but these were then translated into underbody. Through this close relationship there were also plenty of failures where material was inappropriate or the design caused distortion. Seeing the cause and effect of these failures allowed me to better understand the parameters and capabilities of the technology.

Working with FibreTech was an insightful experience because the firm had limited design-led experience, but strong interest in technological advancement. Through this project, I confirmed that the speculative design work was quite different to development work. The speculative design was about the idea, or a shift in focus, and the development side was tuned into performance/quality evaluation and market output. The two can and should work closely together, but they are quite different in terms of output. I had to move between these two spaces, speculative design and development work, throughout this collaborative project in order to resolve designs. Testing helped inform design decision-making, but in general did not assist with the resolution of the design from a creative standpoint. How does textile design fit into these different roles of speculative design and development work? It was found that speculative design flourished through the making process, involving trial and error process is a key way of creating original works. In contrast, the development work was grounded in a scientific basis very connected to costs, market and end use. This was shown through the necessity for performance testing to inform development decisions. Understanding and reducing the number of processes involved and taking production speed into account were two areas that impacted the product's viability and definitely affected the design process. Throughout this project, commercial constraints needed to be taken into account, and this undoubtedly has influenced the design process. Working in collaboration with FibreTech showed that often less really is more.

Redesigning quilting stitch paths may not appear to be significant, but the work carried out in *Capturing Loft* produced smart design that did not add to costs. This is best shown through the overbody strategies that looked and functioned better - but were specifically faster to produce when compared to classic quilting designs. This has an impact economically for FibreTech as a way to save money through design. I also identified that the same digital quilting machinery could be used in new way by designing for specific edges, shapes and sizes for an expanded underbody application, opening up new market potential.

This project represents a static moment in time where many aspects could still be developed further. Value through this design-led project has certainly been added to New Zealand wool bedding by exploring knoppy web and how to retain loft from a textile design perspective. FibreTechs research and development project is still ongoing and it will be interesting to how the knoppy web progresses to market. The response from FibreTech and their customers to date has been overwhelmingly positive. Through this design research, a new aesthetic direction was achieved that is responsive to loft, the knoppy web and the selection of complementary outer fabrics through the quilting stitch line; departing from previous overbody and underbody bedding. Overall, the look and feel of wool-filled bedding has evolved.

Figure List

Image List (organised by section and order of appearance)

Photography is credited to the author, Kelly Olatunji

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Stage 2

Stage 3

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77. Sample 10, selected lightweight cotton fabrics (OB 1,2,3), created 09/10/2013 during Onsite Visit #4, existing gridded quilting pattern. Semi-transparency
78. Sample 10, selected lightweight cotton fabrics (OB 1,2,3), created 09/10/2013 during Onsite Visit #4, existing gridded quilting pattern. Drape
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84. Sample 20, Lot 6, cotton weave with double pinstripe (OB 3), created 13/10/2013 during Onsite Visit #4. Design 1 (detail)
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87. Sample 20, Lot 6, cotton weave with double pinstripe (OB 3), created 13/10/2013 during Onsite Visit #4. Folding detail
88. Sample 20, Lot 6, cotton weave with double pinstripe (OB 3), created 13/10/2013 during Onsite Visit #4. draping detail
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130. Sample 26, linen/viscose (OB 6) and linen (OB 4), digitally quilted, created 13/11/2013 during Onsite Visit #6. Undulation strategy. Detail: lightweight linen side (OB 4)
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150. Sample 33, wool (UB 8) digitally quilted, created 13/11/2013 during Onsite Visit #6. Terrain strategy. Detail: placement quilting

In the style of APA

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APPENDICES

Appendix D

MASSEY UNIVERSITY
Application for Approval of Request to Embargo a Thesis
(Pursuant to AC98/168 (Revised 2), Approved by Academic Board 17/02/99)

Name of Candidate: Kelly Olatunji ID Number: 06005535

Degree: Master of Design Dept/Institute/School: Textiles / CoCA

Thesis title: Embedded Design: Exploring Loft through Speculative textile design for wool-filled bedding product development

Name of Chief Supervisor: Sandy Heffernan Telephone Ext: 63225

As author of the above named thesis, I request that my thesis be embargoed from public access until (date) 2016 for the following reasons: 1/01/2016 BHP

☑ Thesis contains commercially sensitive information.

☐ Thesis contains information which is personal or private and/or which was given on the basis that it not be disclosed.

☐ Immediate disclosure of thesis contents would not allow the author a reasonable opportunity to publish all or part of the thesis.

☐ Other (specify):……………………………………………………

Please explain here why you think this request is justified:

Due to Callaghan Innovation / MBIE fellowship, project has a commercial element related to partnership with Fibretech NZ Ltd who wishes to protect Intellectual Property during patent / commercialisation process.

Signed (Candidate): [signature] Date: 7/10/2013

Endorsed (Chief Supervisor): [signature] Date: 7/10/2013

Approved/Not Approved (Representative of VC): [signature] Date: 26/11/2013

Note: Copies of this form, once approved by the representative of the Vice-Chancellor, must be bound into every copy of the thesis.

Contemporary reinterpretation of lofted three-dimensional surfaces through sensitivity of line is revealed through the work of Spanish furniture designer Patricia Urquiola, French product designer Inga Sempé and American textile designer Meg Callahan. Urquiola's furniture designs show how fabric can soften the interior space. Biknit (Image 1) shows the use of filled knitted tubing as woven areas of softness. This work was selected as it gives an example of a departure from flat, upholstered furniture, reinterpreting the piece into an interlacing juxtaposition of hard and soft surfaces. Sempé's Ruché series explores controlled puckering through an interrupted stitch line, providing an evolved quilting texture that captures light and shadow. This was softened further by the use of a pile fabric. This design also blurred the lines between overbody and underbody functions by referencing a draped duvet through furniture design (Image 2). From a technical interest, the quilting design indicates that quilting as a bonding mechanism influences the way the textile folds. Callahan's Ada Quilt (Image 3) was created using a design approach that drew on existing traditional quilting methods, such as patch-working, updated through the use of computer-aided design (CAD) for printing, cutting and quilting. The precision of digital technologies creates a different kind of aesthetic, yet Callahan is still heavily personally involved with the construction of her work. Overall, these designers exemplify materially responsive design for a soft surface dealing with areas of loft and compression.

Image 1.

Biknit for Moroso by Patricia Urquiola (2011)

Image 2.

Ruché Bed for Linge Roset by Inga Sempé (2010)

Image 3.

Ada Quilt by Meg Callagan for Mattermade (n.d.)

1. Anon. (2011) Biknit for Moroso by Patricia Urquiola. Retrieved on November 29 from http://www.moroso.it/home_moroso.php?n=products&model=224&l=en
2. Anon. (2010) Ruché Bed for Linge Roset by Inga Sempé. Retrieved on April 08 from http://www.ingasempe.fr
3. Anon. (n.d.) Meg Callahan Ada quilt for Mattermade. Retrieved on October 27 from _http://mattermatters.com/product.asp?id=1309

From Kelly's notes:

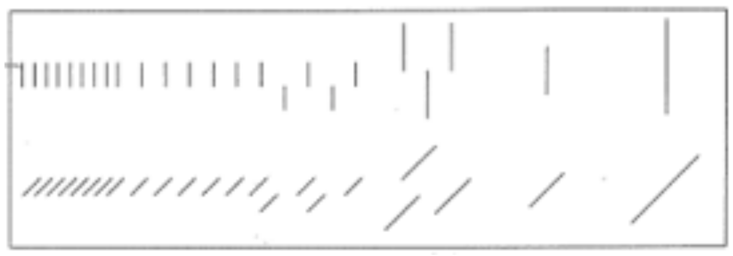
The next quilting tests should still be treated as samples carrying on key samples 1-9 relevant to design direction, to gather the suitable information in order to translate into larger design plans i.e. building blocks. This will help address the difficulty of scaling up to actual bedding size. The changes should include scale, the broken line as well as open and closed shapes. The introduction of pattern on external fabric is important to look at afterwards.

Building block trials:
- Used knoppy web Lots developed by Jack Grigg for PhD
- There is a copy of each design
- These are 'indicative' examples because knoppy web still under development and one side of samples has fabric with default nonwoven on the reverse (can be removed).

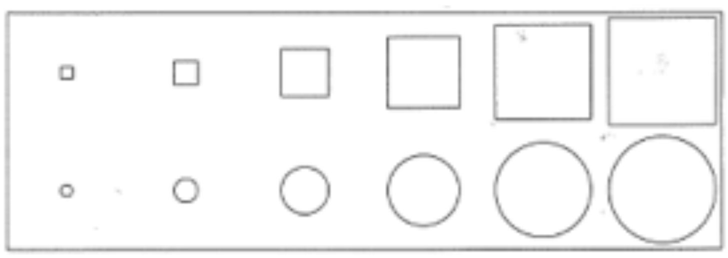
12 different designs; 8 for overbody and 4 for underbody

Overbody - loft/drape/pinning down/ broken line - scale

KO Quilting test Samples 11 and 14 "KO SWATCH 11"
Cotton weave (double pinstripe) w/nonwoven polypropylene on reverse
Fill: Lot 6



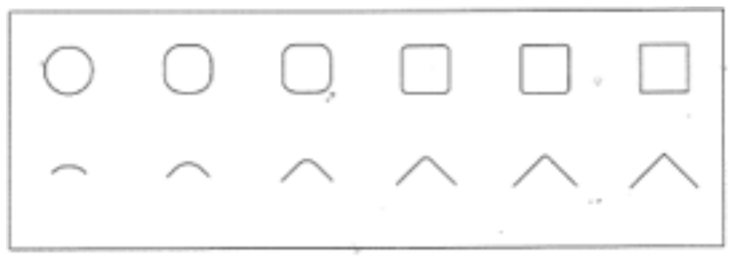
11) Broken line scaled up and angled



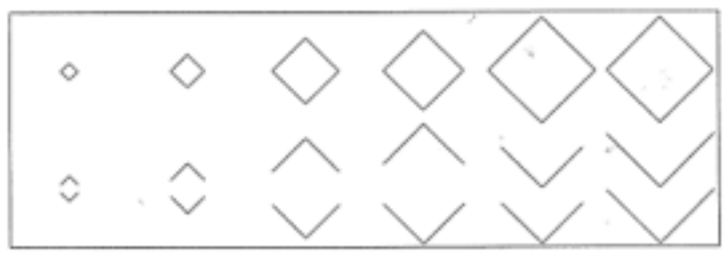
14) Squares/circles small large scale

Why? building blocks for negative and positive space

KO Quilting test Samples 15-16 "KO SWATCH 15"
Cotton weave (stripe) w/nonwoven polypropylene on reverse
Fill: Lot 5



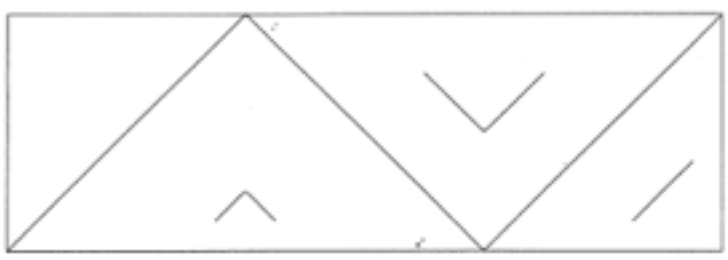
15) Curves to corners



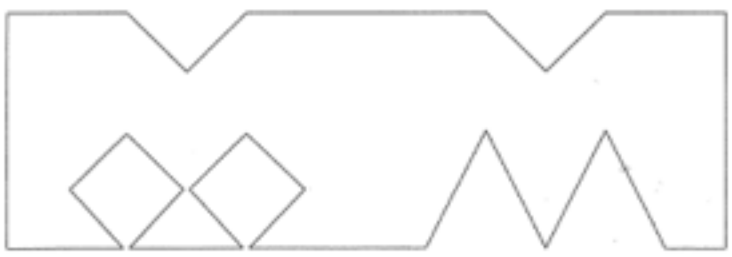
16) 45° shape

Why? Investigation of shapes- open and closed; looking into curves.

KO Quilting test Samples 12-13 "KO SWATCH 16"
Cotton weave (grid) w/nonwoven polypropylene on reverse
Fill: Lot 5



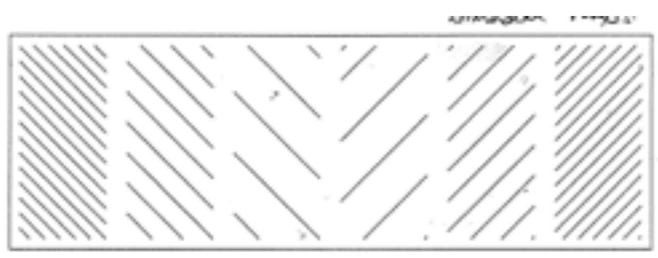
13) 45° chevron with 5mm radius



12) Frame as internal lines

Why? Large lines with more space, relating to large scale designs

KO Quilting test Samples 17 and 20 "SWATCH 18"
Cotton weave (double pinstripe) w/nonwoven polypropylene on reverse
Fill: Lot 6

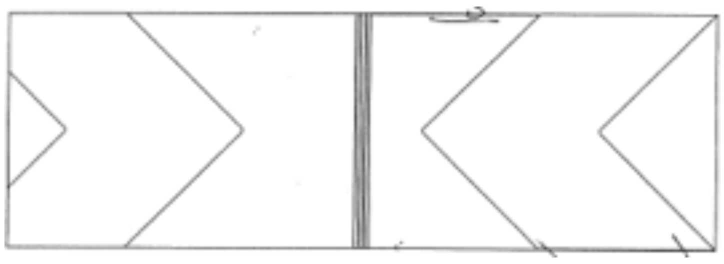


17) 45° angles, alternative line distribution

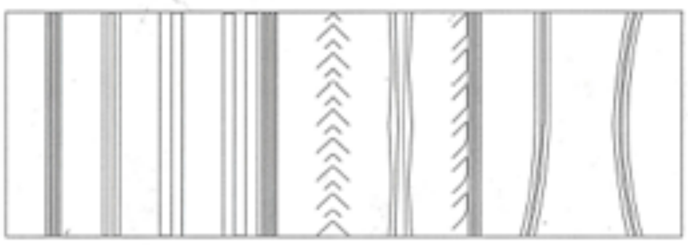
20) Broken line quilting irregular lines

Why? smaller scale quilting, textural look especially with fabric

KO Quilting test Samples 21-22 “SWATCH 17”
Designs: 21-22 - fabric: Jersey knit w nonwoven polypropylene on reverse
Fill: Lot 4



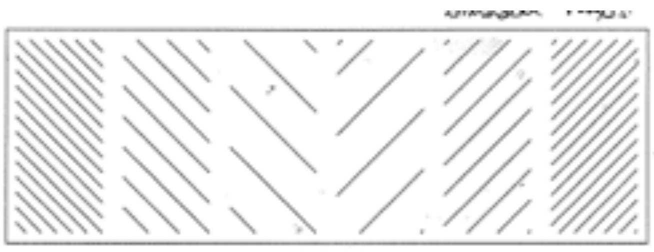
21) alternative lines large scale with centre edging



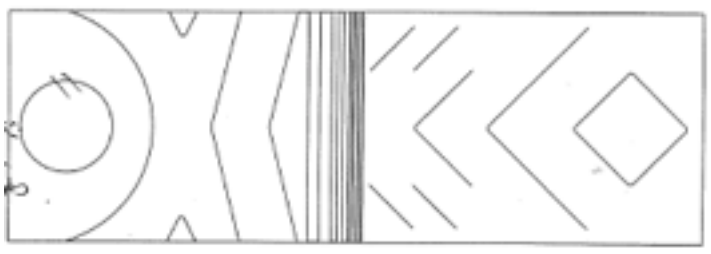
22) shaped crossing over lines with alternative edging

Why? Exploring folding/doubling over and line distance

KO Quilting test Samples 17b and 23 “SWATCH 13B”
Designs: 17 and 23 - fabric: cotton 71.9%/polyester 27.7%/carbon 0.4%
Jacquard knit w/ nonwoven polypropylene on reverse
Fill: Lot 2

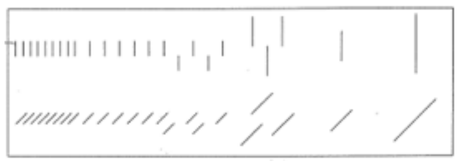


17b) 45° angles, alternative line distribution



23) Edging

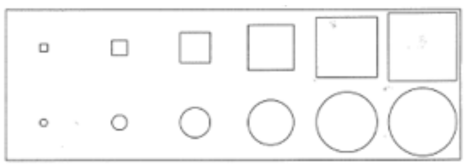
Why? Exploring folding/doubling over through a large area



Sample 11
KO Quilting Test Sample 11 from: KO Quilting test Samples 11 and 14 “KO SWATCH 11”
Double stripe cotton weave w/ nonwoven polypropylene on reverse

Fill: Lot 6
11) Broken line scaled up and angled

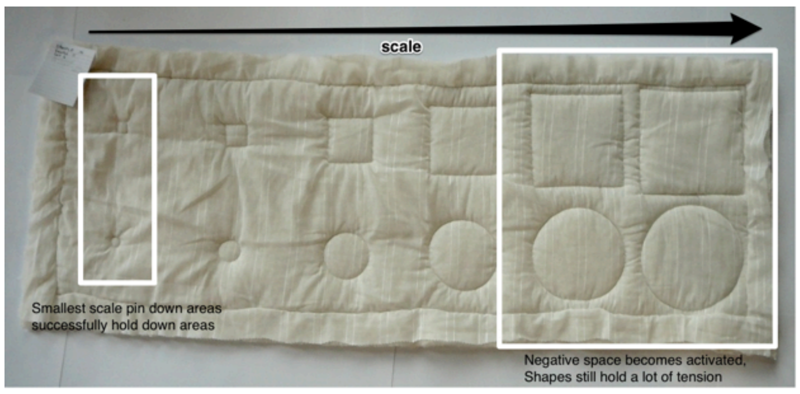
Initial observations:
45º Definitely more effective
Large diagonal lines work well
Pulling on the bias seem some hold tension better that with the selvedge
Indenting look - pulls fabric down in a section - creating a channel
45º has a more defined shadow line and catches the light when viewed on an angle.

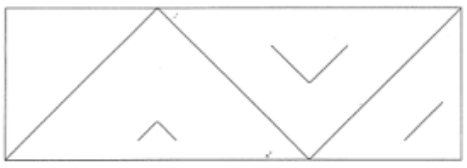


Sample 14
KO Quilting Test Sample 14 from: KO Quilting test Samples 11 and 14 “KO SWATCH 11”
Double stripe cotton weave w/ nonwoven polypropylene on reverse

Fill: Lot 6
14) Squares/circles small large scale

Initial observations:
As the scale gets larger, the less bagging occurs. Closed shape hold tension.
As the scale grows and they become closer together, the negative space becomes activated
Large pin down areas (e.g. large circle/square) have quite a transparent effect as fabric is stretched.
Pulls in stitching as square scale grows -- similar to sample 11/straight lines - circles have less puckering/ more even tension.
Stitching has caused a fair amount of distortion.

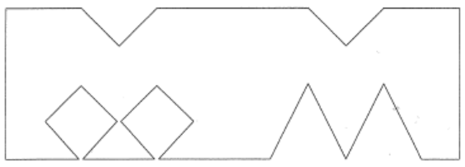




Sample 13
KO Quilting test 13 from: KO Quilting test Samples 12-13 “KO SWATCH 16”
Grid cotton weave w/nonwoven polypropylene on reverse

Fill: Lot 5
13) 45° chevron with 5mm radius

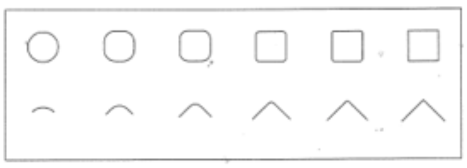
Initial observations:
Tension works well with smaller pin down areas echoing larger stitched sections
outer shell separated from fill
creasing of fabric takes away from pattern



Sample 12
KO Quilting Test Sample 12 from: KO Quilting test Samples 12-13 “KO SWATCH 16”
Grid cotton weave w/nonwoven polypropylene on reverse

Fill: Lot 5
12) Frame as internal lines

Initial observations:
Adding lines that come from the edges/outside works well to create shapes
Have decided to leave this large scale
Areas where puckering/creases a design opportunity?
Diamond/diagonal shaping works well
Horizontal line working well in weave travelling across the sandwiched-structure, more effective than a vertical grid line.

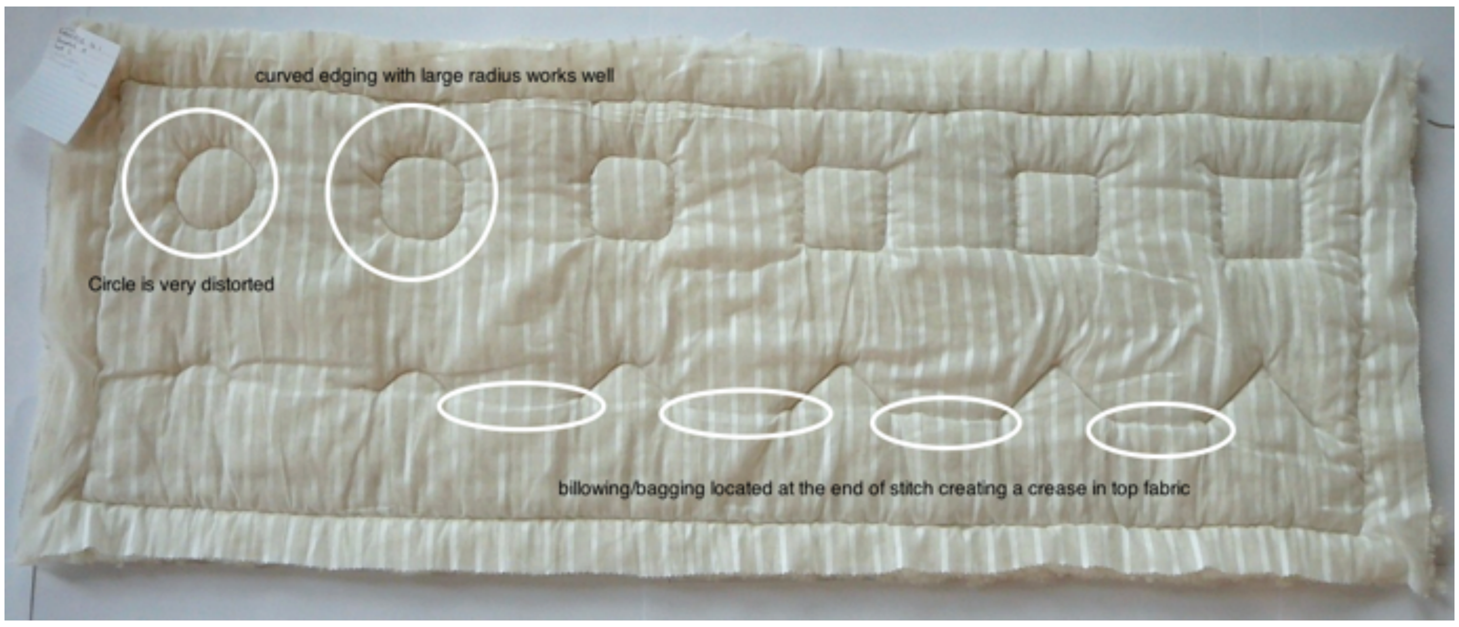


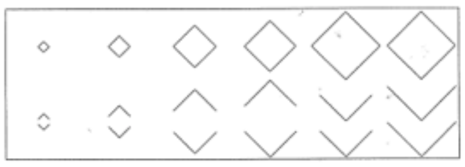
Sample 16
KO Quilting Test Sample 16 from:
KO Quilting test Samples 15-16 “KO SWATCH 15”
Even stripe weave cotton weave w/ nonwoven polypropylene on reverse

Fill: Lot 5
16) Curves to corners

Initial observations:
Circle to square -
Circle has distorted
Can see through fabric
Bagging happening in negative space
Lines are slightly off
Curved corned don’t pucker as much
Square is also distorted through stitch area (puckering)

Open curves to corner -
Where the lines end, a fold is created in top layer of fabric
fabric creases easily
Bagging ends up settling on the edge of stitch lines - pleating these areas gradually

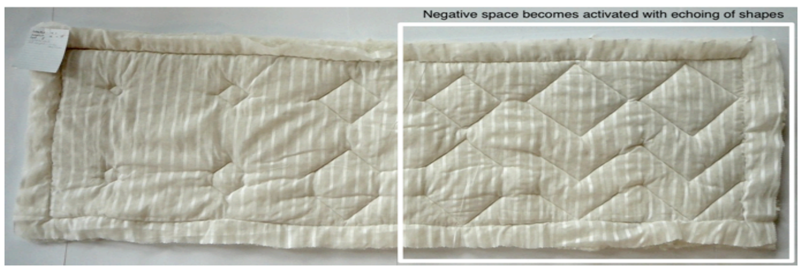


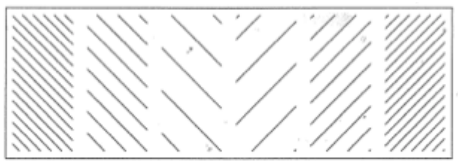


Sample 15
KO Quilting Test Sample 15 from:
KO Quilting test Samples 15-16 “KO SWATCH 15”
Even stripe weave w/nonwoven polypropylene on reverse

Fill: Lot 5
15) 45° shape

Initial observations:
Diagonal/diamond shape works well
Lot 5 knops are more defined than Lot 6 knops
This stripe is quite bold and suits the opaque/transparent nature of knop/ outerlayer relationshp
Open shapes show an increase in creasing and bagging.
Rounded corners should be introduced
Areas where the shapes are ‘echoed’ is quite aesthetically effective, elogates the shapes.





Sample 17A
KO Quilting Test Sample 17 from:
KO Quilting test Samples 17 and 20
“SWATCH 18”
Double stripe cotton weave w/
nonwoven polypropylene on reverse

Fill: Lot 6
17) 45º angles, alternative line distribution

Initial observations:
This was a confirmation that the diagonal line was much more successful that a 90º line for pinning down fabric. It is more aesthetically pleasing loser together/ with more loft - holds the tension better, however effecting drape much more that lines further apart.
The 2nd spacing (similar to sample made with the industrial sewing machine) work well.
Large lines look deflated; due to the bagging of fabric.
Scalloping of straight lines on the edge softens the transition between quilted and un-quilted areas.

Sectioning of diagonal lines have created quite separated areas, negative space creating straight edges.
Straight lines in weave have been distorted via curving_

Sample 20
KO Quilting Test Sample 20 from:
KO Quilting test Samples 17 and 20
“SWATCH 18”
Double stripe cotton weave w/
nonwoven polypropylene on reverse

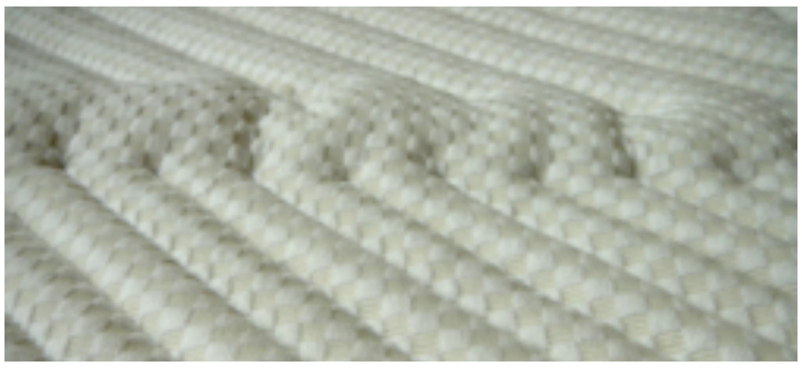
Fill: Lot 6
20) Broken line quilting irregular lines

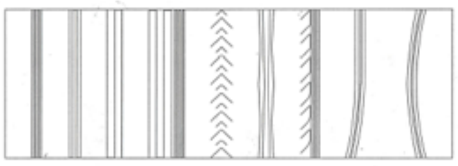
Initial observations:
Section A
Effective use of positive and negative space. Where the diagonal lines are closer together the resulting pull lines are firmer and more intentional
Intersecting ends - create a texture
Shadows for graphic look
Section B
Bagging areas distract from look
- dues to broken line being further apart
not a strong relationship for where ends finish.
Section C
Intermittent line has some interesting surface effects, allowing for drape in both cross directions. There is an ‘opposite’ design in negative space, however fabric is quite baggy.
Over all the lines in fabric are distracting, don’t really add to the designs formed through quilting

Sample 17B
KO Quilting Test Sample 17b from:
KO Quilting test Samples 17b and 23
"SWATCH 13B"
Designs: 17 and 23 - fabric:
Elasticised cotton/polyester/
carbon jacquard knit w/ nonwoven
polypropylene on reverse

Fill: Lot 2
17b) 45º angles, alternative line distribution

Initial observations:
Initial observations:
2 smaller line distance areas are more successful than larger central sections - large lines may work with more fill.
Most dramatic difference is the height distance between small and medium sized lines - mid sized hasn't compressed the fill as much (much more lofty). Structure is created with combination of a thick outer fabric, narrow lines and fill in combination.
Very different handle compared to Sample 17A.
Basically, the larger sized diagonal lines are not as filled so quite baggy.

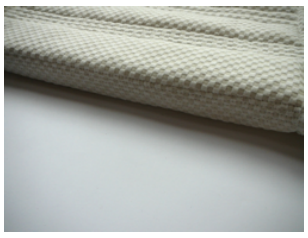


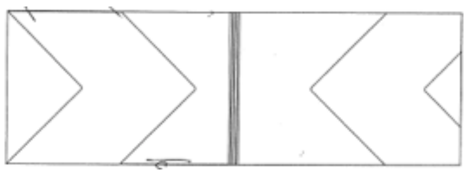


Sample 23
KO Quilting test Samples 17b and 23
"SWATCH 13B"
Designs: 17 and 23 - fabric:
Elasticised cotton/polyester/
carbon jacquard knit w/ nonwoven
polypropylene on reverse

Fill: Lot 2
23) Edging

Initial observations:
Different edging styles can be achieved by changing the line density.
5mm gap between lines creates a crisp edge



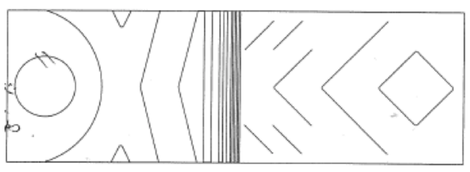


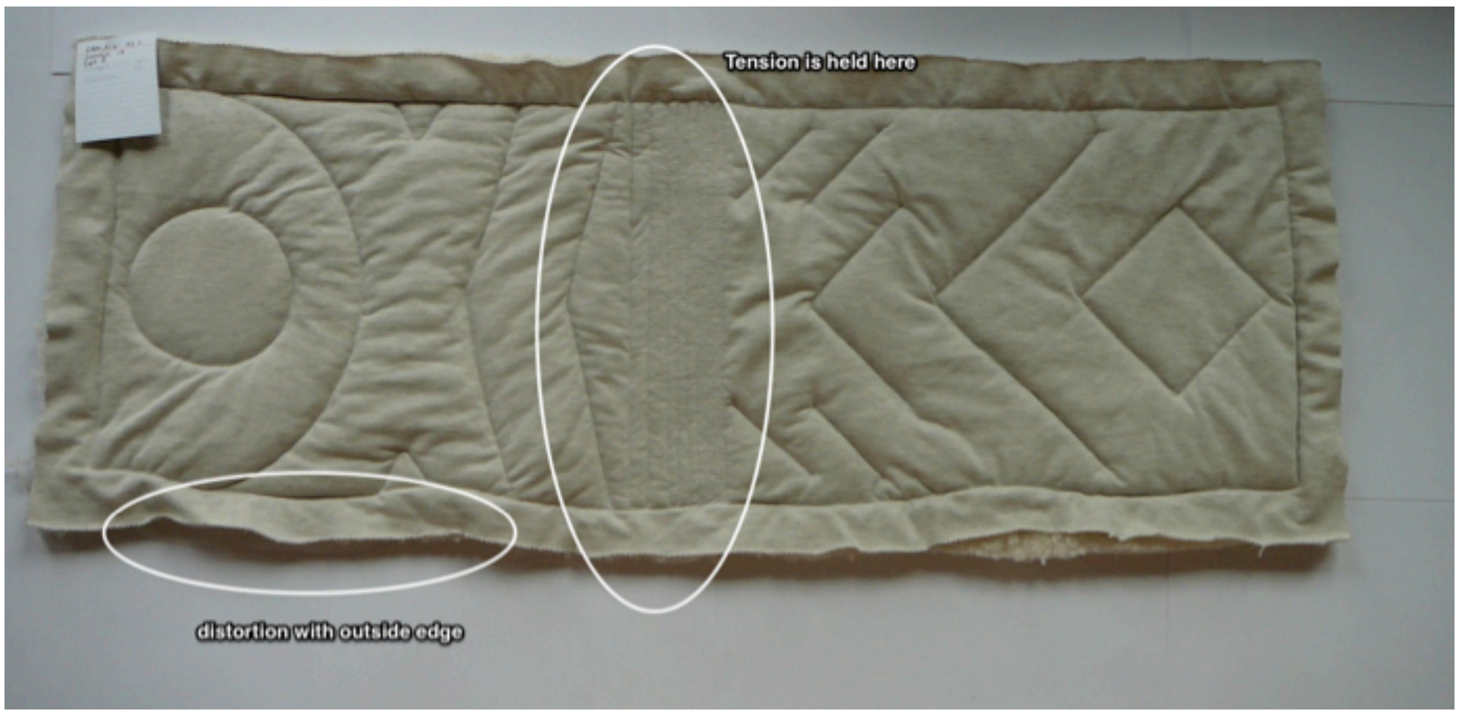
Samples 21
KO Quilting Test Sample 21 from:
KO Quilting test Samples 21-22
“SWATCH 17”
Designs: 21-22 - fabric: Cotton Jersey knit w nonwoven polypropylene on reverse

Fill: Lot 4
21) alternative lines large scale with centre edging

Initial observations:
-Fabric is bagging and is not appropriate for use
-Alternate lines do not make much different when double over

Sectioning of diagonal lines have created quite separated areas, negative space creating straight edges.
Straight lines in weave have been distorted via curving_





Sample 20
KO Quilting Test Sample 22 from:
KO Quilting test Samples 21-22
“SWATCH 17”
Designs: 21-22 - fabric: Cotton Jersey knit w nonwoven polypropylene on reverse

Fill: Lot 4
22) Placement stitching (alternate shapes) with centre edging

Initial observations:
Didn’t work
The knit fabric distorts, not a good quality
Outer edges have pulled in where more stitching has taken place, would need reinforcing.
Puckering very unattractive
Circle has a gap, design flaw.

Testing date:
9/11/2013

Location:
Massey University Wellington,
Textiles Lab

Preparation:
Fabric prepared in accordance to ASTM International's Standard Practice for Conditioning and Testing Textiles D 1776-08

Lab atmosphere:
RH 50.2%;
Temperature: 22%-

Thickness testing:
ASTM International Standard Test Methods for Thickness of Textile Material D 1776-97 (Reapproved 2007)

Schimdt apparatus used for measuring
Waited 5-6 seconds before reading result
5 readings taken and the averages calculated.

Weight testing:
ASTM International Mass Per Unit Area (Weight of Fabric) D 3776/ D776M-09a

Three 100x100mm squares cut from each fabric sample.
Measured on scientific scales
3 readings observed in total

Notes:
Dry atmosphere (target according to Standard is RH 65%, 21°C +/-1)
The same fabric sample was used for both tests method.

Overbody (OB) Outer fabric

OB Outer Layer #	Fibre Content	Structure	Thickness (mm)**	Weight (gsm)***
1	Cotton	Plain weave - stripe (warp)	0.2874	62.03
2	Cotton	Plain weave - stripe (warp/weft)	0.4020	51.95
3	Cotton	Plain weave - double pinstripe	0.2472	46.03
4	Linen (flax) - bleached	Plain weave	0.1828	52.07
5	Linen (flax) - natural	Plain weave	0.4348	108.67
6	Linen/viscose - dyed	Plain weave	0.3544	144.00
7	Cotton (50%)/merino (50%)	Interlock knit	0.5150	146.40
8	Wool - dyed	Double cloth weave	0.7546	213.30
9	Wool (89%)/polyester (11%)	Plain weave	0.2838	79.90
10	Polypropylene*	Nonwoven	0.1770	16.60

Underbody (OB) Outer fabric

UB Outer Layer #	Fibre Content	Structure	Thickness (mm)**	Weight (gsm)***
1	Cotton (71.9%)/polyester (27.7%)/carbon (0.4%)	Jacquard knit	1.6014	383.00
2	Wool	Twill weave, felted	1.6910	390.70
3	Wool	Twill weave, felted	1.0664	350.97
4	Wool	Twill weave, felted	1.4338	353.87
5	Wool	Twill weave	0.5520	186.77
6	Wool (merino)	Jersey knit, single, loop	5.4530	366.66
7	Wool	Jersey knit, single, loop	1.1992	259.83
8	Wool (merino)	Jersey knit, single, fleece	1.4078	372.33

Compression Testing
Kelly Olatunji with supervision from Dr J. Webster

Testing date:
21/11/2013

Equipment:
Using TensoLab machine set up for compression testing.

Aim:
To test effect of compression on multilayered textiles (with knoppy web fill) with varied quilting spacing.

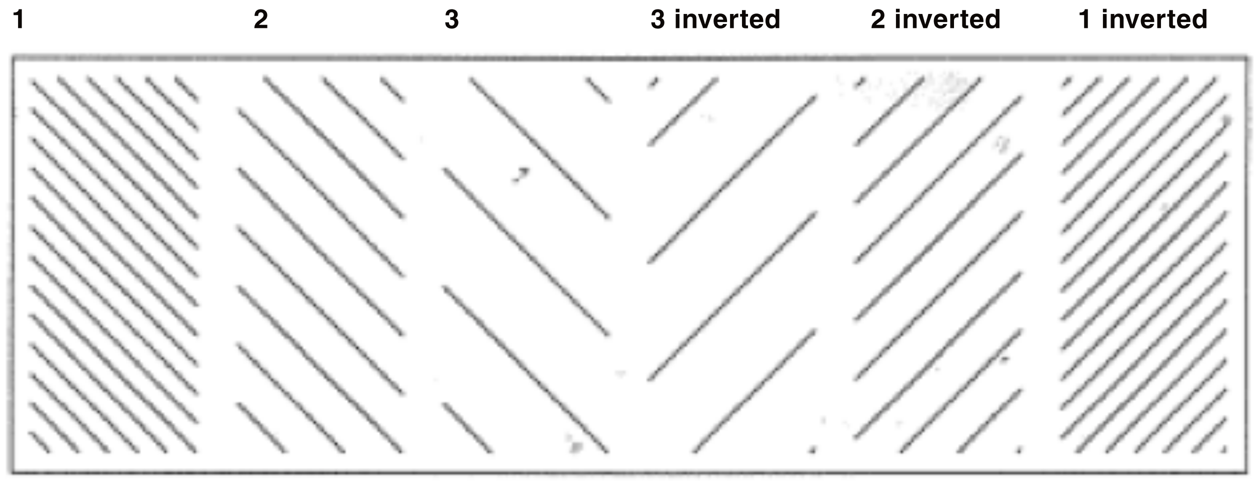
Hypothesis:
The more stitching present, the more resistance to compression.

Testing:
Measuring the force (N) and elongation (difference in height). This also means the thickness can be determined as pressure is exerted on the sample (shown through the data as the clamp comes down) counting from ‘0’. Plate dimension: 45mmx110mm . Force is considered constant with maximum load approx 155N.

Samples:
Sandwich structured textiles, quilted on Dolphin digital quilting machine via CAD
Top layer: Industry standard mattress standard ticking from UB Fabric 1, jacquard knit (top) is Bekaert Australia TR1139 Warp: Knitting, Weft 107. Composition: Cotton/71.9%, Polyester 27.7% Carbon0.4%.
Bottom layer: OB Fabric 10, nonwoven lightweight polypropylene (bottom).
Fill layer: Lot 2; wool/PLA knop wadding.

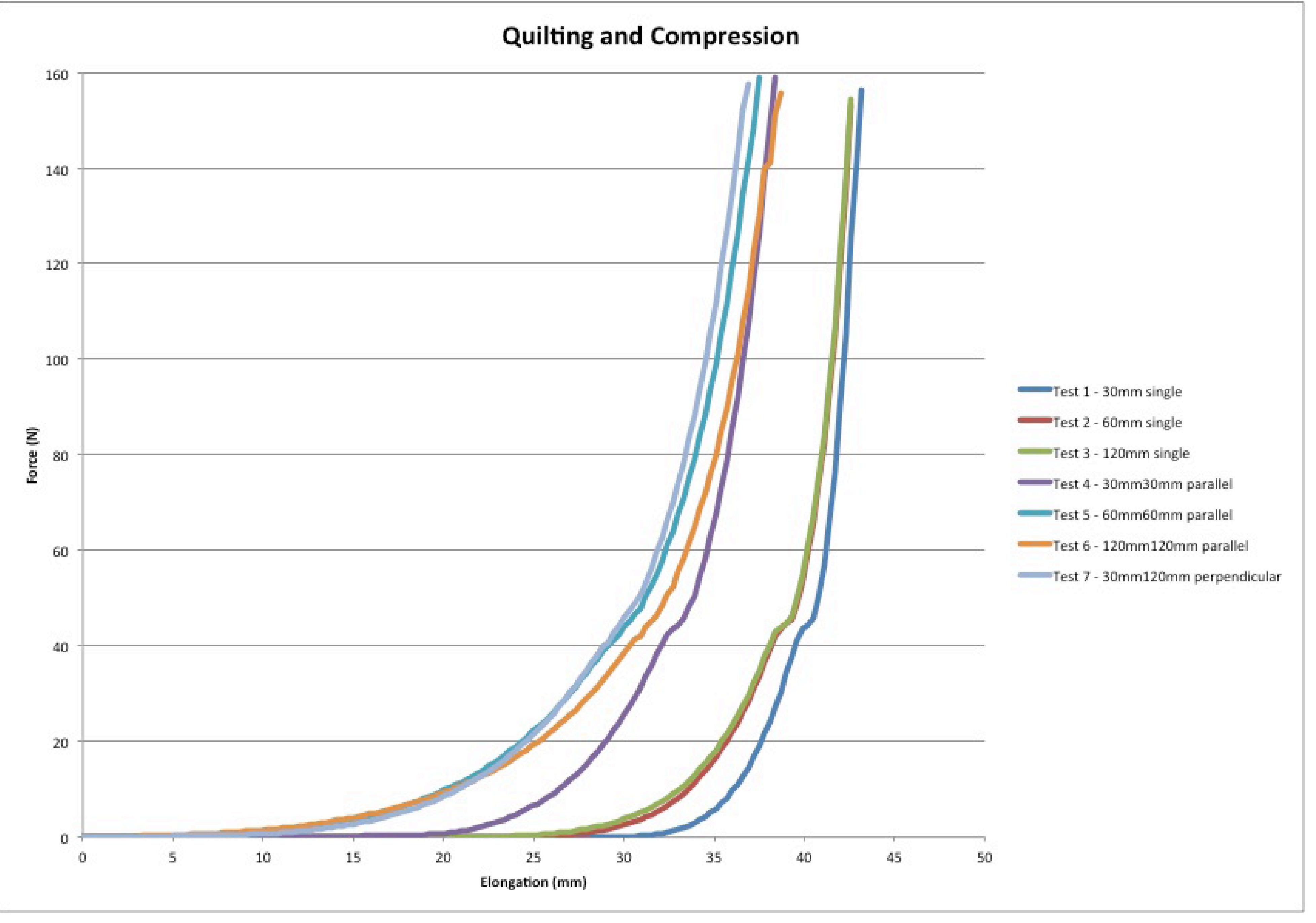
Design:
17B, Swatch 13B

Design details:
45º angled lines at different space intervals. Measurement taken from edge of design and are as follows:
1: 30mm spacing
2: 60mm spacing
3: 120mm spacing



Samples have been conditioned in Massey University Textile Lab for the stipulated 24 hours according to Standard Pracitce for Conditioning and Testing Textiles D 1776-08. Relative humidity at time of testing: 55%, temperature 22.2ºC

Results:



Test design:

Single layer:
Test 1- 30mm spacing
Test 2- 60mm spacing
Test 3- 120mm spacing

Double layer:
parallel (lines up in gaps)
Test 4- 30mm spacing and 30mm spacing
Test 5- 60mm spacing and 60mm (top) spacing
Test 6- 30mm spacing and 120mm (top) spacing

Double layer:
perpendicular (stitch lines cross over)
Test 7- 30mm spacing and 120mm (top) spacing

Samples from each spacing sample to be cut: If the above method is followed then 11 pieces of test fabric in total needed for testing (follow the above specifications)

Number of repeat tests:
3 repeats

Test Settings:
Clamp position: 50mm
Clamp Initial position: 50mm
Test speed: 100.0
Recording rate: 0.3 seconds
Percent rate of fall of max values force: 10
Maximum force: 0.00
Elongation 0.0
Extra elongation 0.0
Pretension: 0.00

Notes:
- Avoid compressing the same area twice.
- Wider samples to go on top, with smaller intervals to go below; nonwoven in the center, fabric on the out side more similar to use.
- Through preliminary testing, the doubling of material had the greatest effect on the compression indicators; N and Elongation
- Elongation is actually a negative description – squashes the sample instead of stretching
Interpreting the data - Excel spread sheet for raw data, find averages and plot in graph

Discussion:
Quilting spacing does effect the modulus of compression as shown through the varying amounts of force needed to compress the textile.