TALLINN UNIVERSITY OF TECHNOLOGY
SCHOOL OF ENGINEERING
Department of Materials and Environmental Technology

USING DIGITAL PRINTING AND EMBROIDERING FOR CREATING A LINGERIE COLLECTION

DIGITRÜKI JA TIKANDITE KASUTAMINE PESUKOLLEKTSIOONI LOOMISEL

MASTER THESIS

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Tallinn 2022

(*On the reverse side of title page*)

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THESIS TASK

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Thesis topic:

(in English) Using digital printing and embroidering for creating a lingerie collection.
(in Estonian) Digitrüki ja tikandite kasutamine pesukollektsiooni loomisel.

Thesis main objectives:

Using digital printing and embroidering for creating high fashion and long-lasting lingerie collection from high-quality and luxurious materials.

Objectives to achieve the main goal:

1. To analyse market trends and perform a survey among potential customers.
2. To study the properties of potential materials for lingerie collection.
3. To test digital printing and embroidering on lingerie fabrics.
4. To create a lingerie collection.

Thesis tasks and time schedule:

No	Task description	Deadline
1.	Researching the market trends and lingerie fabrics	18.03.21
2.	Researching embroidery fabrics suggestions, software and machinery	29.04.21
3.	Submitting and analysing the questionnaire	02.09.21
4.	Drawing of the design ideas	20.12.21
5.	Creating the illustrations	04.01.22
6.	Experiment embroidery and textile printing possibilities and analysing the fabrics and the quality of embroidery and textile printing results	04.03.22
7.	Modifying the illustrations	10.03.22
8.	Construction of the final patterns	29.03.22
9.	Testing the chosen material properties	29.04.22
10.	Sewing of the prototype's samples including modifying the patterns sewing and two lingerie sets of ready-made products	11.05.22

Language: English **Deadline for submission of thesis:** "24" May 2022.a

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CONTENTS

1. INTRODUCTION

Lingerie history has gone a long way from linen to all kinds of new materials. There is a possibility of many different styles, fabrics and colours. Lingerie holds the power of comfortability including confidence and is made for many sizes and different bodies. Lingerie helps a woman and a man to feel good in their body and mind.

Nowadays lingerie can be worn to the private rooms as well outside environment. Lingerie can be worn on different clothing, thereby with time it has evolved into having more decorative elements and materials. These decorative elements include digital print and embroidery. Embroidery is a decorative needlework by using chosen thread to form a decorative design on a specific material that can be done by hand or machine. Digital textile printing on the other hand offers creating prints and illustrations from a computer to textile.

The main aim of this thesis was to use digital printing and embroidering for creating high fashion and long-lasting lingerie collection from high-quality and luxurious materials. To achieve the goal four objectives were set. These include analysing market trends and performing a survey among potential customers. Additionally, study the properties of potential materials for lingerie collection, test digital printing and embroidering on lingerie fabrics and finally create a lingerie collection.

Using digital printing and embroidering for creating a lingerie collection was first inspired by haute couture, “high fashion”. Haute couture is described as high dress making. It is the creation of exclusive custom fit clothing where all the pieces are constructed by hand from start to finish. Haute couture uses only high-quality fabrics with extreme attention to detail that are made by skilled craftsmen. Using haute couture as inspiration came from previous work on hand embroidering field that is very time consuming and expensive, thereby produced to one customer at a time. To achieve unique hand embroidery style digital printing and machine embroidering testings were planned on lingerie fabrics. A short and simple brief questionnaire was compiled for overview of lingerie market as well preferred lingerie options and types, that helped to design the collection idea. The design idea for this collection was to test different variations of product patterns as well looks due to the market having not enough fitting lingerie. The goal was to learn the construction of lingerie patterns according to known measurements.

This thesis consists of theoretical and practical part. The theoretical part includes the story of lingerie, research on the current market trends, construction types and material option. In addition, the introduction on digital printing and embroidering. The theoretical part also includes overview of computer aided design (CAD) software.

The practical part starts with an overview of the product development process and continues with material testing's and methods. While producing different items it is necessary to consider their origin and usage. Choosing the materials is one of the most important parts for the circular economy. In addition, because lingerie is so close to the body, it needs to be naturally chemical free for the health and safety benefits. Following topic on construction and technology of lingerie collection is divided into two subchapters called making of set 1 and 2. These subchapters include an overview of the illustrations, pattern making, specification and sewing technology.

The conclusions chapter at the end of the thesis analyses the overall performance of chosen lingerie fabrics and the problems encountered in testing and product development.

2. LINGERIE THE HISTORY OF LINGERIE AND CURRENT MARKET TRENDS

2.1 The history of lingerie

Lingerie can be many things, mysterious, sensual, seducing, sexy, comfortable and beautiful. Lingerie has many styles and possibilities that are directly and very strongly related to a woman's intimacy [1]. Lingerie needs to be comfortable, stretchy, and good for the body, naturally chemical free. The word "lingerie" itself is a word taken from the French language "linge" meaning "things made out of linen" [2]. Ever since ancient times producing lingerie from wool, linen and hemp was common depending on what people could afford. Linen was usual in France in the 11th century and was used by the Romans, Greeks and Northern Europeans previously [3]. The word "lingerie" itself in English means "women's underwear or nightclothes "[4].

For centuries men have thought that one of the reasons why lingerie was created was to seduce them [1]. There is a phenomenon where women in their lingerie are more sensual then naked. Important role in lingerie plays the fabric, the colour and the feeling. One of the most flattering colours for the skin are black and white. Black, (more particularly) allows the softening of bodily flaws. Hot colours (pink, red, raspberry) are also enhancing colours. On the other hand, cold colours used for lingerie are always more difficult to work with. Greens and blues are magnificent, but all too often evoke swimming costumes. The word underwear is synonymous with lingerie, the term used to refer to specific undergarments such as petticoats and camisoles, and later bloomers, leggings, underpants, undershirts, and full-length slips [1]. Following will present as well the questionnaire results for preferred colour options in 21st century.

Lingerie has the possibility to change mood, affect lives and decide the wearers feelings and views. Lingerie makes women confident and powerful being so close next to the body. Lingerie needs to be clean, chemical free and comfortable. Nowadays lingerie is also worn on other clothing or can be shown off not only in the private rooms but as well outside environment [5]. It is also classy and chic to wear lingerie and some sort of jacket or a coat for example onto it. With preferred coverage this option in fashion is sexy and not so revealing. Additionally, in the 21st century, plenty of young women (especially), wear low-cut trousers with thongs due to the attention

put on underwear. They want their underwear to be seen by someone-if not everyone [6].

2.2 Current market trends for lingerie

Current lingerie market trends have many materials and possibilities as well price options. Short research on different lingerie items and sets can be seen following. The following example pieces include some of the most popular brands such as The Naked Tiger, Calvin Klein, Ralph Lauren, Tommy Hilfiger, Zilyova Lingerie and Bellart. These brands prove that lingerie can be unfunctional but made for fashion, comfortable for every day wear as well sports styled and decorative.

2.2.1 The Naked Tiger Macy bra and ribbed shorts in white

Lingerie market includes metal material options. Wearing metal lingerie is infrequent as well unfunctional but can create a very artistic and appealing appearance. This lingerie style could be worn to festivals or other events where the goal is to stand out by wearing just a bra. The Naked Tiger uses as an example unique 100% metal as a garment in a Macy bra (Figure 2.2.1.1). Price is €120 [7].

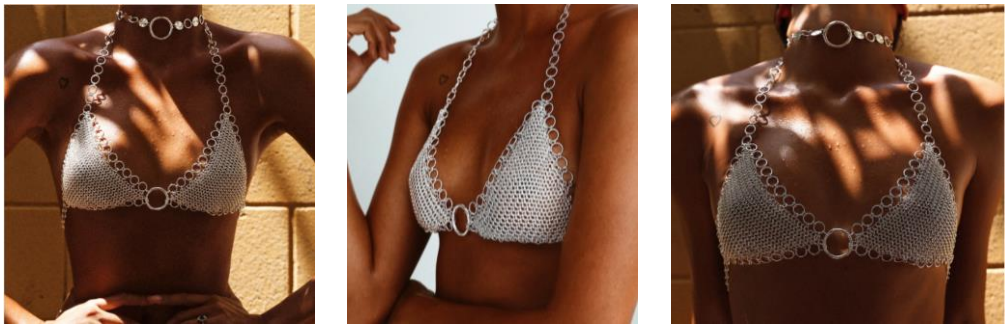


Figure 2.2.1.1 The Naked Tiger Macy bra and choker set [7]

Lingerie market for everyday wear includes mostly of comfortable materials. The Naked Tiger ribbed shorts present very comfortable patterns and materials. These ribbed shorts in white have elastic waistband, cuffed hem and are made of soft cotton rib stretch light weight material presenting possibility of movement and breathability (Figure 2.2.1.2). Price is €32,31 [8].


Figure 2.2.1.2 The Naked Tiger ribbed shorts in white [8]

2.2.2 Calvin Klein modern stretch cotton blend jersey brief and soft cup bra

Lingerie market includes many sports styled lingerie. Calvin Klein modern stretch cotton blend jersey briefs and soft cup bra set presents sport styled simple patterns. Calvin Klein modern stretch cotton blend jersey briefs have a white and black elastic and are lined at base (Figure 2.2.2.1). Stretch jersey soft cup bras are made out of black stretch jersey and have a white and black elastic (Figure 2.2.2.1). The fabric content presents different fibre compositions for both items. For briefs main material is 53% cotton, 35% modal, 12% elastane; trim 67% nylon, 23% polyester, 10% elastane; lining 100% cotton and for bra main material is 69% nylon, 23% polyester, 8% elastane. Price for briefs is €23,82 [9] and for bra €35.71 [10].

Figure 2.2.2.1 Calvin Klein lingerie set brief [9] and bra [10]

2.2.3 Ralph Lauren tropical print stretch cotton trunks

Printing on lingerie is often done for achieving certain goals. These trunks present a very colourful print possibility for men while proving print options for lingerie are endless. Ralph Lauren tropical printed stretch cotton trunks for men have unique design elements and contain 95% cotton 5% elastane (Figure 2.2.3.1). The price for these eye-catching tropical stretch cotton trunks is €29,95 [11].

Figure 2.2.3.1 Ralph Lauren tropical printed cotton trunks for men [11]

2.2.4 Tommy Hilfiger logo print triangle bra

Other print options include focusing on branding. Many printed items on the market include printed fashion house logos or elements. Tommy Hilfiger features an all-over logo print and a branded under band made out of 69% organic cotton, 21% recycled cotton, and 10% elastane (Figure 2.2.4.1). Branded items can be common purchase for a loyal client. The price for this logo print triangle bra is €18 [12].

Figure 2.2.4.1 Tommy Hilfiger logo print triangle bra [12]

2.2.5 Zhilyova and Sashatattooing embroidered Scorpio Red briefs

Embroideries bring focus even to a simpler product making them more special or meaningful. These briefs present simple and effective unique scorpion embroidery. Every Zhilyova Lingerie collection explores several different areas, which combination reveals new facets of femininity and freedom [13]. Zhilyova Lingerie in collaboration with Sashatattooing made high waisted briefs of semi-transparent stretch tulle, with original scorpion embroidery in front (Figure 2.2.5.1). Fabric content 70% nylon, 21% viscose, 9% elastane and lining are 100% cotton. Price for high waisted briefs with embroidery work is €45,33 [14].

Figure 2.2.5.1 Zhilyova Lingerie high waisted briefs [14]

2.2.6 Bellart sensuality embroidered set Olimpēa

Lingerie market trends include also luxury items with hand embroidered details, sequins or crystals. Bellart "Olimpēa" set proves handmade couture lingerie can be made with spending hours on just on product (Figure 2.2.6.1). The lingerie consists of halter cut bralette made of tulle while each piece is intervened with Swarovsky crystals and rose gold coloured Miyuki stones. This set brings unique patterns and embroideries intervened with rhinestones to life. Price for this unique set is €1,803.35 [15].

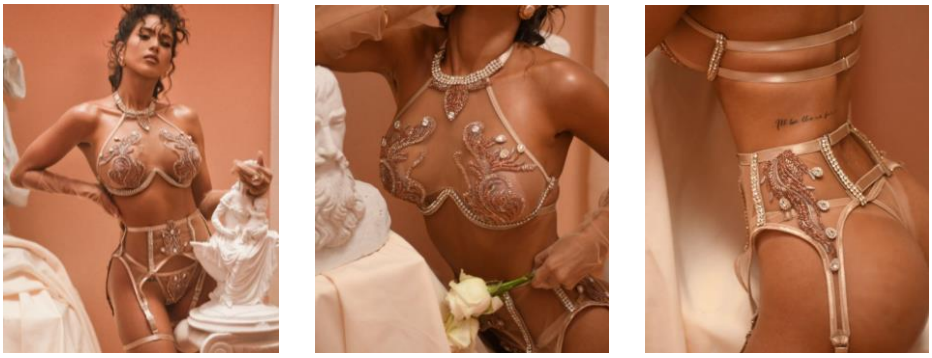


Figure 2.2.6.1 Bellart embroidered set Olimpēa [15]

3. LINGERIE AND NIGHTWEAR TYPES

The construction of different types of bras, panties and sleepwear can vary greatly. The most common lingerie types include sports bra, bralettes, bustier, wired bra, strapless, corsets, high waist and low waist thong, briefs, panties, nickers and other sleepwear Finding and making lingerie inquires taking many measurements (Figure 3.1). The following includes possible samples of lingerie types with visual patterns (Appendix 1).

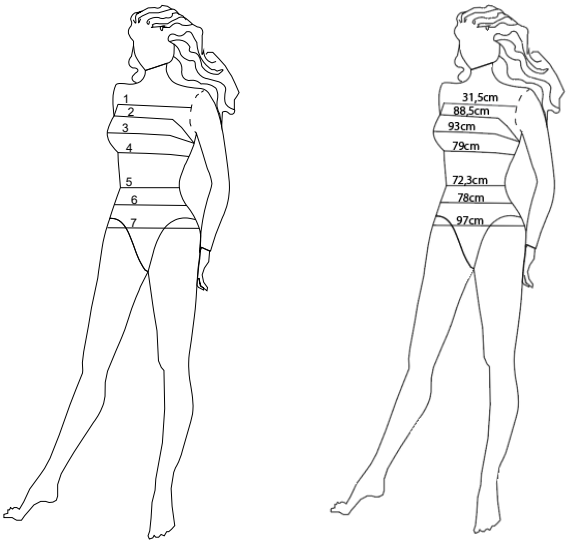


Figure 3.1 Needed measurements for bra and thong including authors measurements. 1-chest width, 2-rib cage, 3-bust, 4-chest circumstance, 5-waist, 6-top hips, 7-hips [16]

The following presents two samples of different bra variations. Pattern variation for bra 1 presents seamless cup bra-style A that is suitable for soft woven fabric (Figure 3.2). Pattern variation for bra 2 presents separated, half cup bra that has an underwired-style C variation. This bra may be also worn strapless (Figure 3.3).

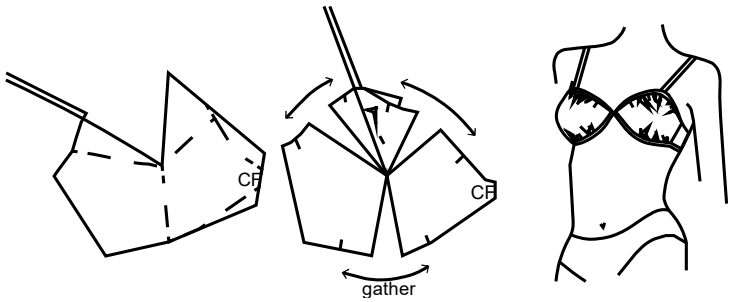


Figure 3.2 Seamless cup bra-style A [16]

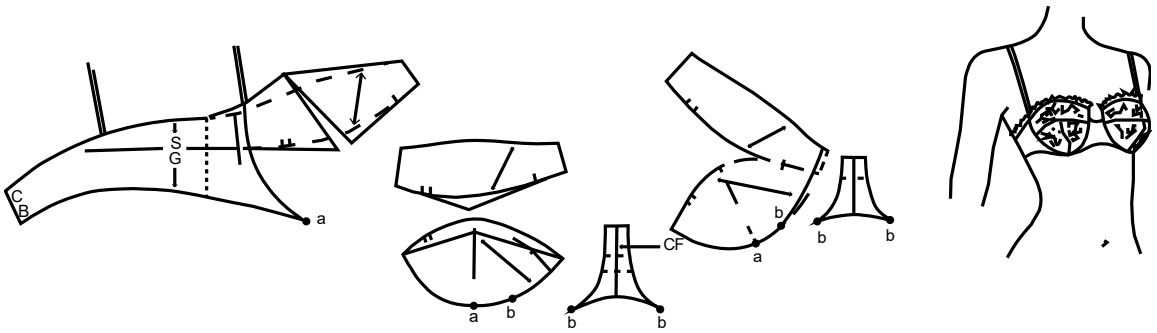


Figure 3.3 Separated, half cup bra, underwired-style C [16]

The following presents two samples of different thong variations preferably to the desired height. Pattern variation for thong 1 presents waist-high thong with no visible pantie line underneath tight or clinging garments (Figure 3.4). Pattern variation for thong 2 presents waist-low thong, hipster style (Figure 3.5).

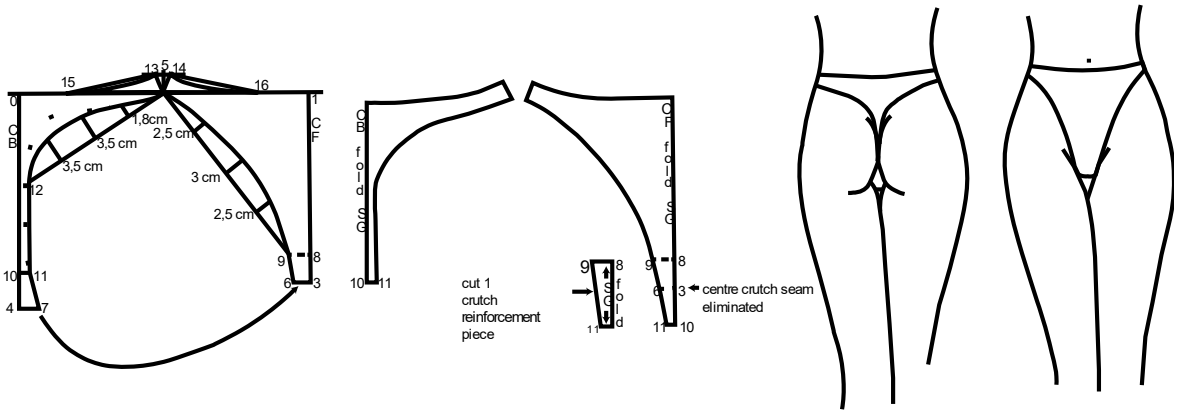


Figure 3.4 Waist-high thong [16]

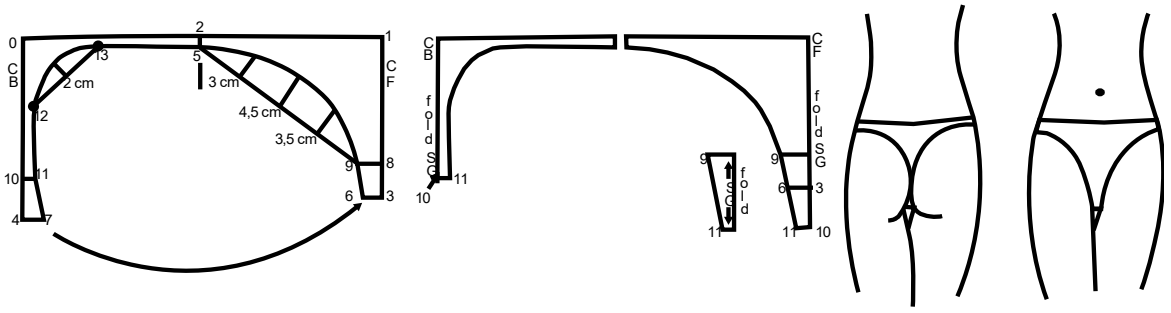


Figure 3.5 Waist-low thong [16]

The following presents two samples of different sleepwear variations. Pattern variation for night clothing 1 presents nightdress, full length shoulder strapped style (Figure 3.6). Pattern variation for night clothing 2 presents pyjamas, easy fitting and double breasted (Figure 3.7).

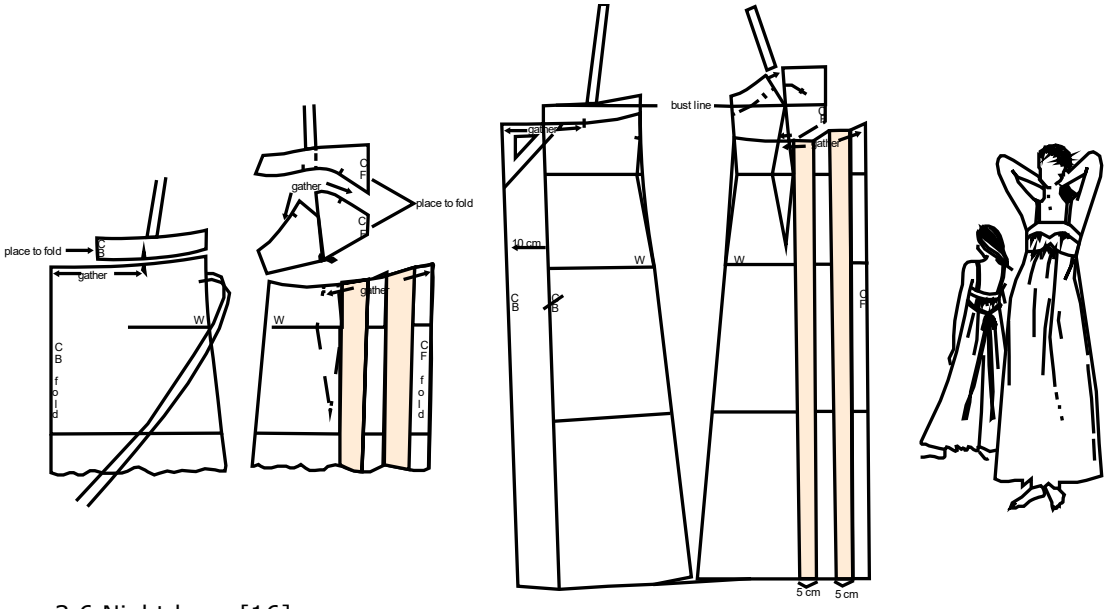


Figure 3.6 Nightdress [16]

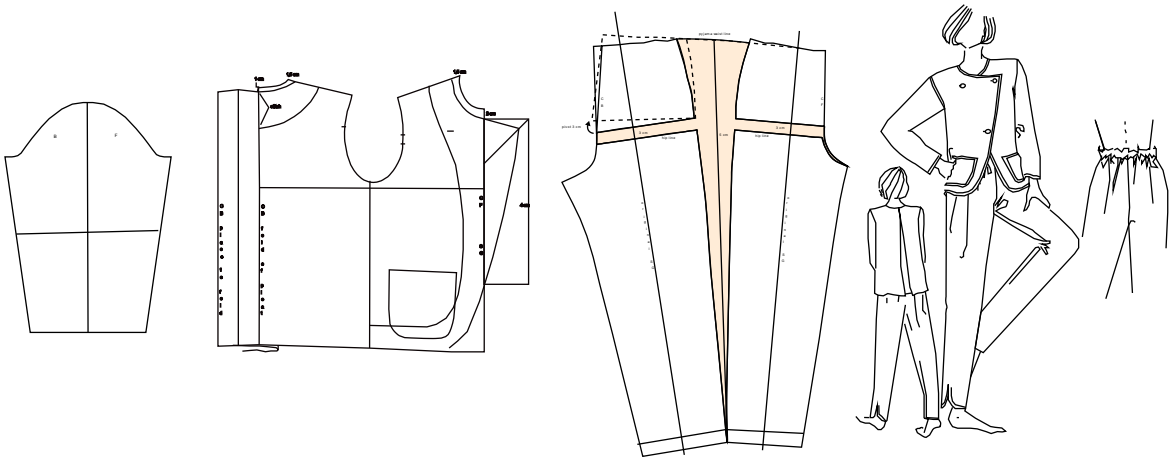


Figure 3.7 Pyjamas [16]

4. DIFFERENT MATERIALS FOR LINGERIE AND REQUIREMENTS FOR LINGERIE MATERIALS PROPERTIES

Over the centuries the materials used for lingerie have evolved greatly into more comfortable, lighter and decorative [3]. Following analyses different natural and man-made fibres, knitted and woven materials.

4.1 Different fibres used in lingerie materials

4.1.1 Natural fibres

Cotton

Cotton, a strong fibre, is the most popular choice for its softness, lightness and high absorbency (Figure 4.1.1.1). Cotton fabrics often have a simple and casual look that works well for everyday lingerie garments (Figure 4.1.1.2) [1]. Cotton is good fabric to print on and there are both knit and woven categories. Cotton can be found growing in nearly all tropical and subtropical regions around the world [17].

Cotton also has good health advantages. While synthetic materials like nylon, polyester, and elastane trap heat and moisture, cotton is very breathable and moisture wicking. Cotton is one of the most popular lingerie material option due to its soft, light and hygienic properties [3]. To produce cotton fabric there are three main steps to transform the raw fibres into threads, yarn and fabric. These three steps include preparation, spinning, and weaving [18].

Figure 4.1.1.1 Unginned and ginned cotton [18]

Figure 4.1.1.2 100% cotton fabric

Linen

Linen has very soft properties and was used in lingerie for centuries although it does not insulate or protect the body from heat or cold [3] (Figure 4.1.1.3). While linen is nowadays not quite as commonly used in lingerie as it was before, it can be a great choice in warm weather due to its breathability. Linen is available both in knit and woven forms. Linen also has the advantage of getting softer with use and washing [19]. Linen has many positive properties but is very prone to wrinkling unless blended with another fabric such as polyester [3].

Figure 4.1.1.3 100% white linen [19]

Wool

When discussing wool fibres, merino wool comes from a merino breed sheep. It has similar properties with wool although merino sheep are said to grow finer fibres. In addition, merino wool does not cause itching or irritation. The coarser wool fibres are stiffer and wider thereby can cause irritation while merino wool is typically softer. In addition, when discussing drying factors and time, merino wool dries faster than coarser wools because of these types of fibres taking more water in [20]. Merino wool and wool naturally help to regulate body temperature and transport sweat away as a vapour. This means that when it is warm outside the fibres transport sweat away from the skin, helping to keep the body cool and dry, while when it is cold outside wool fibres help to trap and insulate air. Merino wool and wool keep away different odours and are biodegradable. The material will dissolve in the ground after about 12 months. The earth takes back the fibrous protein composed of amino acids by releasing carbon and nutrients back into the soil. Merino wool and wool have even more positive effects. For example, they are fire-resistant and provide UPF sun protection [21]. In addition, wool fabrics are extremely durable and tear-resistant. They also drape well since wool is resilient and elastic [22]. Merino wool and wool are often used, for example, in the manufacture of socks, shirts, sweaters, suit jackets,

blankets, hoodies, dresses, skirts and underwear [20]. Figure 4.1.1.4 shows merino wool and Figure 4.1.1.5 100% wool sample that can be ordered from Qualitex AS.

Figure 4.1.1.4 100% Merino wool sample

Figure 4.1.1.5 100% wool sample

Silk

Silk is a strong luxurious fibre made from the cocoons of insects, usually and often from mulberry silkworms (Figure 4.1.1.6). Silk is famous for its delicate, lustrous finish with rich colours and soft feel and is priced for its delicacy and complexity (Figure 4.1.1.7). It is very breathable and not prone to pilling. Silk as a web like fibre has the possibility to be manufactured by wide range of techniques. In addition, silk has high moisture wicking ability and is often used in many garments such as medical dressings, bicycle tires, parachutes, pillow ruffles, bedsheets, curtains, suits, sport coats, robes, eveningwear and lingerie. Silk is the strongest natural fibre in the world and is extremely soft and has non-harmful environmental impact while being sustainable. Silk is 100% biodegradable and does not contribute significantly to pollution [23].

Wearing silk also has many benefits, such as holding it against the skin in the form of towels, beddings as well pillowcases that slow down aging. Silk can help to maintain skin moisture and keep it young and refreshing. Silk is a natural material containing amino acids and natural protein that trick the nervous system into relaxing state thereby smoothing out the wrinkles. The albumen in silk also helps to keep the skins metabolism at its high rate allowing dead skin to develop and repair as much faster rate [23].

Silk is as well best hypoallergic solution for sensitive skin and allergies. The silkworms weave their cocoons into safety shield against dust mites. In addition, silk prevents the build-up of soil, dirt and other microscopic foreign bodies that can cause allergies. Silk can also have sleep beneficial properties and stave off recurring infections in women [24].

Figure 4.1.1.6 Silkworms [25]

Figure 4.1.1.7 Silk fabric

4.1.2 Man-made fibres

Elastane

Elastane is a fibre with high stretch and high recovery (Figure 4.1.2.1). It is mainly used in garments where comfort and fit are both required. Elastane is lightweight, soft, smooth synthetic fibre with unique elasticity [26]. Elastane is also known by the DuPont brand name Lycra. Elastane is most commonly blended in small amounts with other fibres to increase stretch and recovery, and can be found in both knit and woven fabrics [27]. Elastane is synthetic fibre, meaning it is made up of a long chain polymer called polyurethane. The most common way to produce elastane is with a 'solution dry spinning' method. Other methods include melt extrusion, reaction spinning, solution dry spinning and solution wet spinning.

Figure 4.1.2.1 Manmade fibre elastane [26]

Nylon (polyamide)

Nylon is an extremely strong and elastic fibre that has been popular in women's lingerie for decades (Figure 4.1.2.2). It is affordable, easy to care for, maintain, wash and is very durable [3]. It is not very absorbent although the look can be somewhat dowdy depending on how it's used [28]. This synthetic material with high stretch, medium moisture wicking and heat retention abilities can be prone to pilling or bubbling but is used often in many areas like stockings, tights, firefighter gear, sportswear and lingerie (Figure 4.1.2.3) [29]. When comparing nylon with wool, synthetic fibres are not porous meaning they can wick sweat. When body is sweating

it has to heat the sweat up to evaporate it making nylon less comfortable than natural materials [21]. This problem came out from feedback of various people.

Figure 4.1.2.2 100% nylon in purple from Qualitex AS

Figure 4.1.2.3 Nylon elastane that can be ordered

Viscose, lyocell and modal

Viscose is a semi-synthetic and highly versatile fibre made from cellulose that looks similar to silk (Figure 4.1.2.4). It is sometimes as well called as "artificial silk" [3]. Viscose is a good choice for summer garments because it's smooth, cool and highly absorbent [30]. There are many types of viscose available with different properties. These include lyocell (also known by the brand name Tencel™), modal, and viscose [30]. Viscose, made from wood pulp and synthetic substances, is very breathable and commonly used in various garments as well household items, industrial belts or as an alternative for silk. Viscose is very durable and soft to touch fabric with the ability to drape well but shrink and wrinkle easily [31]. Viscose is made from natural components and sustainable source but is made with chemicals thus cause deforestation. The wood pulp is treated with chemicals such as sulphuric acid, acetone, ammonia, or caustic soda to obtain viscose. Viscose being used as Lyocell and having N-Methyl morpholine as well N-oxide as a solvent produces less waste and is eco-friendlier [32].

Figure 4.1.2.4 Viscose elastane fabric

Tencel™ as well lyocell is a good natural and sustainable fabric made from wood chips/regenerated cellulose fibres (Figure 4.1.2.5). Producing Tencel™ has a lower environmental impact by using less energy, chemicals and water. Tencel™ is fully

biodegradable and compostable [33]. It is gentle on the skin with enhanced breathability and strength, perfect for lingerie. Tencel™ has also high moisture-wicking ability, helps with temperature regulation and is not very prone to pilling. It can be said that because of strength properties this material is even more resistant to pilling than cotton. Tencel™ is commonly used for denim, towels, conveyor belts, specialty paper, medical dressings, dress shirts and underwear [34]. Tencel™ also has excellent drape ability and does not wrinkle easily. It also retains in dye very well and makes vibrant colours [35].

Figure 4.1.2.5 Tencel™ sample 260 g/m^2 that can be ordered from Qualitex AS

Bamboo viscose is gaining more popularity due to its softness, antibacterial properties, and high absorbency (Figure 4.1.2.6). Most bamboo fabrics display great stretch capabilities and are mostly susceptible to shrinking and overstretching [36]. Bamboo fabric has high moisture-wicking abilities and is also very prone to pilling. Bamboo fibres are 100% cellulose and as such are biodegradable. (Figure 4.1.2.7). There are still debates about bamboo being sustainable and not. The fibre has also the potential for re-use and remanufacture [36] but one of the reasons why bamboo is not sustainable is because "bamboo viscose" is produced through a highly intensive chemical process [36]. Bamboo fabric can be made in different ways. Therefore, each production method has the impact on the environment accordingly. For example, bamboo viscose is cheaper to produce but it can have environmental disadvantages and lead to workplace hazards. Most bamboo fabrics are not made with methods that exclude harmful ways. To ensure that bamboo is made to high quality fabric and has no hazardous environmental impact, it has to be manufactured mechanically not chemically [37].

Figure 4.1.2.6 Bamboo tree [37]

Figure 4.1.2.7 100% Bamboo Jersey [38]

4.2 Different material types for lingerie

4.2.1 Different knitted materials

Mesh

Mesh is loosely woven or knitted fabric characterized by its net-like open appearance and the spaces between the yarns (Figure 4.2.1.1) [39]. There are many types of mesh including light wear mesh knits, shaper mesh for lingerie and athletic mesh for working out.

Figure 4.2.1.1 Mesh fabric samples and four ways stretch net with Lycra Shanti Lingerie [40]

4.2.2 Lace

Lace is a delicate, web like fabric manufactured using a wide range of techniques (Figure 4.2.2.1). Lace delicate openwork fabric consists of a net ground (mesh) and motives obtained by interlacing, twisting, looping, or braiding threads. Lace is traditionally made out of silk or linen but can be made from cotton, ramie, viscose, wool, or metallic and synthetic threads. There are even different varieties of lace types. Bobbin lace is made by taking threads attached to small bobbins and interlacing them at specific points indicated by pins attached to a backing [1].

Figure 4.2.2.1 Lace used by Shanti Lingerie [41]

4.3 Different woven materials for lingerie fabrics

Satin

In a satin weave, filling threads float over multiple warp threads with a step number of several threads from one pick to another. The staggered arrangement of the intersections inhibits the formation of ribs and gives this weave its smooth and lustrous appearance (Figure 4.3.1) [1].

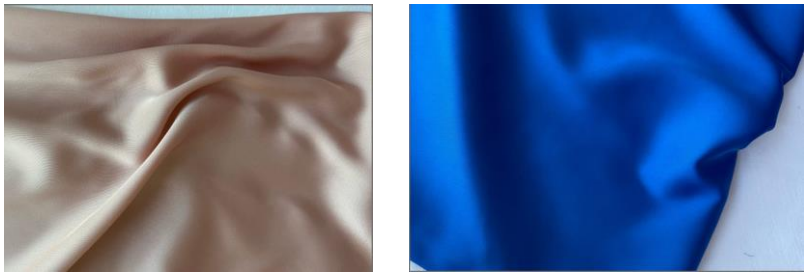


Figure 4.3.1 Satin samples used by Shanti Lingerie [42]

4.4 Requirements for lingerie materials

There are different requirements when wanting to produce underwear in the European market. These include both mandatory and voluntary requirements. In addition, many buyers have non-negotiable terms and conditions for all of their suppliers. Minimum requirements include safety, flammability, breathability and other factors [43]. In table 4.4.1 minimal requirements for the most important properties of lingerie materials and in table 4.4.2 for pyjamas and nightwear are given.

Table 4.4.1 Minimum requirements for lingerie products

Characteristic	**Standard**	**Minimal requirement**	
Mechanical and physical properties			
-Abrasion resistance	EN ISO 12947	9kPa/10 000 cycles	
-Pilling resistance	EN ISO 12945-2	3-4 (2000 cycles)	
-Tensile strength (strip method)	ISO 13934-1	Normal fit: 18 daN.	Slim fit: 22 daN.
-Tensile strength (grab method)	ISO 13934-2	Normal fit: 12 daN.	Slim fit: 15 daN.
Colour fastness	ISO 105 A01-A04	**Colour change**	**Staining**
-To dry rubbing	EN ISO 105-X12	-	4
-To wet rubbing	EN ISO 105-X12	-	4

Table 4.4.2 Minimal requirements for pyjamas and nightwear

Characteristic	**Standard**	**Minimal requirement**	
Mechanical and physical properties			
-Abrasion resistance	EN ISO 12947	9kPa/10 000 cycles	
-Pilling resistance	EN ISO 12945-2	3-4 (2000 cycles)	
-Tensile strength (strip method)	ISO 13934-1.	Normal fit: 18 daN.	Slim fit: 22 daN.
-Tensile strength (grab method)	ISO 13934-2.	Normal fit: 12 daN.	Slim fit: 15 daN.
Colour fastness	**Standard**	**Colour change**	**Staining**
-To dry rubbing	EN ISO 105-X12	-	4
-To wet rubbing	EN ISO 105-X12	-	4

5. DIGITAL TEXTILE PRINTING AND EMBROIDERING FOR DECORATIVE LINGERIE

5.1 Introduction into digital printing

Digital printing is the process of designing and creating prints from a computer to textile. Digital printing can be as well referred as direct to garment printing and physical garment printing [44]. Digital printing was at first introduced to paper printing in 1950 and later developed as well into textiles. Digital printing emerged as a vehicle and a prototyping tool for printing on home textiles, accessories, niche market products and for example clothing. Digital printing helps to shorten the lead time from design to production, speed up the sample production and reduce production inventory as well lot size costs [45].

- **Digital printing process**

The most important part before digital printing on textile substrates is the design selection as well as development. Digital printers then print the prepared design from the computer to the fabric using an inkjet-based method [45]. Figure 5.1.1 displays digital printing machine Brother GT-341 Series and Stahls MAXX® Clam Heat Press in the textile laboratory.

Figure 5.1.1 Brother GT-341 Series textile printer and Stahls MAXX® Clam Heat Press

5.2 Sustainability of digital printing

Using digital printers for textiles is growing in many countries. Figure 5.2.1 shows major growth destinations in digital printing. Digital printing on textile consumes less power and water, leaving as well minimal industrial waste and CO_2 emission when compared to a traditional printing process. That is what makes digital printing on

textiles environmentally friendly. Taking into consideration the environmental impacts of textile printing is essential for the future textile development.

Figure 5.2.2 shows digital printing positive sustainability effects compared to other traditional printing processes. When compared to traditional printing processes digital printing has -80% of reduced lead time, -55% reduced power consumption, -85% reduced waste material, -60% reduced water consumption and -95% reduced CO_2 emissions [46].

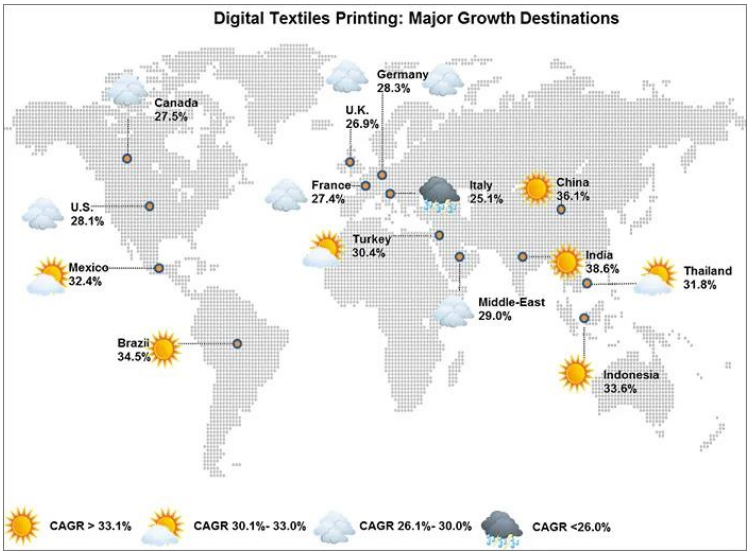


Figure 5.2.1 Major growth destinations for digital printing [46]

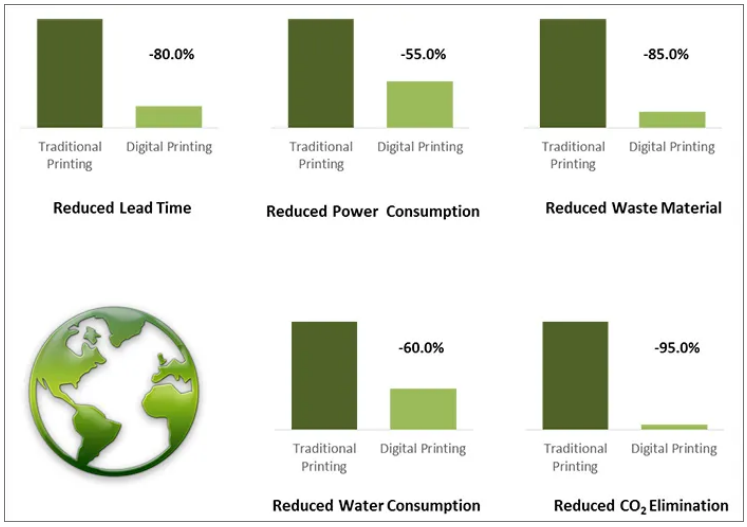


Figure 5.2.2 Digital printing positive sustainability effects comparing to other traditional printing processes [46]

5.3 Digital printing principle of operation

Preparing of the artwork. When printing an artwork, the first thing would be to create the design. This is done by preferred program such as Adobe, Illustrator or Photoshop. The next step would be to export the design to Garment Creator. In high quality textile digital printing technology there needs to be smudge free printing finishing and superior quality that replicates the design on the computer. To achieve the superior quality finish, the fabric needs to be prepared correctly before the digital printing process. The ink received by the fabric fixation is assured by the curing process that follows after the printing process. In the curing process the fabric is passed through the heat chamber (steam) and goes into washing and drying. Pre-treatment technology offers darker blacks more vivid colours, excellent wash durability and shaper definition in design [45]. Textile printer Epson SureColor F2000 can be seen in figure 5.3.1.

Figure 5.3.1 Epson SureColor F2000 digital printing machine [56]

Planning of the selected design. In the Garment Creator program there is a rectangle for visualizing where the printer will print the selected design (Figure 5.3.2). The next step would be to plan the position of the selected print design. If there is a dark textile it will need a lighter printer-based colour option, meaning the printer will know to print white first and a colour on top. In this example there is a black shirt, meaning the lighter printer option is selected.

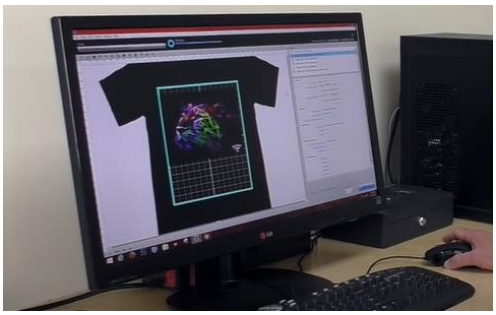


Figure 5.3.2 Using of the Garment Creator program [47]

Pre-treating of the garment. The next step would be to pre-treat the shirt and dry it using a heat press (Figure 5.3.3) Silicone paper will be then used between the heat press and the fabric. Depending on the fabric, suitable temperature is chosen. For cotton, 330°C and heavy pressure is used during this process. The drying process takes about 20 to 30 seconds.

Figure 5.3.3 Sample of a fabric pre-treating machine [47]

Printing on the garment. The next step would be to print the design onto the garment. Measuring the exact location of the print is important when placing the fabric to the printer.

The curing process of the printed design. After the printing process the shirt needs to be cured (Figure 5.3.4). During the curing process the printed fabric will be put in the heat press again. During this process the silicone paper is once more used in between the textile and the press. Exact temperature and time depend on the material. Cotton fabric for instance needs only light pressure, 90 seconds and 330 °C [47]. Figure 5.3.5 shows the final print design on black cotton shirt.

Figure 5.3.4 Sample of the heat press process [47]

Figure 5.3.5 The finished digital printer design [47]

5.4 Digital textile printing system

Serious pollution problems and the difficulty of finding expert technicians who know how to work in dying and printing factories, has made printer manufacturers to develop and supply digital textile printing. It is one of the most advanced technologies

for prints and dye industries [48]. Digital textile printing has many advantages. Advantages and disadvantages are shown in table 5.4.1.

Table 5.4.1. Advantages and disadvantages of using digital textile printing and printers

Advantages	Disadvantages
1. Offers reduction of downtime	1. Is time saving for sampling only
2. Is sustainable	2. Has low printing speed
3. Does not require lengthy set-up time	3. Offers slow lead time for bigger production runs
4. Does not require lengthy clean-up time between pattern operations	4. Sampling and production cost are higher for bigger production
5. Offers high quality printing	
6. Eliminates screen cost in sampling	
7. Offers short production runs in sampling	
8. Offers flexibility	
9. Has many design possibilities	
10. Has the possibility of mass customization	
11. Is easy to use	
12. Easy to make changes in pattern design	
13. Has the possibility to print same patterns using different color variations with no hard effort	
14. Saves time and cost of sampling	
15. Offers many shades, hues of colors and tones	
16. Offers vivid innovative prints, speed and palettes	

5.5 Inks used for digital textile printing system

Reactive ink. Reactive ink is mostly used ink in the general textile industry. Is especially suitable for fashion fabrics and home textiles. Is used for silk, cotton as well as wool. Reactive inks have similar colour density as screen print colours, but for achieving high quality of colours and fastness fabrics have to be steamed +/-100 °C after printing. Reactive inks offer high flexibility [48].

Acid ink. Acid ink is mostly used in general sportswear, swimsuit etc made out of nylon or Lyra as well as animal fibres such as wool and silk. Acid inks are not as well preferred as reactive inks because they don't have the same high flexibility, although they offer bright and fresh colours. High "ultraviolet light resistance" can as well be obtained by a steaming process like in case of the reactive inks [48].

Disperse dye ink. Disperse dye ink is used for polyester and is mostly for home textiles, sportswear, flag printing or fashion wear. Depending on the purpose of use there are many different ways of post printing processes [48].

Pigmented ink. Pigmented ink is mostly used for T-shirt printing and textile design printing. Pigmented inks are suitable for thin fabrics such as polyester, polyester-georgette, chiffon and for example georgette. Pigmented inks need high temperature without the use of steam as post printing process [48].

5.6 Digital textile printing sample system software's

RIP software. RIP software allows to preview the print results on the computer screen as well as change the colours. It offers a possibility to modify the intensity and saturation of inks. Rip software is a good bridge between the design system and the printer. RIP software also allows the printing continuously several meters of fabric without resting [48].

Colour Profiler. Colour profiler allows for the wanted colours to match with various fabrics. Involves complicated procedures but is a really helpful tool in managing of the right wanted colours [48].

5.7 Embroidery

5.7.1 Embroidery machines

Embroidery is a decorative needlework using chosen thread to form a decorative design on a specific material. These embroidered designs can be raised, flat openwork, geometric, floral, animal or historical. Content of the thread depends on the material and the complexity. Some threads are like linen, cotton, silk, wool, ramie, viscose, synthetic and metallic filaments sheathed in polyester. Some embroidered designs include pearls and sequins or lace, soutaches, ribbons and appliqué fabric. Embroidery can be done by hand or by machine [3].

Embroidery made with an embroidery machine will take less time but has many requirements and suggestions when sewing a wanted design. The final embroidery design will result from many factors like what needle, thread, stabilizer and stitch density is used. Many embroidery machines are split into several categories like free-motion, combined sewing and computerized machine embroidery. Embroider machines also have different embroidery software that also have an effect on the finished design. The following subchapter will describe semi-industrial embroider machine Texi Iris 10.

Texi Iris 10 embroidery machine

Texi Iris 10 is a one-head, 10-needle compact embroidery machine perfect for plain embroidery on caps and ready garments (Figure 5.7.1.1). It has a touch screen with 310x210 mm max. embroidery area (Figure 5.7.1.2). Texi Iris 10 has a maximum sewing speed of 1.000 stiches a minute and auto thread break detection. When embroidering on ready garments the machine has a useful tool-cylindrical arm [49].

Texi Iris 10 embroidery machine has 4 hoops come with the purchase. These hoops include one oval 70 x 50 mm, square 110 x 110 mm, rectangular 190 x 140 mm and rectangular 310 x 210 mm. The panel screen offers the possibility to edit, erase, copy, scale the wanted embroidery design. The machine has also automatic thread trimming system and 7`touch panel with functions such as start, stop, auto thread trimming, colour change, frame move, embroidery status and numerical key for the choosing of the needle. This machine also comes with the built in USB port as well Led light and adjustable thread mast that will help with the transport. Another advantage of this embroidery machine is the possibility to check the contour of the embroidery and it`s 150 W energy saving SERVO motor. The machine weights 45 kg and has a power supply of 220-240V / 50-60 Hz [49].

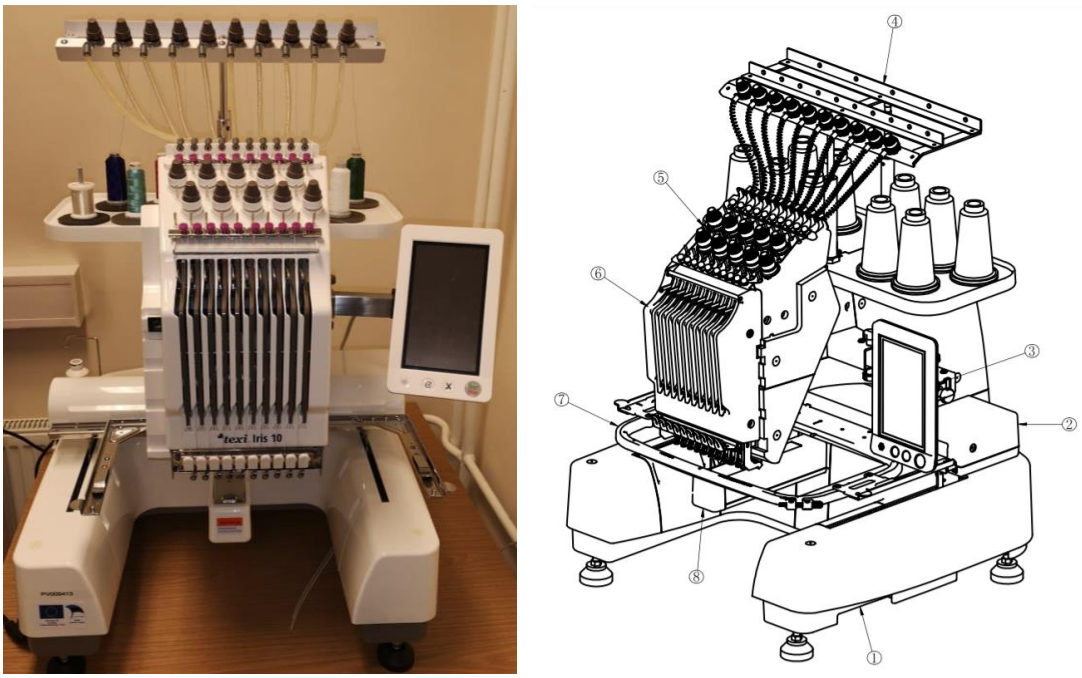


Figure 5.7.1.1 Texi Iris 10 embroidery machine front view and areas numbered, 1-Bast, 2-Driver Assembly-X-EM, 3-Panel-Support, 4-Thread Tray and Thread Stand, 5-Table Guard Cover, 6-Middle Thread-Course, 7-Frames Bracket, 8-Rotary Hook Base [49]

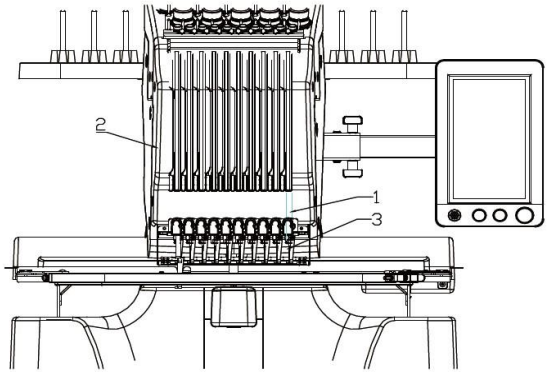


Figure 5.7.1.2 Texi Iris 10 construction, 1# needle bar; 2: Needle bar head; 3:1# needle [49]

Texi Iris 10 construction and main functions

Texi Iris 10 has 10 needles, that each can embroider with different thread colours. When setting the colour and automatic colour change for every needle bar it will give the possibility to embroider with variety of colours. User can regulate the colours and the data into the menu. Needle bars are named in the following order: 10#, 9#, 8#, 7#, 6#, 5#, 4#, 3#, 2#, 1# (Figure 5.7.1.3) although it is not obligatory to embroider with the specific needle bar number sequence. One thing for observation is the fact that needle bars don`t all have to be moved simultaneously, meaning only one needle moves when embroidering.

When using Texi Iris 10 the needle bar frame of the machine will move just in line with the embroidery sequence while needle bar with specific thread colour is being moved to the current position of the embroidery. When operating with Texi Iris 10 the presser foot will be automatically lowered and when embroidering is finished the thread will be cut and the needle will return to the previous position [49].

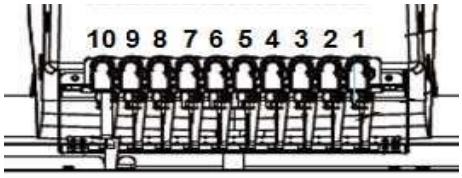


Figure 5.7.1.3 Needle bar [49]

5.7.2 Embroidery accessories

Embroidery threads

Embroidery carries out different varieties of functions and is used in many areas that give the garment an aesthetic appearance There is a possibility to use various different threads with their own demands and standards. Madeira company thread options will be discussed following [50]. Threads like viscose, smooth metallic, polyester CR metallic, polyneon, twisted metallic, glow in the dark, frosted matt, burmilana, monofilament and fire-resistant thread (Figure 5.7.2.1). These threads are compared to in the table 5.7.2.1, 5.7.2.2 and 5.7.2.3.

Figure 5.7.2.1 Madeira thread samples

Table 5.7.2.1 Madeira threads 1-5

Thread name	**Rayon Viscose-Classic**	**Polyester-Polyneon**	**Recycled polyester-Polyneon Green**	**100% Lyocell-Sensa Green**	**Matt effect-Frosted Matt**
Features and proper-ties	100% viscose rayon embroidery thread	100% polyester embroidery thread	100% recycled post-consumer PET bottles	100% Lyocell embroidery thread	Polyester thread with matt finish
	Glossy luster	Extremely durable and smooth running	Same features like standard Polyneon while being sustainable	Produced with a low-waste and eco-responsible process	Vivid colors with high-definition appearanc e
	High tensile strength	Suitable for almost any embroidered application	Free from harmful substances and certified for use on baby items	99% of the water and solvents used in its manufacture are reused	Highly colorfast when exposed to sunlight for long periods of

Thread name	Rayon Viscose-Classic	Polyester-Polyneon	Recycled polyester-Polyneon Green	100% Lyocell-Sensa Green	Matt effect-Frosted Matt
					time
	Anti-static	Eliminates looping, puckering and virtually all thread breaks		Intense colors	Colors do not fade
	Soft and flexible	Vibrant, glossy and shiny colors that are resistant to chlorine bleach		Feather-soft with a velvet finish	Bleach resistant colors
	Ideal for high-speed commercial embroidery machines	Ideal for uniforms, safety garments and commercial linens		Oeko-Tex® certified	Oeko-Tex® certified

Table 5.7.2.2 Madeira threads 6-10

Thread name	Metallized-Metallic	Fire resistant-Firefighter	High conductive-HC	Invisible thread-Monolon	Sewing thread-Aerostitch
Features and proper-ties	Offers variety of colors and thread thicknesses	100% Aramid containing Nomex® branded fibers from Dupont®	Flexible nylon thread with durable 100% silver plating around every filament	100% nylon transparent sewing thread	100% Polyester
	Threads have very different properties	Flame-resistant embroidery thread	Offers high conductivity, optimized contact points and circuit paths	Ideal for quilting, topstitching and sequin attachment	Suitable for a wide range of applications
	Options from smooth to sparkling	Developed for fire and safety	Ideal for innovative textiles and e-textile applications	Oeko-Tex® certified	Bleach and chlorine resistant
	Extremely fine to more substantial weights	Ideal for aeronautics, utility services, motorsports and other fields where safety standards are required	Can be used to create circuitry for sensors, actuators, heating, sound transmission		Withstands frequent or heavy duty washing up to 95°C
	Bleach, chlorine and denim wash resistant	Does not melt or drip, will self-extinguish without heat source	Good option for attaching LED sequins		High strength
	Oeko-Tex® certified	Oeko-Tex® certified	Oeko-Tex® certified		Oeko-Tex® certified

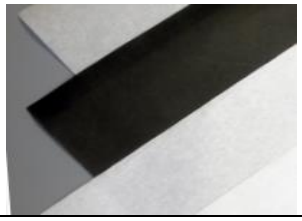
Table 5.7.2.3 Madeira threads 11-15

Thread name	Reflective-Reflect T50	Wool effect-Burmilana	Cotton bend-Burmilana	Glow in the dark-Luna	Economy rayon-Rheingold
Features and proper-ties	Polyester embroidery thread	Thicker embroidery thread	Thicker embroidery thread	Glowing in the dark embroidery thread	Economy rayon viscose embroidery thread
	Covered with a layer of glass micro-spheres	50% natural wool, 50% acrylic for durability	50% natural cotton, 50% acrylic for durability	Activated by being exposed to bright light	High quality
	Reflective finish when illuminated by a light source	Soft texture	Very soft and cool due to high cotton content	Soft and smooth feel	Good alternative to cheap, low-quality threads
	Ideal for enhancing visibility in the dark	Produces a hand embroidered look	Ideal for chenille embroidery, chain stitch or fringing	Ideal for outdoors items, children's wear and costumes	Oeko-Tex® certified
	Ideal for high-Vis workwear, sportswear, fashion and other industrial applications	Ideal for chenille, loop pile or chain stitch embroidery	Ideal for decorative seams and other special effects	Off-white thread appears to glow a greenish hue when seen in the dark	
	Requires slower speed	Oeko-Tex® certified	Oeko-Tex® certified	Oeko-Tex® certified	

Embroidery stabilizers

For a smooth and clear finishing, it is recommended to use a stabilizer while embroidering with an embroidery machine. There are three main stabilizers, tear away stabilizer, wash away stabilizer and cut away stabilizer (Table 5.7.2.4) [51].

Table 5.7.2.4 Three types of embroidery stabilizers

Stabilizer	Tear away	Wash away	Cut away
Mostly used for	Any stable woven fabric that doesn't stretch, such as leather, towels, vinyl. Tests although proved that tear away is a good option for stretchy merino wool and cotton fabric 	Any sheer fabrics, such as organza, freestanding lace, 3D and cutwork designs 	Products that are worn and washed regularly. Is the most stable of the three stabilizer types. Used on any fabric type, suggested for knits or stretchy fabrics. The excess stabilizer is cut away, but is visible behind the stitch's whole lifetime of the garment. Prevents the design's stitches from popping as the garment is stretched or manipulated

Stabilizer	Tear away	Wash away	Cut away
			

Embroidery machine needles

Using the right needle is crucial aspect of machine embroidery. Specifications of embroidery machine, type of fabric, stabilizer, stitch density and thread should be taken into account. Using the right needle will avoid problems like thread breaks and uneven embroidery designs. Machine embroidery needles have longer eye and specially-shaped scarves if compared to an embroidery needle for example. Figure 5.7.2.2 shows embroidery machine needle characteristics [52].

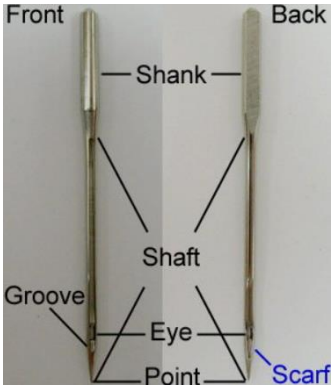


Figure 5.7.2.2 Embroidery machine needle [52]

There are three types of embroidery machine needles: sharp, universal and ballpoint needle (Figure 5.7.2.3). The most commonly used embroidery machine needle has a universal point, meaning slightly more rounded tip. If using fine stabilizers such as washable stabilizer a sharp needle will be needed, otherwise universal point needles will suit most kinds of fabrics and stabilizers [52].

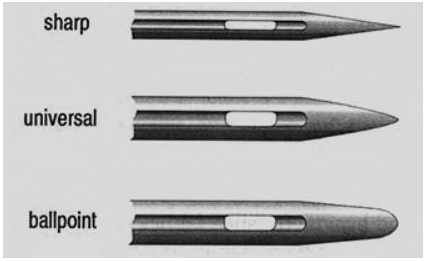


Figure 5.7.2.3. Sharp, universal and ballpoint needle [52]

Embroidery needles have different size variations that vary between 7-11 (US) and 70-110 mm. The lower the number means the finer the needle is. The size will be chosen according to the fabric, thread and stitch density [52]. If a project needs a heavy duty needle it is suggested to use a needle made out of titanium. Titanium needle lasts 3-5 times longer than the regular chromium needle and helps to embroider through dense and tough materials without the surface losing their original shape and dimensions [52].

6. COMPUTER AIDED DESIGN (CAD) SOFTWARE IN PRODUCT DEVELOPMENT

6.1 Adobe Illustrator

Adobe Illustrator is a creative program to easily turn shapes into logos, drawings and icons. It offers creating freehand drawings, prints, illustrations and graphics. Illustrator is a vector-based program, meaning when artwork is increased to stadium size, the design will still stay clear (Figure 6.1) [53].

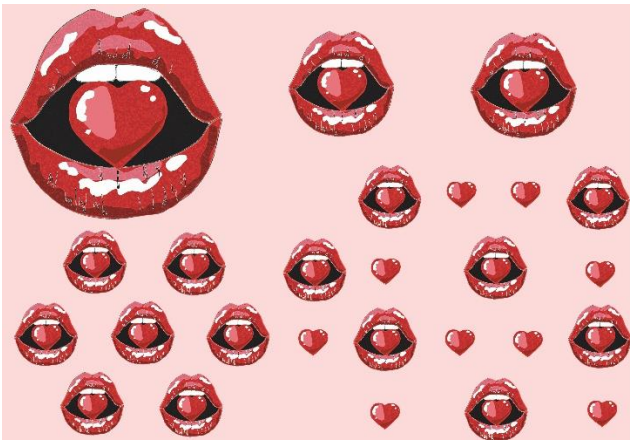


Figure 6.1 Sample drawn pattern idea in Adobe Illustrator

6.1.1 Using Illustrator in this project

Adobe Illustrator was used as creative program for every design in this thesis. The illustrations were used as print and embroidery ideas. Adobe Illustrator also helped to design all the sets. First lingerie design ideas can be seen in figure 6.1.1.1, 6.1.1.2 and 6.1.1.3

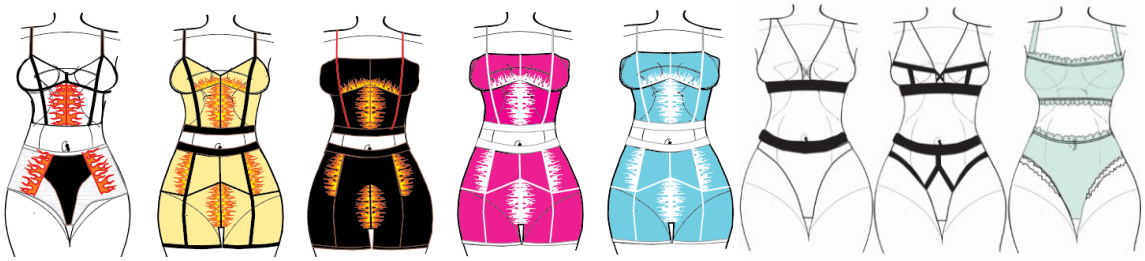


Figure 6.1.1.1 Lingerie illustration ideas, flame

Figure 6.1.1.2 Lingerie illustration ideas, everyday comfort

Figure 6.1.1.3 Lingerie illustration ideas, colours and nature

6.2 Wilcom CorelDRAW graphics suite

CorelDraw Graphics Suite is a program that is designed for achieving multi-decoration, cutting, engraving and printing designs. It is a full vector and bitmap graphics software where Adobe Illustrator style can be configured to use for interface. This professional graphic design software is the usual industry`s preferred option for digital textile printing, screen printing, heat press and more. With CorelDraw, user can edit and open formats such as Corel, Adobe, Al, Pdf, EPS. In addition, by auto or manual digitizing converting graphics into virtual embroidery can be made. All the designs are saved as Wilcom.EMB design file [54].

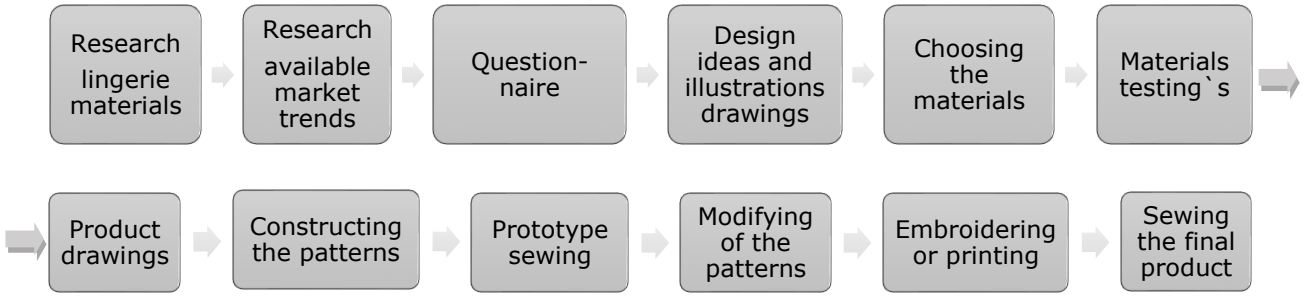
6.3 Lectra Modaris

Lectra's Modaris Classic offers different complete pattern modification tools that are designed especially for the industrial demands. It can be used for all stages of pattern development including Digitization to 3D virtual prototyping. Pattern pieces can easily be created and modified with combining the screen, keyboard and the mouse. Lectra Modaris also offers the possibility to "stitch together" the pattern pieces and open them in the 3D environment. This 3D environment offers a good visual inspection of the patterns on a virtual mannequin. Lectra Modaris for this thesis was used as a tool to digitalize the hand-made patterns onto screen [55].

7. OVERVIEW OF THE PRODUCT DEVELOPMENT PROCESS

The product development process included 12 stages (Table 7.1). Starting with research on lingerie materials as well available market trends and contiuned with a questionnaire analysis. The questionnaire helped to design the ideas as well illustrations for this thesis. The next step was focusing on materials choise an continued with the tests. Thereby came product drawings and the pattern construction processes that continued with prototype sewings. Prototype sewings helped to see needed changes. The next step was to mofify the patterns and thereby sew another prototype or the final ready-made product, depending on the fit.

Figure 7.1 The overview of product development process for this thesis



7.1 The goal of the lingerie sets

A short and simple brief questionnaire was compiled in Google forms to get an inspiring overview of lingerie market as well preferred options of underwear including types, patterns as well colours. Questionnaire of 146 answers from women is analysed following (Appendix 2).

7.2 Questionnaire

First question was to analyse different preferred colour variations for lingerie (Figure 7.2.1). This question was important for understanding what colours make the wearer most comfortable. Results show that black is the most preferred colour for lingerie. 88,4% of 146 women prefer black underwear the most. Second comes red with 38,4%, while the third option is white with 31,5%. Pink and mix of tones as well

patterns come next in line with the same amount of 21,9%. Next in the ranking were different variations 17,1% and blue 16,4%. 13,7% answered green, purple and other tones. The least preferred colour in the first question is yellow with 8,2%.

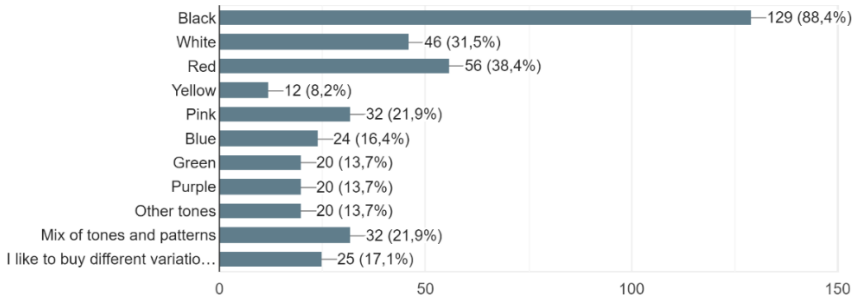


Figure 7.2.1 Question nr 1

The second question was to find out if women rather prefer simple and minimalistic or mixed colour and lace lingerie (Figure 7.2.2). The results showed that minimalistic lingerie is preferred rather on a daily basis while mixed colour, lace and/or embroidered lingerie is wanted on special occasion with 58,2% of votes. Other answers resulted that there is actually no big difference in wanting more minimalistic or mixed colour, lace and/or embroidered lingerie for daily activities. It is rather just a way of expression to use different styled and detailed lingerie. 19,2% of 146 people chose mixed colour/lace and/or embroidered lingerie while 22,6% chose minimalistic lingerie.

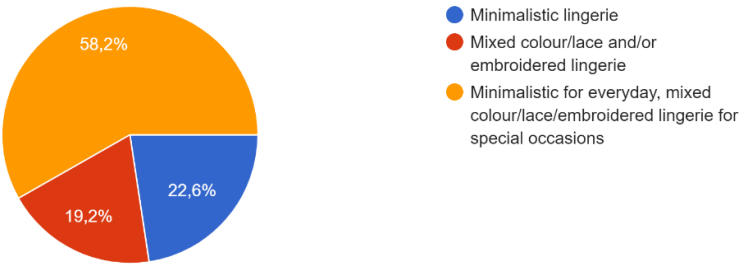


Figure 7.2.2 Question nr 2

The third question was to find out if women prefer one clothing style overall (Figure 7.2.3). 59,6% answered displayed that their style is a little bit of everything. The goal for this question was to find out if all lingerie should be as well only defined as "sexy" or "classy". Lingerie can be a little bit of everything and is worn in the goal of feeling comfortable and confident. In addition, the results show that the range of producing different pattern and detailed underwear has still many options and possibilities. To feel comfortable, confident and well in one`s body it is important to choose the right lingerie with special patterns, fabrics and colours.

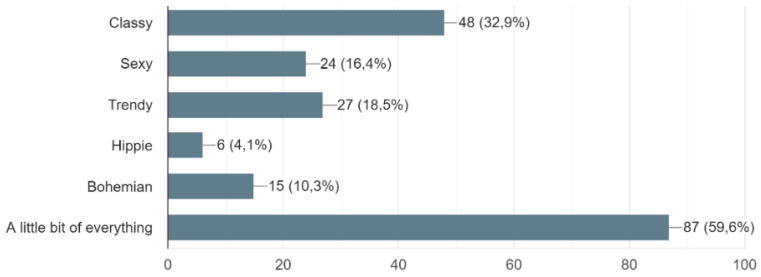


Figure 7.2.3 Question nr 3

Question number four was to find if there has been a change in lingerie preferred body types (Figure 7.2.4). With majority of 54,1% people thought that lingerie is created for more than one body type. 27,4% answered lingerie is made for only one body type while 18,5% answered maybe for this question. It shows that lingerie is getting more variations of patterns and models with different body types with each year but still has room for improvement.

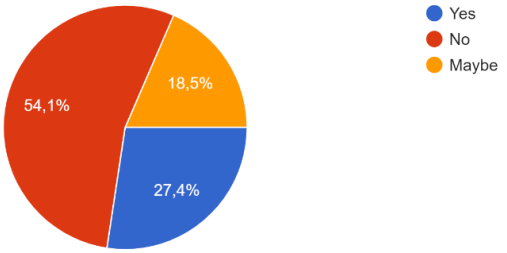


Figure 7.2.4 Question nr 4

Question number five was to get an overview about if there are enough different size and patterned lingerie on the market (Figure 7.2.5). This question gave some controversial answers. 41,1% answered more options of lingerie with different pattern variations would be better, while 26% answered there are enough and 32,9% answered no there are not enough of variations of lingerie out on the market. The next question number six showed that it is hard to find the right lingerie and night clothing or corsets for most people (Figure 7.2.6). Majority, 76% answered that it is hard to find the right lingerie and night clothing or corsets. That means there are not actually enough of size and patterns or even looks of lingerie for different body types as well personas.

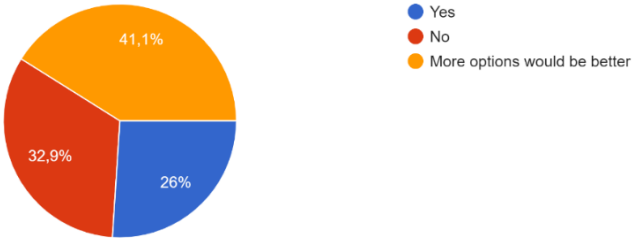


Figure 7.2.5 Question nr 5

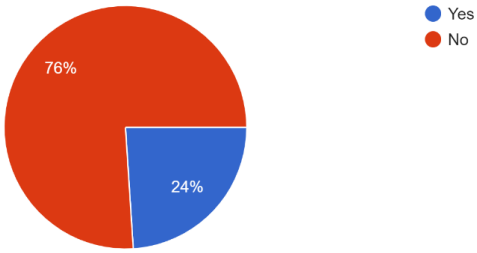


Figure 7.2.6 Question nr 6

Question number seven was about finding out if women prefer rather high waists, low waists, bodies, corsets, sports underwear or other types of underwear (Figure 7.2.7). There are more various types of lingerie but these were the main types for comparison the author was curious about. This question in the questionnaire showed that high waists are mostly preferred with 70,5%. The next in ranking was low waists with 38,4% and sports underwear with 26,7%. Interesting was to as well find out that bodies with 19,2% of votes are a bit more preferred than corsets with 13,7%.

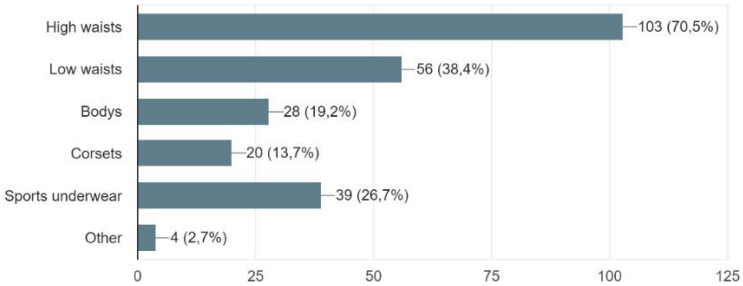


Figure 7.2.7 Question nr 7

Question number eight was to find out if there should be or if there is a possibility for sport underwear to develop more different variations of looks (Figure 7.2.8). 67,8% answered that they would wear more sports underwear if it had more variations of looks. 32,2% answered they would still not wear sports underwear with different reasons. Still the majority would even wear more sports underwear if there would be extra variations of designs.

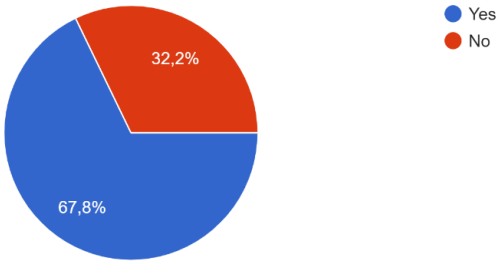


Figure 7.2.8 Question nr 8

Question number nine was to get acquainted with how many times, in a year, women actually buy lingerie (Figure 7.2.9). 53,4% buys lingerie once in 6 months, while 24,7% once a year. 21,9% of women out of 146 buy lingerie more often, once a month.

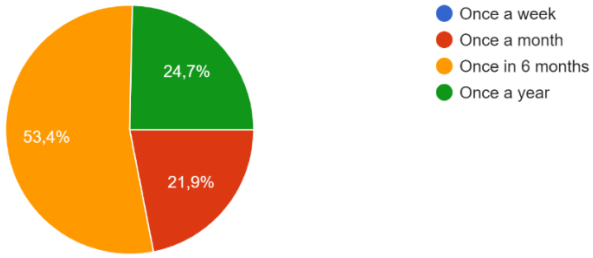


Figure 7.2.9 Question nr 9

Question number ten was to analyse how much are women ready to invest in lingerie (Figure 7.2.10). 35,6% spends 20-30 euros once when buying lingerie while 20,5% spends more, 30-40 euros. 17,8% of women do not invest a lot for lingerie. They are willing to pay very little, 10-20 euros once on lingerie. 15,1% of women out of 146 spend 40-50 euros on lingerie while 11% is ready to invest the most on lingerie at once, starting from 50 euros.

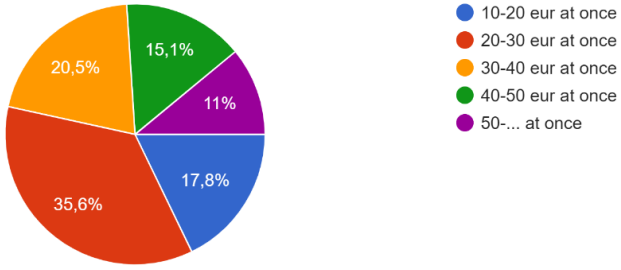


Figure 7.2.10 Question nr 10

Question number eleven was for finding out if the quality of lingerie has dropped in certain stores (Figure 7.2.11). While writing a Victoria`s Secret audit, author got to read about the feedback of many clients saying there is a drop in the store quality. Fabric as well stitches have lost their previous strength for example. This gave the author more thoughts about finding out if it is the same for other stores.

47,9% of women answered the quality of lingerie in certain shops has dropped while only 14,4% answered there is no drop in quality of underwear. 37,7% of 146 women could not actually specify about if there is a drop in quality in certain stores. Overall, the answers show that most women still have found the quality drop when buying lingerie from certain stores.

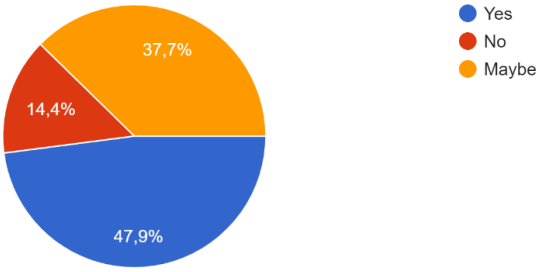


Figure 7.2.11 Question nr 11

Question number twelve was to find out the specifics of lingerie pricing (Figure 7.2.12). If clients are willing to buy higher quality and unique lingerie for a higher price. The results show that only 7,4% would not be willing to spend more money on a higher quality and unique lingerie. Majority of women, 69,9%, answered they are definitely ready to buy quality and unique lingerie at its worth if they have the money while 22,6% of women are still willing to pay nevertheless the pricing.

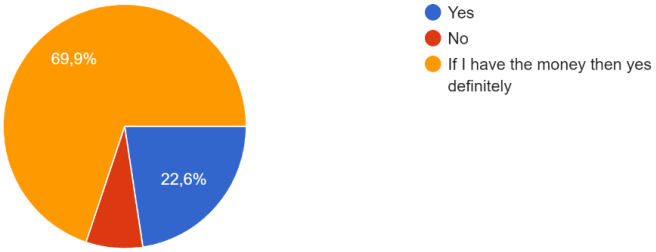


Figure 7.2.12 Question nr 12

Question number thirteen was asked for finding out if money is a certain obstacle when buying lingerie (Figure 7.2.13). 63,7% women out of 146 answered that they would definitely spend more money on lingerie if they could. 28,1% answered yes while 8,2% is happy with the lingerie pricing on the market or would not spend more money on lingerie.

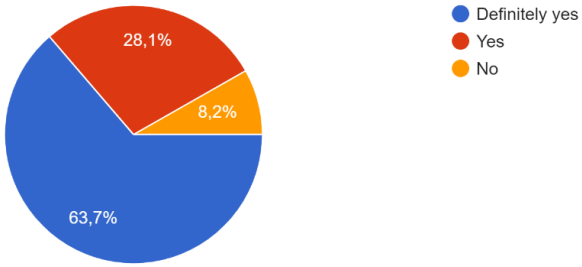


Figure 7.2.13 Question nr 13

Question number fourteen was to find out how women feel after buying lingerie (Figure 7.2.14). Majority of women, 66,4% out of 146, feel sexy when buying lingerie. 62,3% feel as well more confident while 54,1% feel happiness. Positive

feelings are always not the case. 6,2% answered actually that buying lingerie makes them sad and 11,6% feels that buying lingerie is rather just a necessary purchase. While the reasons are unclear, there are some women that find searching for underwear not overall a good feeling. That could be because of not enough pattern or type variations for their body type or because they would spend money more on lingerie if they could. It could also be because of the client service from certain lingerie stores. Author has heard of many cases where there is no actual chance to just look around in a lingerie store. Sometimes the employee could pressure buying the lingerie or sometimes all women are not confident with expressing their sizes to a stranger.

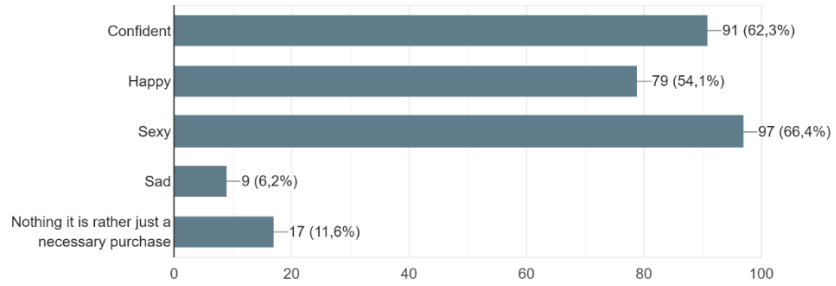


Figure 7.2.14 Question nr 14

Question number fifteen, extra question 1, was to find out if women buy lingerie from known stores in Tallinn or some shops that are very famous all over the world (Figure 7.2.15). Majority of women 55,2% buy lingerie from H&M. It is unknown where 53,8% buys lingerie from. It would be as well good to ask the specifics in the next coming questionnaire. Some women mentioned for example Bravissimo. It is a company that is marketed for as well bigger busts.

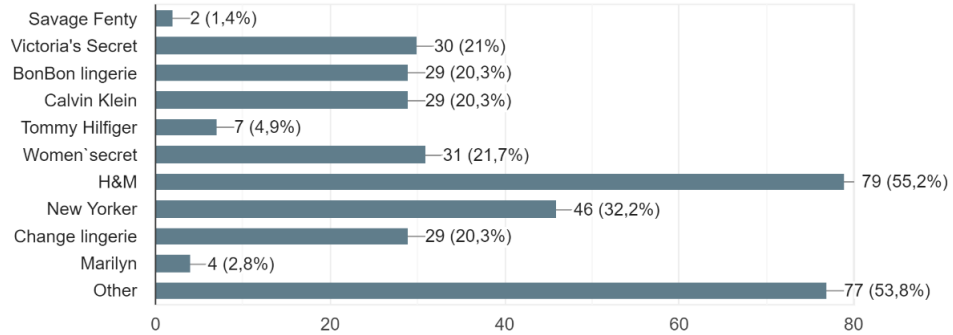


Figure 7.2.15 Extra question nr 1

Question number sixteen, extra question 2, was to find out if some inspirational images catch women`s eye (Figure 7.2.16-7.2.21). These lingerie sets were rather images out of not usually marketed underwear.

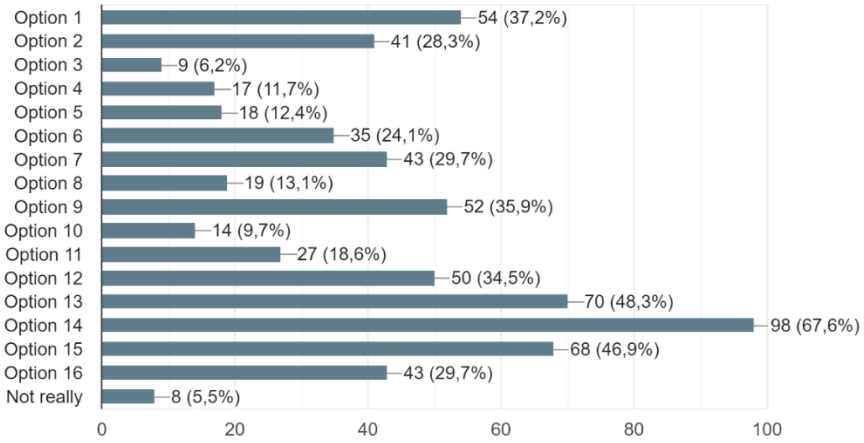


Figure 7.2.16 Extra question nr 2




Figure 7.2.17 Option 14 with 98 votes from 146 women, top 1 in the ranking and Figure 7.2.18; Option 13 with 70 votes from 146 women, top 2 in the ranking; Figure 7.2.19 Option 15 with 68 votes from 146 women, top 3 in the ranking



Figure 7.2.20 Option 1 with 54 votes from 146 women, top 4 in the ranking; Figure 7.2.21 Option 9 with 52 votes from 146 women, top 5 in the ranking

7.3 Overview of designing the lingerie collection

The questionnaire analysis gave an idea to construct patterns according to exact measurements and find unique decorative design style to lingerie with using embroidery and print (Figure 7.3.1 and 7.3.2). The collection has three digital print illustrations and one butterfly embroidery. The purpose of these illustration was to focus on the environment and natural wellbeing while using the colours of love under

a microscope. These included oxytocin hormone crystals, serotonin and protropin colours (Figure 7.3.3).

Figure 7.3.1 Lingerie set 1

Figure 7.3.2 Lingerie set 2

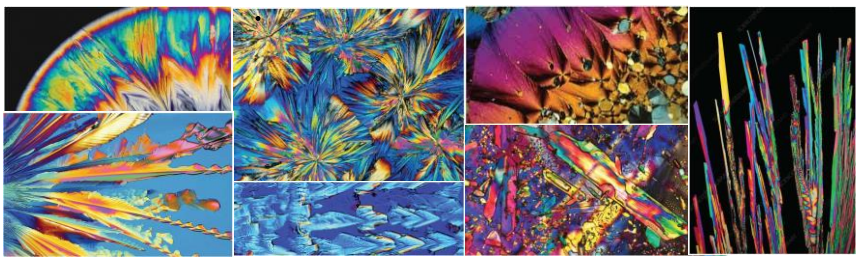


Figure 7.3.3 Mood board for choosing the colours

8. MATERIAL CHOICE FOR LINGERIE COLLECTION AND TESTING OF DIGITAL PRINTING AND EMBROIDERING ON LINGERIE MATERIALS

8.1 Materials

8.1.1 Materials for lingerie collection

Choosing of the fabric is one of the most important steps. The fabric affects the appearance, durability, comfort and other design elements like embroidery and print. When choosing the material for this collection, natural fibres were the most important factor for the circular economy. Thereby natural white as well dark grey merino wool and silk were chosen as the main materials. Further information about the main fabrics used is presented in table 8.1.1.1.

Table 8.1.1.1 Main fabrics used for the collection

Lingerie collection set 1					
Garment name	**Material type**	**Fibre content**	**Mass per unit area**	**Colour**	**Company**
Set 1 bra	Knitted fabric, interlock	100% merino wool	250g/m^2	Natural white	Riimetex OÜ
Set 1 high waisted thong	Knitted fabric, interlock	100% merino wool	250g/m^2	Natural white	Riimetex OÜ
Silk robe	Woven fabric	100% silk	64,9g/m^2	Mint green	Trendtekstiil OÜ
Lingerie collection set 2					
Set 2 bra	Knitted fabric, Interlock	100% merino wool	250g/m^2	Dark grey merino wool	Riimetex OÜ
Set 2 high waisted thong	Knitted fabric, Interlock	100% merino wool	250g/m^2	Dark grey merino wool	Riimetex OÜ

8.1.2 Materials for digital printing and embroidering

The goal for first digital printing and embroidering tests was to test different materials and analyse the results. Digital printing tests started with polyamide elastane. Next in line was silk elastane with cotton jersey and finally merino wool. Embroidering tests were done on polyamide elastane and mostly on cotton fabric. The final butterfly embroidery was tested on merino wool that was also chosen as the main material. Madeira embroidery threads were used during embroidery tests.

8.2 Methods for testing fabrics

8.2.1 Determination of fabric propensity to surface fuzzing and pilling

This test is carried out for determining fabrics resistance to pilling and surface change by using the Martindale method according to EVS-EN ISO 12945-2:2020 Textiles-Determination of fabric propensity to surface fuzzing and to pilling-Part 2: Modified Martindale method [57]. Pills form when fibres on a fabric "tease out" and become entangled during wear. The level of pilling is graded and determined by the rates of fibre entanglement leading to pill formation, development of more surface fibre and fibre as well as pill wear off. Rating scale of 1-5 is given while measuring the degree of customer tolerance for a given level of pilling (Figure 8.2.1.1). Minimal pilling and fuzzing requirement for pyjamas and nightwear/lingerie is graded 3-4 up to 2000 cycles [43]. For these tests, the fabric was tested for 7000 cycles for the optimal, longer wear results.

Test specimen merino wool was conditioned over 16 hours prior to testing according to EVS-EN ISO 139:2005/A1:2011 Textiles-Standard atmospheres for conditioning and testing. Then three circular test specimens, abrasive cloth and woven felt from company James Heal were cut out according to the ISO 12945-2:2020 standard. After cutting the merino wool specimens were attached to the circular specimen holders and secured with rubber bands. These circular specimen holders were fastened to the James Heal Midi-Martindale machine for testing (Figure 8.2.1.2). Test results were viewed under a colour assessment cabinet VeriVide and rated after every certain cycles according to the rating scale. The viewing assessment needed to be done by the right category for the pilling test. Category is dependent on the type of the textile and abradant. For merino wool knitted fabrics category was followed. Table 8.2.1.1 shows the knitted fabrics category for pilling test.

Table 8.2.1.1 Category of pilling test

3[a]	Knitted fabrics (except upholstery fabrics).	Knitted fabric under test (face/face) or wool fabric.	155+-1	1	125
				2	500
				3	1 000
				4	2 000
				5	5 000
				6	7 000

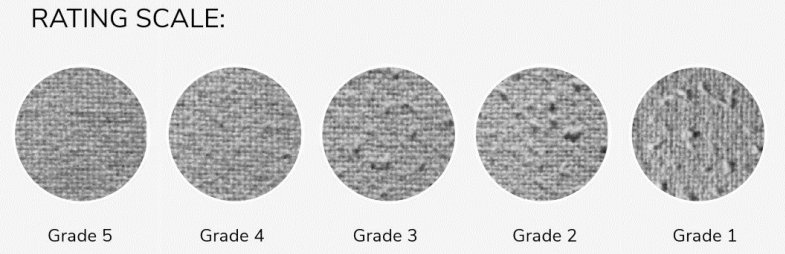


Figure 8.2.1.1 Illustrative rating scale for pilling test [58]


Figure 8.2.1.2 James Heal Midi-Martindale machine [59]

8.2.2 Determination of abrasion resistance

Abrasion is the ability of the fabric to resist surface wear, rubbing, chafing caused by contact with another material. Testing of abrasion resistance is important because lingerie is constantly in contact with outerwear, which causes abrasion. To determine merino wool abrasion results, James Heal Midi-Martindale is used according to ISO 12947-2:2016 Textiles-Determination of the abrasion resistance of fabrics by the Martindale method-Part 2: Determination of specimen breakdown. Abrasion and pilling testers are used to determine fabrics abrasion resistance (Figure 8.2.1.2) [57].

8.2.3 Determination of colour fastness to dry and wet rubbing

Colour fastness to dry and wet rubbing is done according to the standard Textiles-Tests for colour fastness-Part X12: Colour fastness to rubbing (ISO 105-X12:2016). The method can be applied to different types of textile materials. During the test specimen are rubbed with dry rubbing cloth and with a wet rubbing cloth from SDC Enterprises Limited, accordingly to the standard ISO 105-F09 [57]. These colour fastness dry and wet rubbing tests were done with crockmeter M238AA and viewed under colour assessment cabinet VeriVide (Figure 8.2.3.1).

For the dry and wet rubbing test, four specimens with dimensions 12cmx16cm were cut out using scissors. Standard white cloth was fixed to the crockmeter and rubbed

at a rate of one cycle per second to and fro in a straight line for 20 times (10 times forward, 10 times back). To make a wet rubbing test the standard fabric was be soaked with distilled water with water intake of 95% to 100% [57].

Figure 8.2.3.1 Crockmeter M238AA [5]

8.3.4 Methods of digital printing and embroidering

According to the fabric properties, different parameters are chosen for the process of digital printing. These include saturation, ink volume, contrast, and temperature for setting. These parameters are important settings for the clear printing results.

According to the fabric properties and its stretch, different embroidery accessories are chosen for the process of embroidering. These include the right stabilizer, needle and thread choice for each individual material.

8.3 Results and discussion of fabrics testing

8.3.1 Determination of fabric propensity to surface fuzzing and pilling results

Dark grey merino wool

Dark grey merino wool was tested with same parameters as natural white merino wool. Three specimens were each graded till 7000 cycles. First grading was done after 125 pilling rubs and showed only slight fuzzing and no pilling. Fuzzing and slight pilling occurring in one area could be seen after 500 rubs. Moderate pilling and fuzzing occurred after 1000 rubs where the worst pilling results were graded average 4,2 for three specimens. After 2000 rubs only very slight pilling was seen. After 5000 cycles there was less pilling and fuzzing while after 7000 cycles specimen looked as before the testing with only small fuzzing. Table 8.3.1.1 shows pilling results for each dark grey merino wool specimen (Appendix 3).

Table 8.3.1.1 Dark grey merino wool specimen pilling test results

Dark grey merino wool									
Number of pilling rubs	Pilling				Fuzzing				Minimal requirement
	Result 1	Result 2	Result 3	**Average**	Result 1	Result 2	Result 3	**Average**	Rated as 3-4 up to 2000 cycles
125 rev.	5	5	5	**5**	4	4	4	**4**	Passed
500 rev.	4	4	4	**4**	4	4	4	**4**	Passed
1000 rev.	4	4	4	**4**	4	4	4	**4**	Passed
2000 rev.	4	4	4	**4**	4	4	4	**4**	Passed
5000 rev.	5	5	4	**4,5**	4	4	4	**4**	Not required but passed
7000 rev.	5	5	4,5	**4,5**	4	4	4	**4**	Not required but passed

Natural white merino wool

First grading was done after 125 pilling rubs after which slight pilling and fuzzing was seen. Moderate pilling and fuzzing started to occur in the beginning stage after 500 rubs. More pilling could be seen after 1000 rubs and continued to be the worst after 2000 rubs with pills varying in size as well density covering large proportion of the specimen surface. During the 2000 cycles two other specimen had started to lose the pilling. After 5000 cycles there was only small amount of pilling as well fuzzing. The specimens looked almost as before the testing after 7000 cycles. Merino wool seems to have loose fibres that affect the pilling as well fuzzing but fall off during wear. Table 8.3.1.2 shows pilling results for each natural white merino wool specimen (Appendix 3).

Table 8.3.1.2 Natural white merino wool specimen pilling test results

Natural white merino wool									
Number of pilling rubs	Pilling				Fuzzing				Minimal requirement
	Result 1	Result 2	Result 3	**Average**	Result 1	Result 2	Result 3	**Average**	Rated as 3-4 up to 2000 cycles
125 rev.	4	4	4	**4**	4	4	4	**4**	Passed
500 rev.	3	3	3	**3**	3	3	3	**3**	Passed
1000 rev.	3	3	3	**3**	4	4	4	**4**	Passed
2000 rev.	3	2	3	**3**	4	4	4	**4**	Passed

Natural white merino wool									
Number of pilling rubs	Pilling				Fuzzing				Minimal requirement
	Result 1	Result 2	Result 3	**Average**	Result 1	Result 2	Result 3	**Average**	Rated as 3-4 up to 2000 cycles
5000 rev.	4,5	4,5	4,5	**4,5**	4	4	4	**4**	Not required but passed
7000 rev.	4,5	4,5	4,5	**4,5**	4,5	4,5	4,5	**4,5**	Not required but passed

Silk

Silk was tested with same parameters as merino wool. Three specimens were each graded till 7000 cycles. First grading was done after 125 pilling rubs and showed no pilling or fuzzing. Minimal fuzzing with no pilling was visible after 500 rubs. Testing results show only minimal fuzzing and no pilling till 7000 rubs. Table 8.3.1.3 shows pilling results for each silk specimen (Appendix 3).

Table 8.3.1.3 Green natural silk specimen pilling test results

Natural silk									
Number of pilling rubs	Pilling				Fuzzing				Minimal requirement
	Result 1	Result 2	Result 3	**Average**	Result 1	Result 2	Result 3	**Average**	Rated as 3-4 up to 2000 cycles
125 rev.	5	5	5	**5**	5	5	5	**5**	Passed
500 rev.	5	5	5	**5**	4,5	4,5	4,5	**4,5**	Passed
1000 rev.	5	5	5	**5**	4,5	4,5	4,5	**4,5**	Passed
2000 rev.	5	5	5	**5**	4,5	4,5	4,5	**4,5**	Passed
5000 rev.	5	5	5	**5**	4,5	4,5	4	**4,5**	Not required but passed
7000 rev.	5	5	5	**5**	4,5	4,5	4,5	**4,5**	Not required but passed

8.3.2 Determination of abrasion resistance results

Dark grey merino wool

Merino wool showed good signs of abrasion resistance. Merino wool before the abrasion test can be seen in figure 8.3.2.1 Resistance at 12 000 rubs can be seen in figure 8.3.2.2. Pilling occurring during abrasion test can be seen in figure 8.3.12.3. Martindale testing showed merino wool resists 16 0000 rubs (Figure 8.3.2.4). The

abrasion resistance test was carried out until one thread broke. Thread breakage can be seen after 18 000 rubs (Figure 8.3.2.5). For this test, merino wool specimen needed to be removed from the ring to have the right visual inspection under the microscope. The material was visualised to 25 000 rubs (Figure 8.3.2.6).

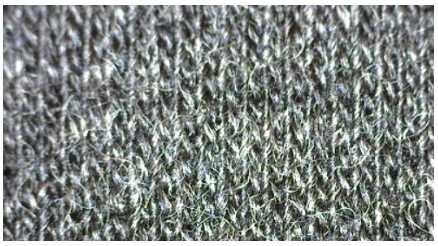



Figure 8.3.2.1 Merino wool before the abrasion test and loose wool fibres

Figure 8.3.2.2 Merino wool after 12 000 rubs

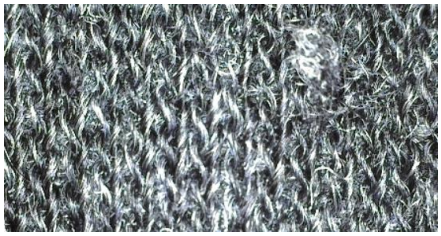


Figure 8.3.2.3 Merino wool after 14 000 rubs

Figure 8.3.2.4. Merino wool after 16 000 rubs

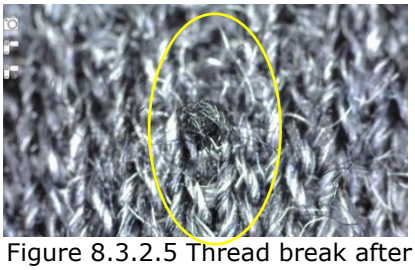


Figure 8.3.2.5 Thread break after 18 000 rubs

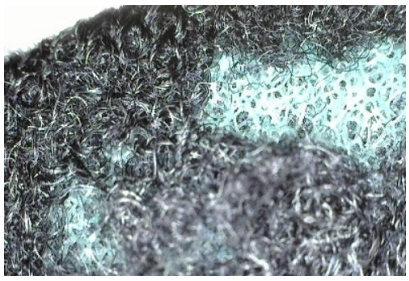
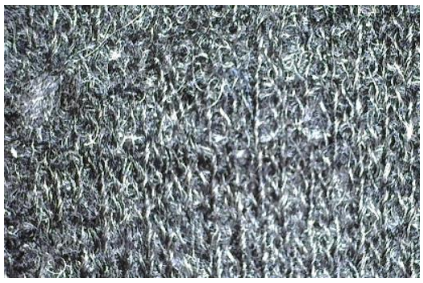



Figure 8.3.2.6 Merino wool under a microscope after 25 000 rubs

Silk

Silk was tested with same parameters as dark grey merino wool The abrasion resistance test was carried out till 6000 rubs when breakage occurred. Figure 8.3.2.7 shows silk before abrasion test, while figure 8.3.2.8 shows silk after 5000 rubs. The

abrasion results shows that silk is a very fragile luxury fabric breaking after 5000 rubs (Figure 8.3.2.9).

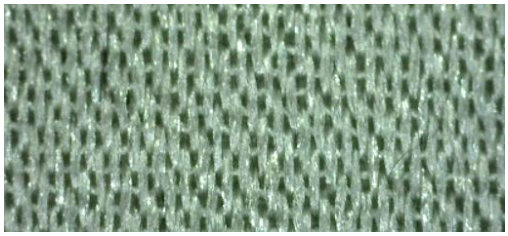


Figure 8.3.2.7 Silk before abrasion test

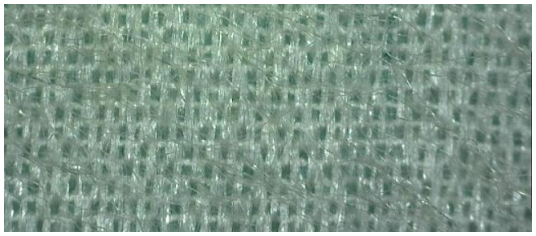


Figure 8.3.2.8 Silk after 5000 rubs

Figure 8.3.2.9 Silk after 6000 rubs, thread breakage

8.3.3 Determination of colour fastness to dry and wet rubbing results

Colour fastness results for dark grey merino wool

Two different colours of merino wool fabrics have been used for making these lingerie sets. These include natural white and dark grey merino wool fabrics. Due to natural white merino wool having no colouring, dark grey merino wool fabric was used for this test. This colour fastness test included dry as well wet rubbing by using the crockmeter M238AA.

Results are shown in table 8.3.3.1. Dry rubbing showed no change in the fading of the dark grey merino wool fabric or in the staining of the white standard fabric. As a result, it was graded as 5. For the wet rubbing test, water was added to the white standard fabric. Results show there was again no change in the merino wool fabric or staining of the white cloth fabric. This time only some small fibres were carried on to the white cotton cloth.

Table 8.3.3.1 Colour fastness results for dark merino wool

Testing of colour fastness-dark grey merino wool		
Dry rubbing		
Specimen 1	**Specimen 2**	**Minimum requirement-grade 4**
No change, grade 5	No change, grade 5	Both specimens have passed

Testing of colour fastness-dark grey merino wool		
Wet rubbing		
Specimen 3	**Specimen 4**	**Minimum requirement-grade 4**
Some loose fibres but no fading or staining, grade 5	Some loose fibres but no fading or staining, grade 5	Both specimens have passed

Silk

Silk was tested with same parameters as dark grey merino wool. Results are shown in table 8.3.3.2. Dry rubbing showed no change in the fading of the silk or in the staining of the white standard fabric. As a result, it was graded as 5. For the wet rubbing test, water was again added to the white standard fabric. Results show there was no fading of the silk or staining of the white standard fabric.

Table 8.3.3.2 Colour fastness results for natural silk

Testing of colour fastness-green natural silk		
Dry rubbing		
Specimen 1	**Specimen 2**	**Minimum requirement-grade 4**
No change, grade 5	No change, grade 5	Both specimens have passed
Wet rubbing		
Specimen 3	**Specimen 4**	**Minimum requirement-grade 4**
No change, grade 5	No change, grade 5	Both specimens have passed

8.3.4 Digital printing and embroidering results

Set 1 lingerie digital printing tests

The first step in digital printing was to set up selected fabric piece and the file. For printing, drawn objects in Adobe Illustrator were converted as a jpg file (Figure 8.3.4.1). Table 8.3.4.1 presents all digital textile printing testing's parameters.

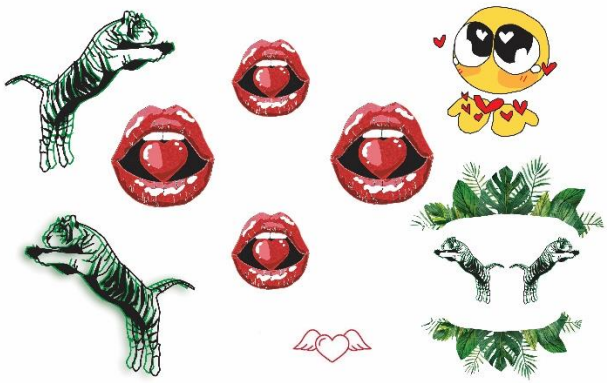


Figure 8.3.4.1 Drawn illustrations in Adobe Illustrator

- **Test 1-printing on white elastane fabric**

The test one was done on white elastane fabric. The printer took less than a minute to complete after which the fabric had to be prepared for the heat press for curing. This curing process involved pressing the fabric between silicone paper and the press. Because the white elastane fabric is made from man-made fibres, the heat was set to 135 °C for 35 seconds (Figure 8.3.4.2).

Figure 8.3.4.2 Textile setting process and results on white elastane

- **Test 2-printing on silk elastane and 100% silk fabric**

The test two was done on a silk elastane fabric (Figure 8.3.4.3). Because silk is very absorbable the print started to fade and diffuse after few seconds. The first silk elastane print test is shown on the left where the ink volume setting was set to 5 that was too high. The second test on the right shows where the ink volume was lowered to 2. For the real product a smaller ink volume of 1 was used that finally resulted in clear finishing (Figure 8.3.4.4). For the curing process, the heat was set to 120 °C for 35 seconds.

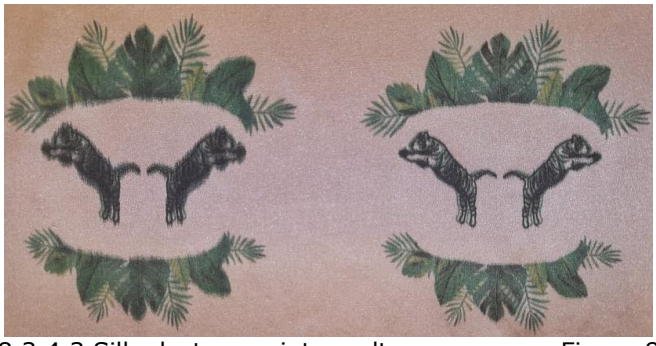


Figure 8.3.4.3 Silk elastane print results

Figure 8.3.4.4 100% silk print results

- **Test 3-printing on cotton jersey fabric**

The test three was done on a white cotton jersey fabric (Figure 8.3.4.5). The setting of 135 ^{o}C and 35 seconds was set once more for the heat press. The ink volume was set to 8 and the saturation to 5.

Figure 8.3.4.5 Cotton jersey digital printing results

- **Test 4-printing on merino wool fabric**

The test four was done on natural white merino wool fabric. The setting of 135 ^{o}C and 35 seconds was set for the heat press with ink volume of 8, contrast and saturation 5 (Figure 8.3.4.6).

Figure 8.3.4.6 Merino wool digital printing results

Table 8.3.4.1 Digital textile printing testing's parameters

Material	Saturation	Ink volume	Contrast	Temperature for setting	Needed changes
Elastane test	5	3	5	135 degrees for 35 seconds	Saturation could be set to 6
Silk elastane test 1	5	5	5	120 degrees for 35 seconds	-
Silk elastane test 2	5	2	5	120 degrees for 35 seconds	Ink volume to 1 on final product
Merino wool test	5	8	5	135 degrees for 35 seconds	-

Set 2 lingerie embroidery tests

For making the embroideries, DST file was saved and prepared to the embroidery machine. Changing the threads can be a pretty complicated and time-consuming process due to the threads connected in the machine having different numbers compared to the program. Thereby existing available threads were used for embroidery test to save time. The following will analyse the process from the first embroidery to the last.

- **Test 1 embroidery-emoji**

The test one embroidery was done to get acquainted to the embroidery machine and embroidery software Wilcom CorelDRAW. The initial wanted illustration was drawn using Adobe Illustrator and saved as a jpg file (Figure 8.3.4.7). The embroidery results showed that the complexity of the design did not match the desired illustration. Although the design seemed to be simple at first, embroidery results show contour of the face as well the hearts and hands of the emoji moving and causing puckering (Figure 8.3.4.8). In addition, because this design was made smaller in the embroidery machine program, the stitch density was too tense. The results also show that with complex design the wash-away stabilizer breaks thus causes fabric puckering.

Figure 8.3.4.7 Test one emoji illustration

Figure 8.3.4.8 Test one emoji illustration embroidery results

After test one embroidery the new goal was to start drawing the butterfly illustration. The creation of the design ideas using Adobe Illustrator can be seen in figure 8.3.4.9.

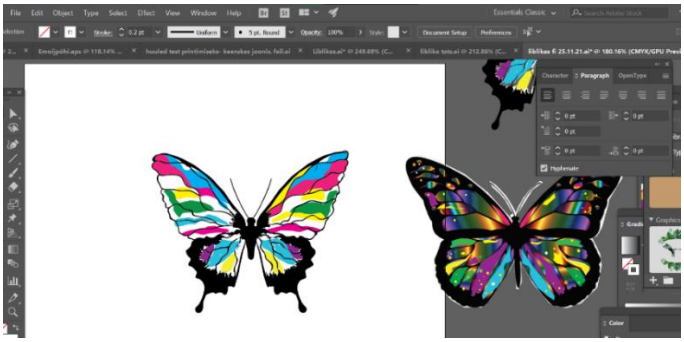


Figure 8.3.4.9 The designing process and the first ideas of butterfly illustration

- **Test 2 embroidery-butterfly**

For the test two one butterfly was designed for a white coloured fabric and the other for black (Figure 8.3.4.10). The first butterfly illustration results displayed too many detailed lines and colours not connected together, making the embroidery too difficult for a lingerie product. The choice of using five different coloured threads, needed to be reconsidered. In addition, the embroidery results showed that the size of the embroidery did not match the complexity. Because the wanted embroidery is on average 3,5cm x 4,7cm the design needs to be very simple. Figure 8.3.4.11 shows the second embroidery test results displaying the difficulty of the drawn design and the thread knots on the backing of the embroidery. Wash away stabilizer was used during the test two embroidery.

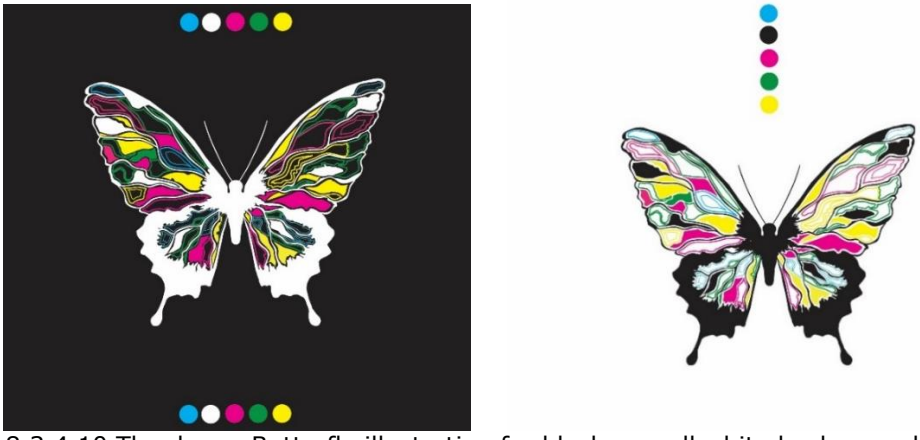


Figure 8.3.4.10 The drawn Butterfly illustration for black as well white background

Figure 8.3.4.11 The process and results of test two embroidery on cotton fabric

- **Test 3 embroidery-butterfly**

The test three embroidery illustration was made less complicated (Figure 8.3.4.12). The butterfly lines were minimized as well colours altered. Four thread colours instead of five were chosen. In addition, the wash away stabilizer was switched to tear away stabilizer. Previous test displayed that the wash away stabilizer kept breaking in the middle of the embroidering. Figure 8.3.4.13 displays irregularity in the test three embroidery results where the side of the butterfly lines moved during embroidering.

Figure 8.3.4.12 The test three butterfly illustration


Figure 8.3.4.13 The test three embroidery on cotton fabric

- **Test 4 embroidery-butterfly**

The test four embroidery had even simpler complexity but was still not enough to be chosen for the final. Results display one small step missing embroidery stitches. Figure 8.3.4.14 shows the difference between test 3 and test 4 embroidery.


Figure 8.3.4.14 The difference between test 3 and test 4 embroidery

- **Test 5 and 6 embroidery-butterfly**

The test four embroidery gave a new goal to start changing most of the stitches in Wilcom CorelDRAW by hand. More than half of the stitches were drawn in the embroidery software by hand. Because test 5 missed a step another test 6 was done. Test 6 goal was to find out if an error accorded during the embroidering process. The results on the other hand show that the Texi Iris 10 still left out a step without no stitches. It cannot be due to the stretchy fabric otherwise the next test would have come out correct. Test 6 fabric was fastened tighter with using the tear away stabilizer. Figure 8.3.4.15 shows the illustration used for test 5 and test 6 embroidery. The process of changing the stitches one by one can be seen in figure 8.3.4.16 while figure 8.3.4.17 displays embroidery results for test 5 butterfly and the comparison of

test 4, test 5 and test 6. The embroidery complexity had changed firmly. In addition, the backing of the embroidery got a lot smoother which is important for a lingerie product.

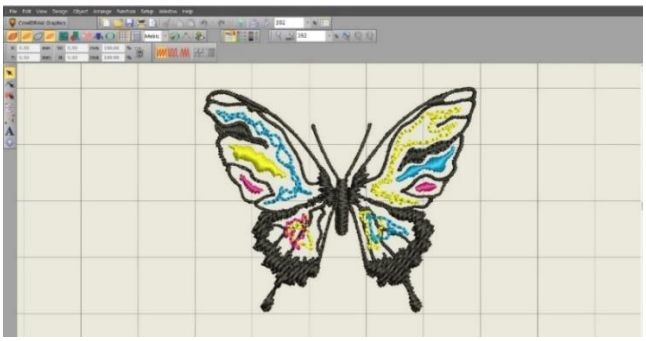


Figure 8.3.4.15 The test 5 and 6 butterfly CorelDRAW illustration

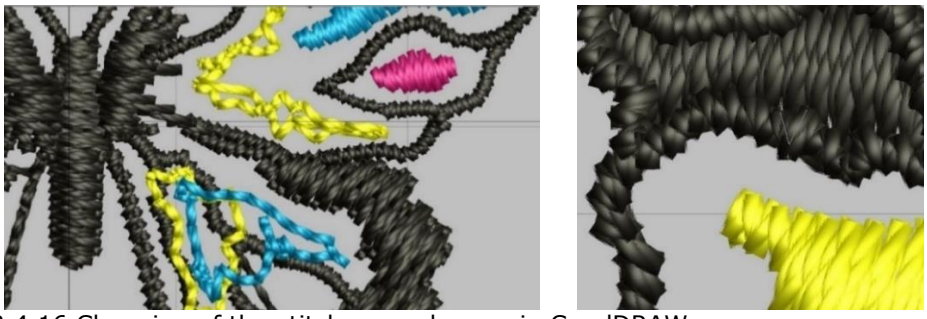


Figure 8.3.4.16 Changing of the stitches one by one in CorelDRAW

Figure 8.3.4.17 The results of test 5 butterfly and difference between test 4, test 5 and test 6

- **Test 7 embroidery-chosen butterfly**

Final butterfly embroidery was modified in Wilcom CorelDRAW and was named test 7, the final chosen butterfly. The following table 8.3.4.2 and 8.3.4.3 present embroidery test process from test 1 to test 7.

Table 8.3.4.2 Embroidery tests 1-3

Embroidery tests 1-3			
Description	**Test 1 embroidery**	**Test 2 embroidery**	**Test 3 embroidery**
Name	Emoji illustration.	Butterfly illustration 2.	Butterfly illustration 3.
Nr of colours	5.	5.	4.

Embroidery tests 1-3			
Description	**Test 1 embroidery**	**Test 2 embroidery**	**Test 3 embroidery**
Complexity	Too tense stitch density	Too detailed illustration-many lines and colours	Less complex but still too detailed illustration
	Too complex-many unconnected lines	Too complex-many unconnected lines	
Stabilizer	Wash away	Wash away	Tear away
Unwanted results	Contour lines moved during embroidering	Contour lines moved during embroidering	Contour lines moved during embroidering
	Fabric puckering	Many thread knots on the backside of the embroidery	Too thick embroidery
	Stabilizer breakage	Stabilizer breakage	
	Strong fabric puckering	Small amount of fabric puckering	

Table 8.3.4.3 Embroidery tests 4-7

Embroidery tests 4-7				
Description	**Test 4 embroidery**	**Test 5 embroidery**	**Test 6 embroidery**	**Test 7 embroidery**
Name	Butterfly illustration 4	Butterfly illustration 5	Butterfly illustration 6	Butterfly illustration 7
Nr of colours	4	4	4	4
Complexity	Less complex but still too detailed illustration	Good complexity	Good complexity	Wanted complexity
				All missing stitches were filled
				Well finished backside
Stabilizer	Tear away stabilizer	Tear away stabilizer	Tear away stabilizer	Tear away stabilizer
Unwanted results	Small step was missing stitches	Parts of the butterfly were missing stitches	Parts of the butterfly were missing stitches	No unwanted results
	Too thick stitches			

- **Changing of the stabilizer**

The testing results have shown that tear away stabilizer was better for a stretchy fabric such as knitted cotton fabric. The reason lies behind the strength of the stabilizer. While wash away stabilizer often broke during embroidering, tear away stabilizer stayed in place and did not cause any thread knots on the back of the embroidery. For this project tear away stabilizer "Fliseliin" was used (Figure 8.3.4.18). This tear away stabilizer helped to stabilize the fabric on place with optimal results.

Figure 8.3.4.18 Tear away stabilizer Fliseliin

9. CONSTRUCTION AND TECHNOLOGY OF LINGERIE COLLECTION

9.1 MAKING OF THE SET 1

Set 1 includes comfortable everyday merino wool bra and high waisted thong (Figure 9.1.1). Additionally, silk robe (Figure 9.1.2). The special design elements, illustrations are printed to each product of set 1 lingerie.

Set 1 bra and thong purpose is comfort, uniqueness and sustainability for everyday wear. This bra and high waisted thong have two different unique printed designs and no metal elements or straps. This bra has removable soft cups and wide 3 cm elastic band for the support under the bust. The neckline and armholes are finished with 1 cm scalloped edge elastic band. The thongs have 3 cm wide elastic waistband and leg openings are finished with 1 cm scalloped edge elastic band.

Set 1 robe purpose is luxurious and cosy kimono with wide collar, beltloops and long belt. The length of the robe is constructed to be just above the knee with wide semi long sleeves. This robe is made out of relaxing and smooth material silk.

Figure 9.1.1 Set 1 bra and thong

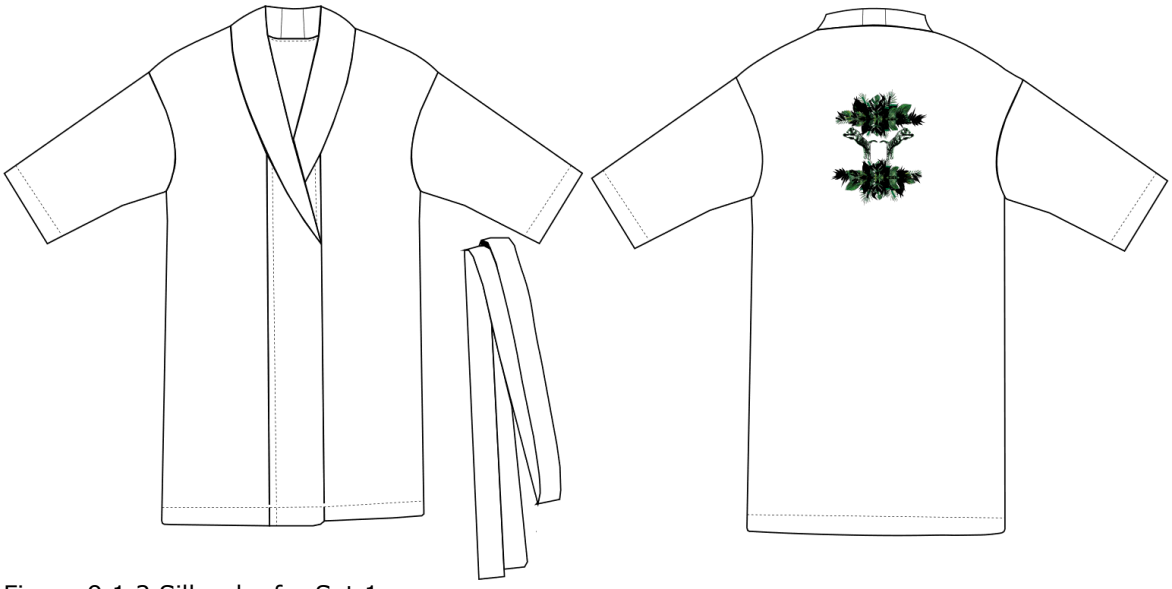


Figure 9.1.2 Silk robe for Set 1

9.1.1 The illustrations

The set 1 lingerie and robe have printed design elements. These following illustrations were drawn in Illustrator and printed on the fabrics with direct garment printer- Brother GT-3 Series. The purpose of these illustration was to focus on the environment and natural wellbeing. The illustrations include "The Botanical Garden" for set 1 bra (Figure 9.1.1.1), "The Tigers" for set 1 high waisted thong (Figure 9.1.1.2) and "The Mystical Print" for set 1 robe (Figure 9.1.1.3).

Figure 9.1.1.1 "The Botanical Garden" illustration for set 1 bra

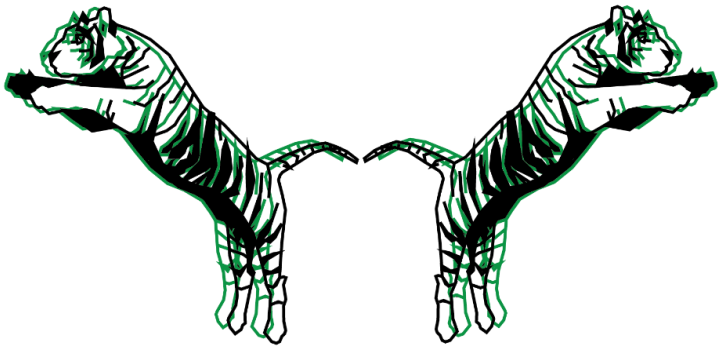


Figure 9.1.1.2 "The Tigers" print illustration for set 1 high waisted thong

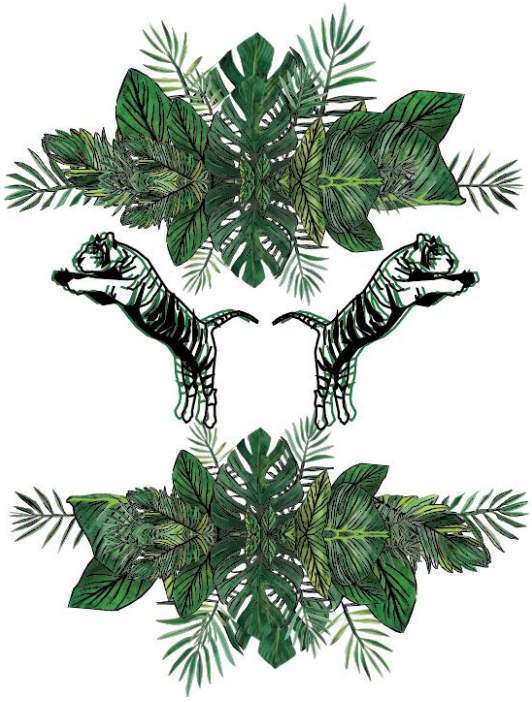
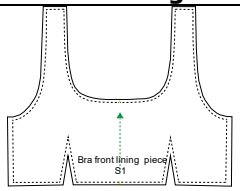


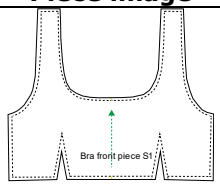
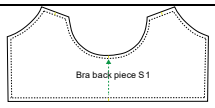
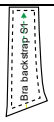
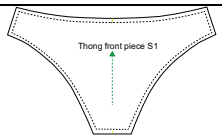
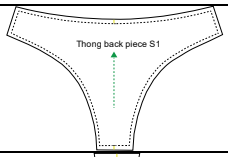
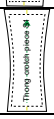
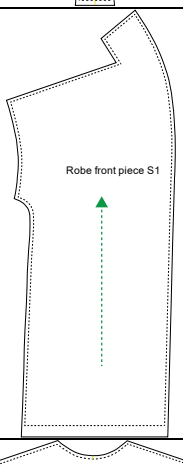
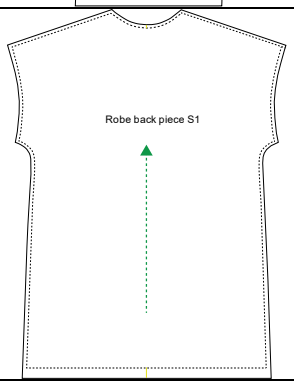
Figure 9.1.1.3 "The Mystical Print" for set 1 robe

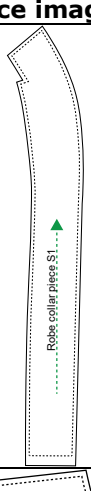
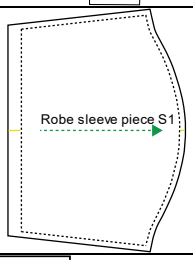
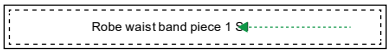
9.1.2 Pattern making

Set 1 patterns were constructed following the instructions of the bra and thong construction combining draping techniques on mannequin (Table 9.1.2.1). Based on the patterns, two prototypes of bra and thong were sewed to get comfortably fitted final product patterns. Small changes were made between the steps. For the second prototype, high waisted thong gusset was lengthened to the front piece. Additionally, small curve to the waist was added. For the bra, shoulder straps were lengthened and a small curve was added to the bust area. Set 1 robe was constructed according to wanted measurements. One prototype was sewed and for the ready-made product robe was shortened in length. These hand-drawn final patterns where digitalized using Lectra Modaris (Appendix 4).

Table 9.1.2.1 Pattern pieces for set 1

Piece name	Piece image	Fabric	Pieces	Flips
Bra front lining piece S1		Natural white merino wool	1	0

Piece name	Piece image	Fabric	Pieces	Flips
Bra front piece S1		Natural white merino wool	1	0
Bra back piece S1		Natural white merino wool	1	0
Bra back piece strap S1		Natural white merino wool	2	1
Thong front piece S1		Natural white merino wool	1	0
Thong back piece S1		Natural white merino wool	1	0
Thong crotch piece S1		Natural white merino wool	2	1
Robe front piece S1		Silk	2	1
Robe back piece S1		Natural white merino wool	1	0

Piece name	Piece image	Fabric	Pieces	Flips
Robe collar piece S1		Silk	2	1
Robe sleeve piece S1		Silk	2	1
Collar piece X		Silk	2	1
Robe belt piece S1		Silk	2	1
Robe belt piece 2 S1		Silk	1	0

9.1.3 Specification and sewing technology

Product specification sheet for everyday comfortable merino wool bra is presented in table 9.1.3.1. Table 9.1.3.2 shows product specification sheet for everyday comfortable merino wool high waisted thong and table 9.1.3.3 product specification sheet for silk robe. Table 9.1.3.4 displays sewing technology description and order of processing steps of the set 1 everyday bra and table 9.1.3.5 sewing technology description and order of processing steps of the set 1 everyday high waisted thong. Table 9.1.3.6 shows sewing technology description and order of processing steps of set 1 robe.

Table 9.1.3.1 Product specification sheet for everyday comfortable merino wool bra

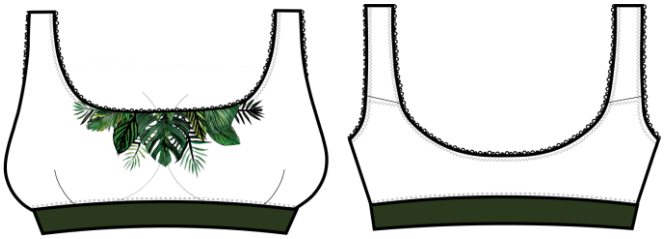
Product	**Season**	**Product type**	**Model**	**Process engineer, designer**	**Sewing thread**
Everyday comfortable bra	All year	Bralette	SET1-BRA	Kätlin Kummel	1. Goldspun, color 103 (120 thickness) 2. Red Butterfly in colour white (overlock) 3. Art no 42424 100% Polyester
Main fabric	**Elastic band, wide**	**Elastic band, narrow**	**Shoulder straps**	**Design element**	**Needle size**
Natural white merino wool 250g/m^2	3 cm wide green Elastic Tape (20% Polyester, 25% Latex, 55% Polyamide)	1 cm narrow natural white	Made from merino wool	"The Botanical Garden" print 	Needle nr 80 (spike FG), nr 75 for overlock
Product drawing				**Machinery**	**Seam allowances**
				4-thread overlock machine-514, 2-needle cover stitch machine-406, 301 lockstitch machine, Zig-zag machine-304	0,6 cm for all other seams except 0,8cm for under bust elastic band
Care instructions	Machine gentle wash with wool washing program and wool detergent Low heat ironing (up to 110 *C) Bleaching and machine drying is not allowed				

Table 9.1.3.2 Product specification sheet for everyday comfortable merino wool high waisted thong

Product	**Season**	**Product type**	**Model**	**Process engineer, designer**	**Sewing thread**
Everyday comfortable high waisted thong	All year	High waisted thong	SET1-THONG	Kätlin Kummel	1. Goldspun, col. 103 (120 thickness). 2. Red Butterfly in colour white (overlock). 3. Art no 42424 100% Polyester

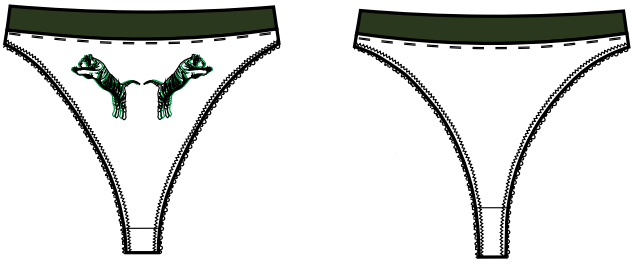
Main fabric	Elastic band, wide	Elastic band, narrow	Shoulder straps	Design element	Needle size
Natural white merino wool 250g/m^2	3 cm wide green Elastic Tape (20% Polyester, 25% Latex, 55% Polyamide)	1 cm narrow natural white	Made from merino wool	"The Tigers" print 	Needle nr 80 (spike FG), nr 75 for overlock
Product drawing				**Machinery**	**Seam allowances**
				4-thread overlock machine, 2-needle cover stitch machine 406-stitch, 301 lockstitch machine, Zig-zag machine	0,6 cm for all other seams except 0,8cm for waist elastic band
Care instructions.	Machine gentle wash with wool washing program and wool detergent Low heat ironing (up to 110 *C) Bleaching and machine drying is not allowed				

Table 9.1.3.3 Product specification sheet for silk robe

Product	Season	Product type	Model	Process engineer and designer
Light, exclusive silk robe	All year	Robe	SET1-ROBE	Kätlin Kummel
Main fabric	**Design element, print**	**Sewing thread**	**Needle specification**	**Seam allowances**
100% silk, 64,9g/m^2	"The Mystical Print" 	Thread G1 and B1	Needle nr 80, spark R, overlock needle nr 75	1,3 cm for all overlocked seams, 1cm for other except 0,6cm for belt loop

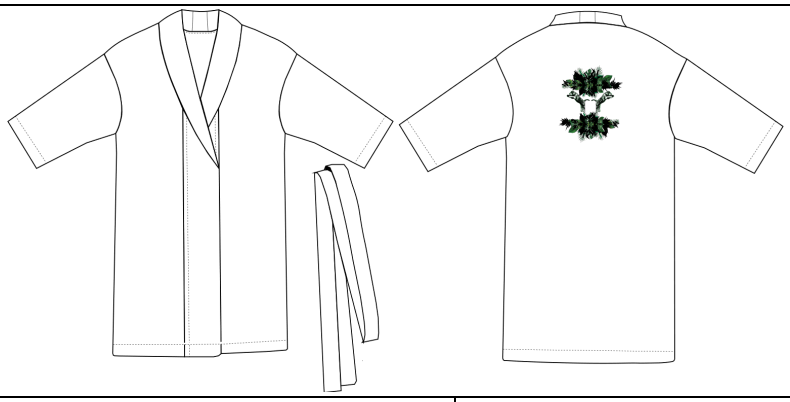
Product drawing		Machinery
		3-thread overlock machine, 301-lockstitch machine
Care instructions	Hand wash only. Use gentle detergent and no bleach Store away from the sun to avoid fading the colour and weakening the fibre	

Table 9.1.3.4 Sewing technology description and order of processing steps of the set 1 everyday bra

Sewing technology, description of the operation	Seam allowance	Machine
1. Printing of the illustration	-	Brother GT-341 Series textile printer
2. Heat pressing the illustration	-	Stahls MAXX® Clam Heat Press
3. Cutting of the patterns	-	By hand
4. Preparation of the fabric and patterns	**-**	By hand
5. Sewing the bra darts. (The lining and front piece)	0,6cm	301- lockstitch machine. Single needle lockstitch machine. Stitch type 301
6. Sewing the lining cup openings to the lining (fabric turned once)	0,5 cm (seam width)	4-thread overlock machine. Overlock nr 514
7. Sewing together the backside straps	0,6 cm	4-thread overlock machine. Overlock nr 514
8. On the right side sewing the overlocked straps with a zig zag machine (Stitch density set to 3,5 and size to 5)	0,6cm	Zig zag machine
9. Sewing the 1cm wide elastic band to the lining and the front piece (Keeping elastic band tight during sewing to avoid wrinkling. Stitch density-3,5, size-5)	0,6cm	Zig zag machine
10. Turning the elastic band to the inside of the bra right side facing up and sewing once again	-	Zig zag machine
11. Repeating the step for all of the bra front side edges that will have the 1cm wide elastic band	-	Zig zag machine
12. Sewing the 1cm wide elastic band to the back piece	0,6cm	301- lockstitch machine. Single needle lockstitch machine. Stitch type

Sewing technology, description of the operation	Seam allowance	Machine
		301
13. Turning the elastic band to the inside of the bra right side facing up and sewing once again	-	Zig zag machine
14. Repeating the step for all of the bra back piece edges that will have the 1cm wide elastic band	-	Zig zag machine
15. Sewing together the bra backside and frontside edges and straps	0,6cm	4-thread overlock machine. Overlock nr 514
16. Preparing the bra downside edge for the 3cm wide elastic band (prototype 1-overlock machine nr 514. Prototype 2 and product-406 stitch)	-	406 stitch type
17. Measuring the wanted 3cm wide elastic band circumstance and sewing it to the bra	0,8cm	4-thread overlock machine. Overlock nr 514
18. Finishing the elastic band sides together	0,6cm	4-thread overlock machine. Overlock nr 514Overlock machine 514
19. Fastening seams to elastic band	-	301- lockstitch machine. Single needle lockstitch machine. Stitch type 301
20. Checking all the loose threads	-	Scissors

Table 9.1.3.5 Sewing technology description and order of processing steps of the set 1 everyday high waisted thong

Sewing technology, description of the operation	Seam allowance	Machine
1. Printing of the illustration	-	Brother GT-341 Series textile printer
2. Heat pressing the illustration	-	Stahls MAXX® Clam Heat Press
3. Cutting of the patterns	-	By hand
4. Preparation of the materials and patterns	**-**	By hand
5. Sewing together the lining and the fabric piece (crotch area, gusset)	0,6 cm	4-thread overlock machine. Overlock nr 514
6. Sewing the 1cm wide elastic band to the high waisted thong sides (keeping elastic band tight during sewing to avoid wrinkling. Stitch density set to 3,5 and size to 5)	0,6 cm	Zig zag machine
7. Turning the elastic band to the inside of the thong right side facing up and sewing once more	-	Zig zag machine
8. Measuring the wanted elastic band circumstance and sewing it to the thong	0,8 cm	406**-**stitch machine
9. Sewing of the sides of the thong	0,6 cm	4-thread overlock machine. Overlock nr 514

Sewing technology, description of the operation	Seam allowance	Machine
10. Fastening seams to elastic band	-	301- lockstitch machine. Single needle lockstitch machine. Stitch type 301
11. Checking all the loose threads	-	Scissors

Table 9.1.3.6 Sewing technology description and order of processing steps of set 1 robe

Sewing technology, description of the operation	Seam allowance	Machine
1. Printing of the illustration	-	Brother GT-341 Series textile printer
2. Heat pressing the illustration	-	Stahls MAXX® Clam Heat Press
3. Preparation of the fabric and patterns	-	By hand
4. Sewing of the belt (leaving open 1cm for pulling)	1,3 cm.	Overlock and 301-lockstitch machine. Single needle lockstitch machine. Stitch type 301
5. Ironing down the seamline	-	Primula ironing machine
6. Sewing of the belt loop (suggested basting stitching)	0,6 cm	Overlock and 301-lockstitch machine. Single needle lockstitch machine. Stitch type 301
7. Ironing down the seamline	-	Primula ironing machine
8. Placing the belt loops and sewing of the robe sides (suggested basting stitching)	1,3 cm	Overlock and 301-lockstitch machine. Single needle lockstitch machine. Stitch type 301
9. Sewing the shoulders together	1,3 cm	Overlock and 301-lockstitch machine. Single needle lockstitch machine. Stitch type 301
10. Connecting the collar piece (sewing together and one side to the front piece edge)	1,3 cm	Overlock and 301-lockstitch machine. Single needle lockstitch machine. Stitch type 301
11. Ironing down the seamlines	-	Primula ironing machine
12. Sewing the collar other edge to the piece	1,3 cm	Overlock and 301-lockstitch machine
13. Sewing of the sleeves	1,3 cm	Overlock and 301-lockstitch machine. Single needle lockstitch machine. Stitch type 301
14. Sewing bottom. Additionally, the collar other side	4 cm	Overlock and 301-

Sewing technology, description of the operation	Seam allowance	Machine
and connecting them to the piece		lockstitch machine. Single needle lockstitch machine. Stitch type 301
15. Ironing down the seamline	-	Primula ironing machine
16. Finishing the collar bottom	4 cm	Primula ironing machine

9.2 MAKING OF THE SET 2

Set 2 includes embroidered push-up bra and high waisted thong and focuses on maximalism and is made for special occasions (Figure 9.2.1). Set 2 has unique designed butterfly embroideries. Pearls are as well sewed for adding extra attention to details. This set is made from merino wool. The push-up bra has moulded cups, metal underwires and a hook-and-eye closure on the back. A 1 cm wide scalloped edge elastic band is sewn under the bust, sides and back. A 2,2 cm wide adjustable shoulder straps add comfort and support. Centre front frame is underlined with tulle fabric to prevent stretching. Bra cup consists of five pattern pieces and is sewn to the moulded cup. The bra frame is all in one piece, including the front and back.

The high waisted thong has decorative triangle patterns added to the front as well the back piece. The natural white merino wool has decorative zig zag stitches sewn with black thread. A 1 cm wide scalloped edge elastic band is sewn to the thong edges.

Figure 9.2.1 Set 2 bra and high waisted thong

9.2.1 The butterfly illustration

Butterfly represents femininity and beauty. As the colourless caterpillar changing into exquisite winged butterfly and delicate beauty, it is a metaphor for transformation and hope as well symbolises rebirth and resurrection. Five Madeira threads were chosen for the creation of the butterfly (Table 9.2.1.1). The final butterfly illustration drawn in Wilcom CorelDRAW is displayed in figure 9.2.1.1.

Table 9.2.1.1 Threads for the final embroidery

Colour	**Black**	**White**	**Pink**	**Yellow**	**Blue**
Thread	Polyneon Green	Sensa Green	Polyneon	Sensa Green	Polyneon
Code	col 6800	col 101	col 1994	col 024	col 1977

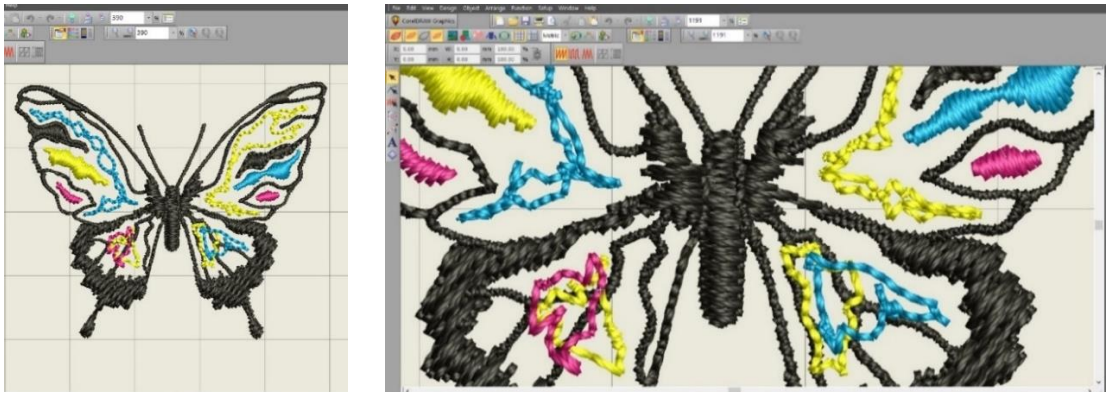
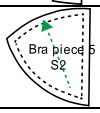
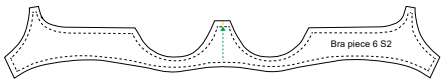
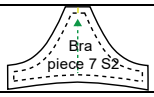


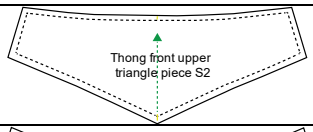
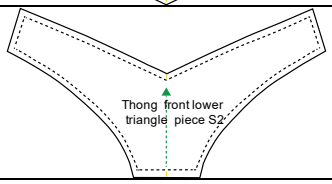
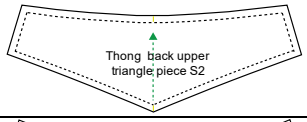
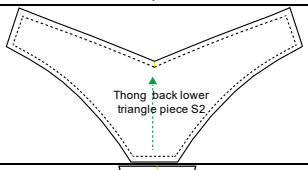
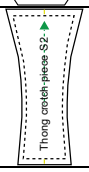
Figure 9.2.1.1 The final chosen butterfly in Wilcom CorelDRAW

9.2.2 Pattern making

The patterns of the set 2 were constructed as set 1. For the set 2 one prototype for the bra was sewn. For the prototype chosen bra cup was too big. For the final product bra cup was changed and patterns modified according to the cups (Table 9.2.2.1). Additionally, high waisted thong gusset was lengthened more to the front piece compared to set 1 thong (Appendix 4).

Table 9.2.2.1 Pattern pieces for set 2

Piece name	Piece image	Fabric	Pieces	Flips
Bra piece 1 S2		Natural white merino wool	2	1
Bra piece 2 S2		Dark grey merino wool	2	1
Bra piece 3 S2		Natural white merino wool	2	1
Bra piece 4 S2		Dark grey merino wool	2	1
Bra piece 5 S2		Dark grey merino wool	2	1
Bra piece 5 S2		Dark grey merino wool	1	0
Bra piece 6 S2		Tulle	1	0

Piece name	Piece image	Fabric	Pieces	Flips
Thong front upper triangle piece S2		Natural white merino wool	1	0
Thong front lower triangle piece S2		Natural white merino wool	1	0
Thong back upper triangle piece S2		Dark grey merino wool	1	0
Thong back lower triangle piece S2		Natural white merino wool	1	0
Thong crotch piece S2		Dark grey merino wool	2	1

9.2.3 Specification and sewing technology

Table 9.2.3.1 presents product specification sheet for special occasion merino wool underwired bra. Product specification sheet for special occasion merino wool high waisted thong is displayed in table 9.2.3.2. Following table 9.2.3.3 and table 9.2.3.4 show sewing technology description and order of processing steps of set 2 underwired bra and high waisted thong.

Table 9.2.3.1 Product specification sheet for special occasion merino wool underwired bra

Product	Season	Product type	Model	Process engineer, designer	Sewing thread
Underwired merino wool bra	All year	Wired bra	SET2-BRA	Kätlin Kummel	Coats epic, 100% polyester, color C9760 and Amann Group col. 1000

Main fabric	Bra cup and shoulder straps	Elastic band, narrow	Other accessories	Design element	Needle size
Natural white and dark grey merino wool 250g/m^2	85B bra cup, 2,2cm wide shoulder straps	1 cm black	Bra wire, ribbon for the wire or pocket, shoulder straps, metal fastener and hooks	The butterfly embroidery and pearls 	Needle nr 80 and for overlock nr 75 (spike FG)
Product drawing				**Machinery**	**Seam allowance**
				4-thread overlock machine-516, 301 lockstitch machine, Zig-zag machine	0,6 cm for all other seams except 0,5 for the cup area and 0,3 for the wire pocket, ribbon
Care instructions	Machine gentle wash with wool washing program and wool detergent. Low heat ironing (up to 110 *C). Bleaching and machine drying is not allowed				

Table 9.2.3.2 Product specification sheet for special occasion merino wool high waisted thong

Product	Season	Product type	Model	Process engineer, designer	Sewing thread
High waisted merino wool thong	All year	High waisted thong	SET2-THONG	Kätlin Kummel	Coats epic, 100% polyester, color C9760 and Amann Group col. 1000
Main fabric	**Added elements**	**Elastic band, narrow**	**Decorative stitching**	**Design element**	**Needle size**
Natural white and dark grey merino wool 250g/m^2	Colorful pearls	1 cm, black	Decorative zig zag stitch on natural white merino wool	Butterfly embroidery 	Needle nr 80 and for overlock nr 75 (spike FG)

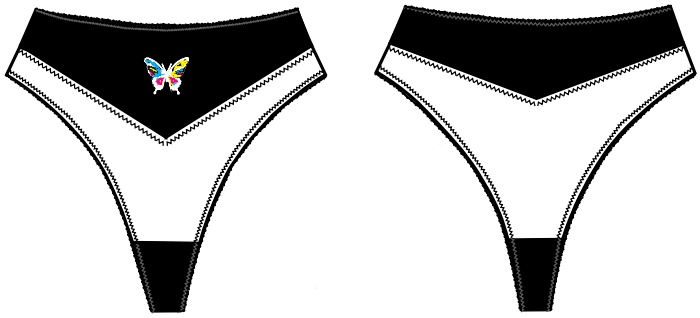
Product drawing		Machinery	Seam allowances
		4-thread overlock machine, 301- lockstitch machine, Zig-zag machine	0,6 cm for all seams except 0,4 cm for beauty stitch
Care instructions	Machine gentle wash with wool washing program and wool detergent. Low heat ironing (up to 110 *C). Bleaching and machine drying is not allowed		

Table 9.2.3.3 Sewing technology description and order of processing steps for special occasion merino wool underwired bra

Sewing technology, description of the operation	Seam allowance	Machine
1. Embroidering the illustration	-	Texi Iris 10
2. Cutting out the patterns	-	By hand
3. Preparation of the materials and the underwire bra	-	By hand
4. Tulle connection sewing to the bra centre	0,6 cm	301- lockstitch machine. Single needle lockstitch machine. Stitch type 301
5. Sewing of the 1cm elastic band for bra long side edges while stretching and keeping it tight for avoiding wrinkling in the curves	0,6 cm	Zig zag machine
6. Turning the elastic band to the inside of the bra right side facing up and sewing once again	0,6 cm	Zig zag machine
7. Sewing of the bra cup patterns together (5 pieces)	0,6 cm	301- lockstitch machine. Single needle lockstitch machine. Stitch type 301
8. Sewing the bra cup patterns to the cups (turn to right side facing up)	-	301- lockstitch machine. Single needle lockstitch machine. Stitch type 301
9. Sewing the bra downside piece to the cup	0,5 cm	301- lockstitch machine. Single needle lockstitch machine. Stitch type 301
10. Sewing the elastic to the other parts of the bra (upper part of the bra)	0,6 cm	301- lockstitch machine. Single needle lockstitch machine.

Sewing technology, description of the operation	Seam allowance	Machine
11. Sewing of the wire pocket and attaching of the wire	0,3 cm	Zig zag machine
12. Sewing and setting up the bra straps	0,6 cm	Zig zag machine
13. Sewing of the bra hooks	-	Zig zag machine
14. Adding pearls to the bra piece	-	By hand

Table 9.2.3.4 Sewing technology description and order of processing steps special occasion merino wool high waisted thong

Sewing technology, description of the operation	Seam allowance	Machine
1. Embroidering the illustration	-	Texi Iris 10
2. Cutting out the patterns	-	By hand
3. Preparation of the materials and the high waisted thong patterns	**-**	By hand
4. Sewing together the front and back pieces (front and back pieces have both triangled shaped two patterns)	0,6 cm	4-thread overlock machine. Overlock nr 514
5. Beauty stitch (stitch density set to 3 and size to 5)	0,4 cm	Zig zag machine
6. Sewing together the lining and the fabric piece (crotch area, gusset)	0,6 cm	Overlock machine 514
7. Sewing the 1cm wide elastic band to the high waisted thong sides (keeping elastic band tight during sewing to avoid wrinkling. Stitch density set to 3,5 and size to 5)	0,6 cm	Zig zag machine
8. Turning the elastic band to the inside of the thong right side facing up and sewing once more	-	Zig zag machine
9. Sewing of the sides of the thong	0,6 cm	4-thread overlock machine. Overlock nr 514
10. Measuring the wanted elastic band circumstance and sewing it to the thong	0,6 cm	406**-**stitch machine
11. Sewing the elastic band sides together	0,6 cm	4-thread overlock machine. Overlock nr 514
12. Fastening seams to elastic band	-	301-lockstitch machine. Single needle lockstitch machine. Stitch type 301
13. Checking all the loose threads	-	Scissors

10. CONCLUSIONS FROM THE TESTING AND PRODUCT DEVELOPMENT ANALYSES AND DISCUSSION

The overview of product development process concluded compiled Google forms that helped to design this collection and give an overview of possible future clients. Some design changes were done according to the available materials. Lack of lingerie materials and accessories in Estonia was a distributing factor in all stages of product development. Determination of fabric propensity to surface fuzzing and pilling results showed merino wool having loose fibres that affect the pilling as well fuzzing but fall off during wear. Determination of abrasion resistance results showed that merino wool is a very strong material with Martindale of 16 000 rubs. Silk showed to be a very delicate luxury fabric with Martindale of only 5000 rubs. Determination of colour fastness to dry and wet rubbing resulted in no change in the merino wool and silk specimen fading or staining of the white cloth fabric. As result of the testing's natural white and dark grey merino wool and silk were chosen as the main materials.

Digital printing and embroidering tests showed to be good tools to create decorative elements on products. Different parameters for digital printing including saturation, ink volume, contrast, and temperature for setting are dependent on the materials used. Before developing an embroidery of a print many testing's are required especially for embroidery. Embroidering with Texi Iris 10 was more complicated than it seemed. Due to the used small embroidery size, the complexity of the embroidery design needed to be even simpler than first planned. In addition, because lingerie fabrics contain elastane or are stretchy in their nature, they required more needed time for testing's. As a result, test seven was the finally chosen embroidery for the finished results.

Prototype sewing and careful construction of the patterns resulted in very fell fitting lingerie from high-quality and luxurious materials. These final ready-made soft and comfortable unique products can be seen following. (Figure 10.1 and 10.2) (Appendix 7).

Figure 10.1 Set 1 lingerie and silk robe, photos by Markus Vares (Vares Stuudio OÜ)

Figure 10.2 Set 2 lingerie, photos by Markus Vares (Vares Stuudio OÜ)

SUMMARY

Lingerie has many styles and possibilities and while being so close to the body it is strongly related to intimacy. Lingerie can be made out of different materials like natural and man-made fibres, knitted or woven materials. Lingerie should be comfortable, stretchy, and naturally chemical free but does not always need to be functional. Nowadays lingerie can be worn or displayed as well in outside environment. Thereby lingerie has often many decorative elements or materials that are achieved with printing and embroidering.

Embroidery is a decorative needlework that takes time and testing's for developing every design but as a result adds uniqueness to the materials. The process of embroidering was although not as easy as it seemed. Texi Iris 10 needed a constructer by its side while the machine was embroidering. In addition, the embroidery program did not guarantee the illustration results on fabric as it was seen on screen. This is due to embroidery machine sometimes not cutting stitches, thereby pulling the stretchy fabric. In addition, because lingerie fabrics are often stretchy, they required more for testing's. The process of machine embroidering one butterfly design took 23 minutes while hand embroidering would take at least twice as much. Thereby machine embroidering saves a lot of time comparing to hand embroidering.

Digital printing has many advantages compared to other printers. It is one of the most advanced technologies for prints and dye industries. Digital printing on textile consumes less power and water, leaving minimal industrial waste and CO_2 emission. Digital textile printing offers quality sharp designs with only process time of some minutes and preparation depending on the wanted print.

For creating the illustrations different computer aided design (CAD) software were used. The illustrations that had their backstory were drawn in Adobe Illustrator and for the embroidering Wilcom CorelDRAW was used additionally for creating stitches. Lectra Modaris was used for digitalizing hand-drawn constructed patterns. These programs were simple and effective for usage that take time depending on the work as well experience.

Before designing the collection, questionnaire was formed to get an overview of lingerie market and preferred options of underwear including types, patterns as well

colours. The questionnaire helped to process, construct the patterns and design decorative products inspired by haute couture, "high fashion". Haute Couture is described as high dress making and is the creation of exclusive custom fit clothing. In haute couture all the pieces are constructed by hand from start to finish with only high-quality fabrics and extreme attention to details. The design idea for this collection was to test different variations of product patterns as well looks due to the market also having not enough fitting lingerie. The goal of learning the construction of lingerie patterns according to known measurements was achieved.

The collection consists of two sets, 5 products, where natural white as well dark grey merino wool and silk were chosen as the main materials. It was important to use natural high-quality materials. As a result, many testings were done to create the finished products. Set 1 bra and high waisted thong is comfortable, stretchy and perfectly suited for everyday wear. Set 2 bra and high waisted thong have more elements while also achieving the main goal of comfortability and maximalism for special occasion wear. Lingerie products made of merino wool result in very soft and cosy items. Digital printing on merino wool when stretched results in fading lighter in colour. The construction of the set 1 and set 2 lingerie and robe has been successful. Set 1 silk robe is light and exclusive fabric and item while taking more time for sewing. Embroidery and digital printing for lingerie proved to be a good decorative element.

The main aim and objectives of this thesis were achieved. To use digital printing and embroidering for creating high fashion and long-lasting lingerie collection from high-quality and luxurious materials. To achieve the main aim four objectives were set and followed. These include analysing market trends and performing a survey among potential customers. Additionally, study the properties of potential materials for lingerie collection, test digital printing and embroidering on lingerie fabrics and finally create a lingerie collection. The goal has been successful however when starting to produce these items on a long term an investment needs to be made. Processing of the digital printing and embroidery machines needs often care and observation.

KOKKUVÕTE

Pesul on palju võimalikke stiile, kasutusvõimalusi ning lõikeid. Olles kehalähedane toode, on pesu tugevalt seotud intiimsusega. Pesu võib valmistada erinevatest materjalidest nagu looduslikest ja keemilistest kiududest, trikotaažist või riidest. Pesu peaks olema mugav, veniv ja loomulikult kemikaalivaba. Pesu ei pea aga alati olema funktsionaalne. Tänapäeval on normaalsus kanda pesu ka väliskeskkonnas, seetõttu on pesule sageli omaseks dekoratiivsete elementide või materjalide kasutamine, mis on saavutatud trükkimise ja tikkimisega.

Tikand on dekoratiivne näputöö, mis vajab aega ning katsetusi vastavalt kangale iga kujunduse väljatöötamiseks. Tikand lisab materjalidele ja toodetele unikaalsust. Tikkimisprotsess ei ole aga nii lihtne kui see näib. Tikkimismasin Texi Iris 10 vajab protsesside pidevat jälgimist. Tikkimismasin ei taga tikkimisprogrammis joonistatud illustratsioonitulemusi kangale alati nii nagu see ekraanil esialgu näib. Selle põhjuseks on asjaolu, et tikkimismasin ei lõika mõnikord õmblusi läbi, tõmmates seeläbi venivat kangast ning põhjustades sõlme või auke kangasse. Lisaks, kuna pesukangad on sageli venivad, nõuavad need testimiseks rohkem katsetusi. Ühe liblika masintikandi protsess läbis 23 minutit, käsitsi tikkimine nõuab aga vähemalt kaks korda rohkem aega. Selle tulemusena säästavad masintikandid palju aega võrreldes käsitsi tikkimisega.

Digitaalprintimisel on teiste printerite ees palju eeliseid. Digiprint on üks kõige arenenumaid tehnoloogiaid trüki- ja värvitööstuses. Digitaaltrükk tekstiilile kulutab vähem energiat ja vett, jättes minimaalselt tööstusjäätmeid ja CO_2 heitmeid. Digitaalne tekstiilitrükk pakub kvaliteetseid teravaid kujundusi, mille töötlemisaeg on vaid mõni minut ja ettevalmistus olenevalt soovitud trükist.

Illustratsioonide koostamisel kasutati erinevaid arvutipõhise disaini (CAD) tarkvarasid. Illustratsioonid, millel oli kõigil oma taustalugu, on joonistatud Adobe Illustrator`is. Lisaks tikandite loomisele ning õmbluste muutmisele leidis tihedat kasutust programm Wilcom CorelDRAW. Käsitsi joonistatud konstrueeritud mustrite digiteerimiseks leidis kasutust Lectra Modaris. Antud programmid olid lihtsad ja tõhusad kasutuseks, võttes aega sõltuvalt tööst ja varasemast kogemusest.

Enne kollektsiooni kujundamist leidis olulisust ankeedi koostamine, et saada ülevaade pesuturust ja eelistatud aluspesu valikutest nii tüüpide, mustrite kui ka värvidega.

Ankeet aitas töödelda, konstrueerida lõikeid ja kujundada dekoratiivtooteid, mis on inspireeritud kõrgmoest "haute couture". Kõrgmoele on omane eksklusiivsete kohandatud rõivaste loomine. Kõrgmoes on kõik esemed algusest lõpuni valmistatud käsitsi, kasutades ainult kvaliteetseid kangaid ja palju pööratakse tähelepanu detailidele. Lõputöö kollektsiooni disainiidee oli katsetada erinevaid tootemustrite variatsioone ja lõikeid, kuna turul pole ka piisavalt liibuvat pesu. Eesmärk õppida teadaolevate mõõtude järgi pesulõigete ehitust, sai täidetud.

Lõputöö kollektsioon koosneb kahest komplektist, viiest tootest, kus põhimaterjalideks valiti nii naturaalne valge kui ka tumehall meriinovill ja siid. Oluline oli kasutada looduslikke kvaliteetseid materjale. Selle tulemusena viidi valmistoodete loomiseks läbi palju katsetusi. Komplekt 1, rinnahoidja ja kõrge vöökohaga stringid, on mugavad, venivad ja sobivad ideaalselt igapäevaseks kandmiseks. Komplekti 2 rinnahoidja ja kõrge vöökohaga stringid sisaldavad rohkem elemente, saavutades samal ajal ka peamise eesmärgi milleks on mugavus ja maksimalism erilistel puhkudel kandmiseks. Meriinovillast valmistatud pesutoodete tulemuseks on väga pehmed ja hubased esemed. Arvestada tuleb aga, et digitaalne trükk meriinovillale muudab värvitooni heledamaks ning seda just kangast venitades. Komplekti 1 ja komplekt 2 pesu ja hommikumantli konstruktsioon ning disain on õnnestunud nagu tahetud. Komplekti 1 siidist hommikumantel on kerge ja eksklusiivne toode mis vajab õmblemiseks rohkem aega. Digitrükk ning pesutikandid osutusid tulemusena heaks dekoratiivseks elemendiks.

Lõputöö kõrgem eesmärk ja järgnevad lisaeesmärgid said saavutatud nagu planeeritud. Digitrüki ja pesutikanditega kõrgmoe kauakestva pesukollektsiooni loomine kvaliteetsetest ja luksuslikest materjalidest õnnestus edukalt. Põhieesmärgi saavutamiseks püstitati ja järgiti nelja lisaeesmärki. Need hõlmavad turusuundumuste analüüsimist ja potentsiaalsete klientide seas küsitluse läbiviimist. Lisaks uuringut pesukollektsiooni potentsiaalsete materjalide omadustest, teste pesukangastel digitaalsest printimisest ja tikkimisest ning lõpuks pesukollektsiooni loomist. Eesmärkide täitmine on olnud edukas, kuid nende esemete pikaajalise tootmisega alustamisel tuleb teha investeeringuid. Digitrüki- ja tikkimismasinatega töötamine vajab sageli hoolt ja jälgimist.

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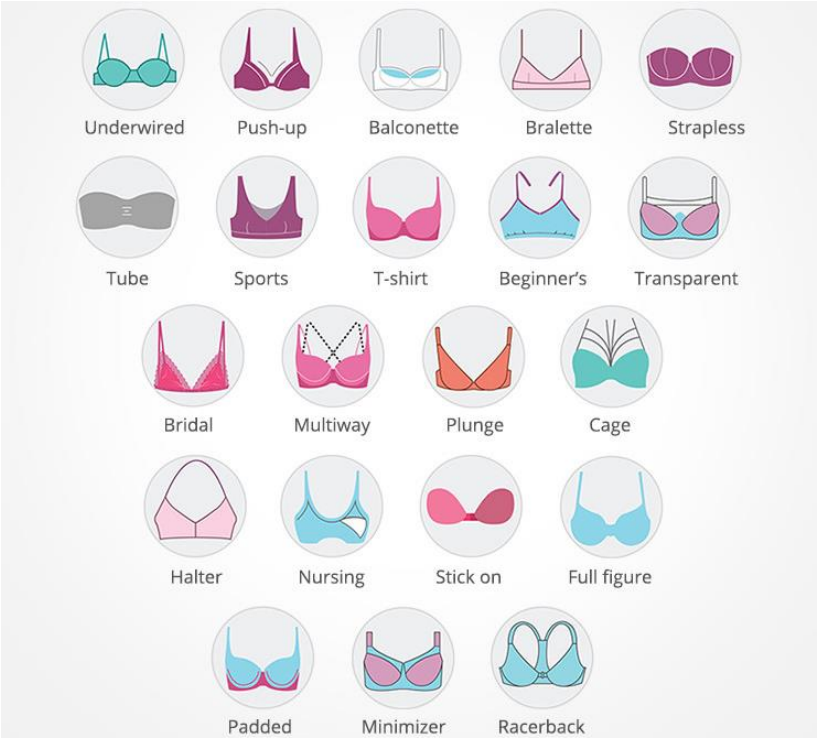
APPENDICES

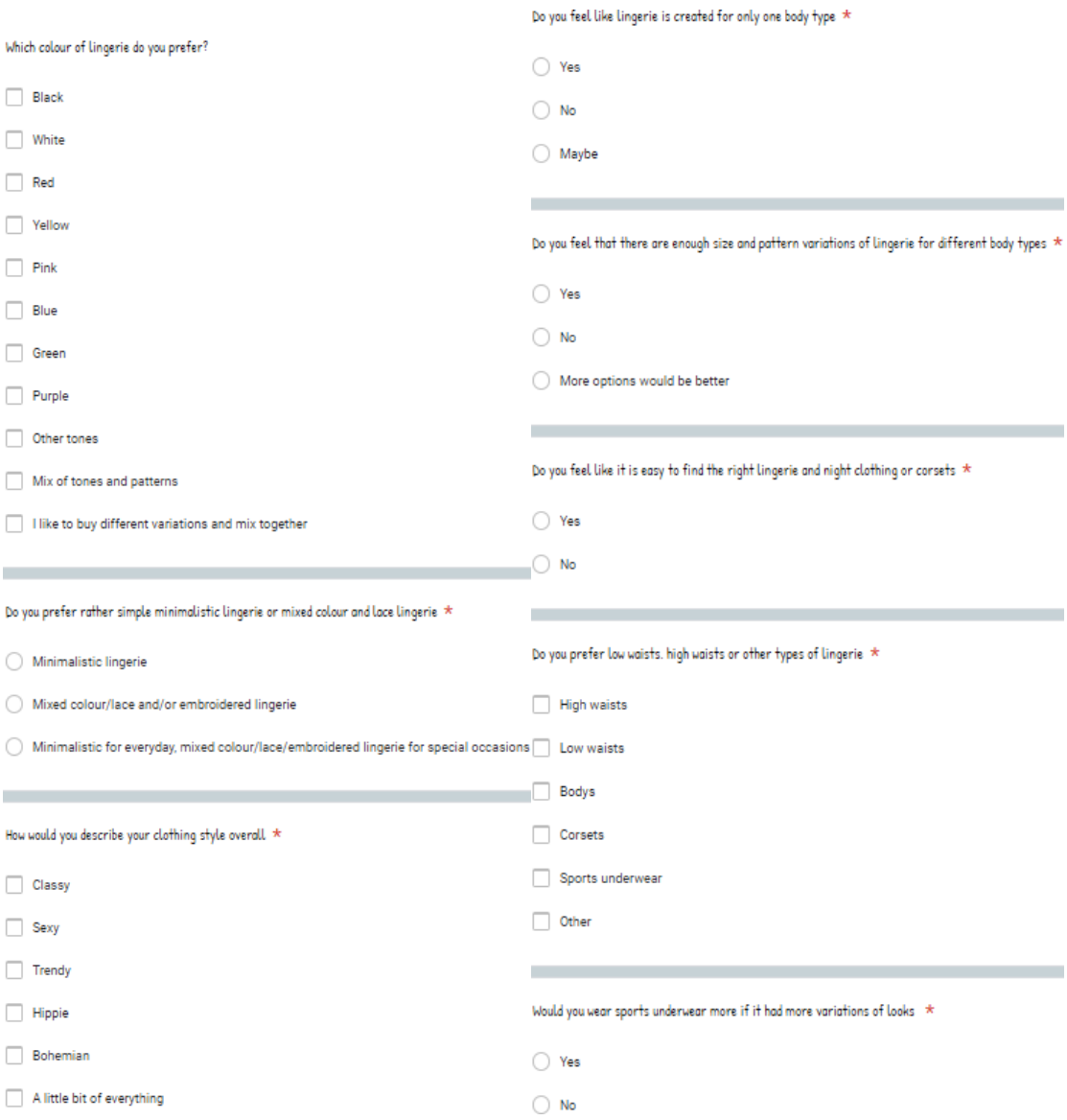
Appendix 1 Different types of bras and panties



A1.1 Types of bras [60]

A1.2 Types of panties [61]

Appendix 2 Questionnaire



A2.1 Questionnaire questions 1-8

How often do you buy lingerie *

- Once a week
- Once a month
- Once in 6 months
- Once a year

How much are you willing to spend on lingerie? *

- 10-20 eur at once
- 20-30 eur at once
- 30-40 eur at once
- 40-50 eur at once
- 50-... at once

Do you feel like the quality of lingerie in certain stores has dropped? *

- Yes
- No
- Maybe

Would you be willing to buy higher quality and unique lingerie for a higher price? *

- Yes
- No
- If I have the money then yes definitely

If money was no object. would you spend more money on lingerie overall? *

- Definitely yes
- Yes
- No

How does buying lingerie make you feel *

- [ ] Confident
- [ ] Happy
- [ ] Sexy
- [ ] Sad
- [ ] Nothing it is rather just a necessary purchase

Extra question 1- Do you get lingerie from

- [ ] Savage Fenty
- [ ] Victoria's Secret
- [ ] BonBon lingerie
- [ ] Calvin Klein
- [ ] Tommy Hilfiger
- [ ] Women'secret
- [ ] H&M
- [ ] New Yorker
- [ ] Change lingerie
- [ ] Marilyn
- [ ] Other

A2.2 Questionnaire questions 9-15

Extra question 2- Does some image catch your eye?

Option 1

Option 2

Option 3

Option 4

Option 5

Option 6

Option 7

Option 8

Option 9

Option 10

Option 11

Option 12

Option 13

Option 14

Option 15

Option 16

Not really

A2.3 Questionnaire question 16 (Extra question 2)

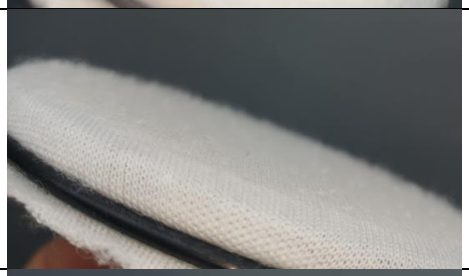
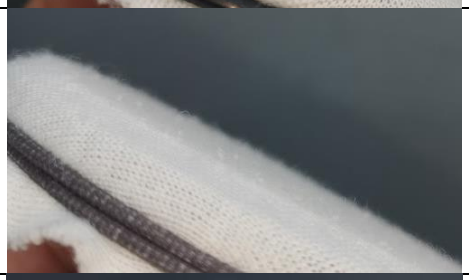
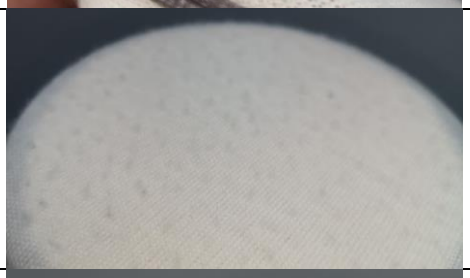
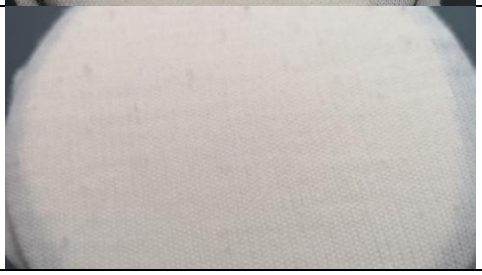
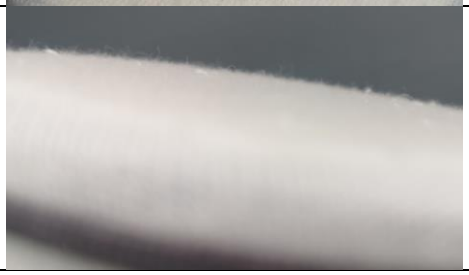
Appendix 3 Determination of fabric propensity to surface fuzzing and pilling results

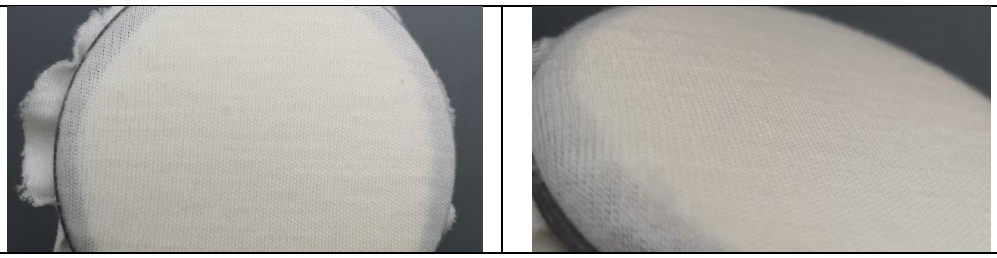
A3.1 Dark grey merino wool specimen visual pilling test results

Nr of pilling rubs	Pilling results for dark grey merino wool
0 rubs	
125 rubs	
500 rubs	
1 000 rubs	
2 000 rubs	
5 000 rubs	

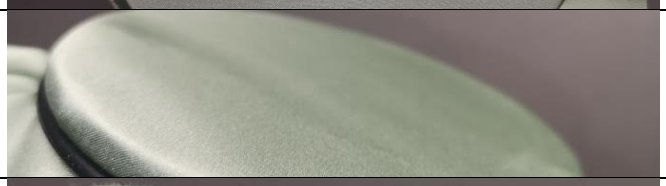
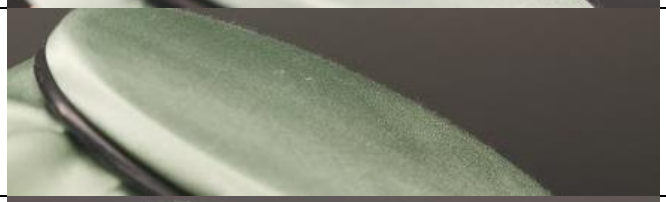
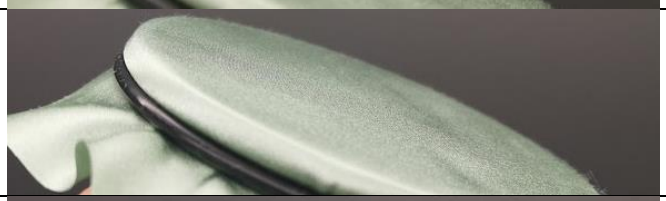
Nr of pilling rubs	Pilling results for dark grey merino wool
7 000 rubs	

A3.2 Natural white merino wool specimen visual pilling test results

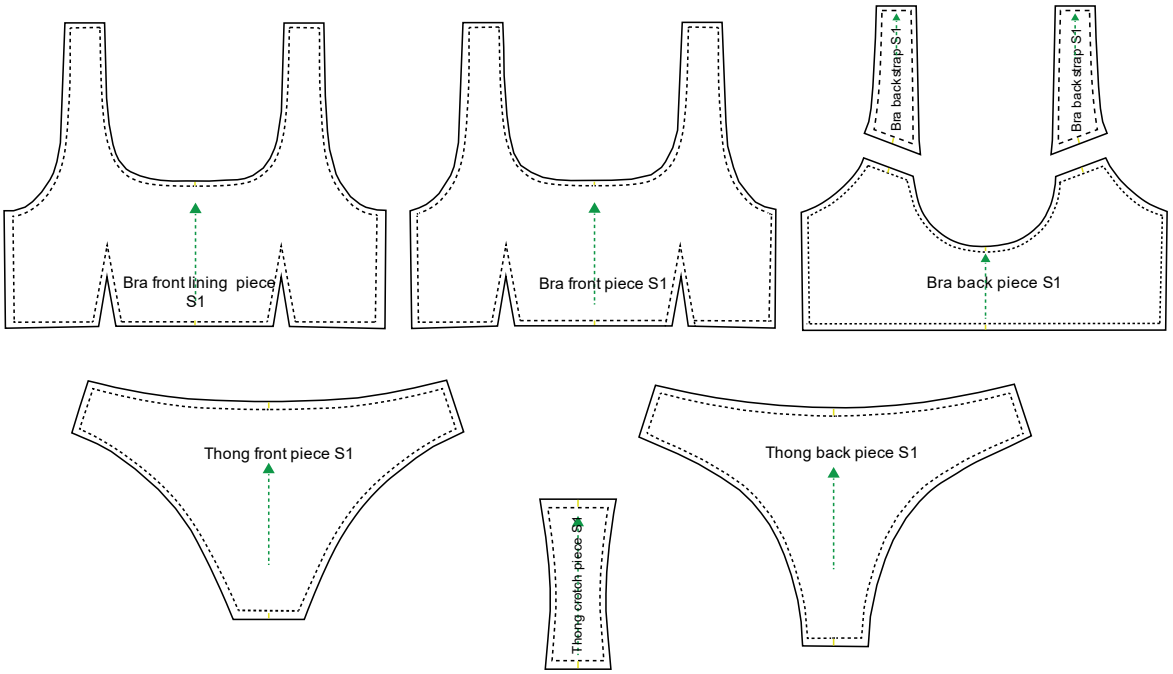
Nr of pilling rubs	Pilling results for natural white merino wool	
125 rubs		
500 rubs		
1 000 rubs		
2 000 rubs		
5 000 rubs		

Nr of pilling rubs	Pilling results for natural white merino wool
7 000 rubs	

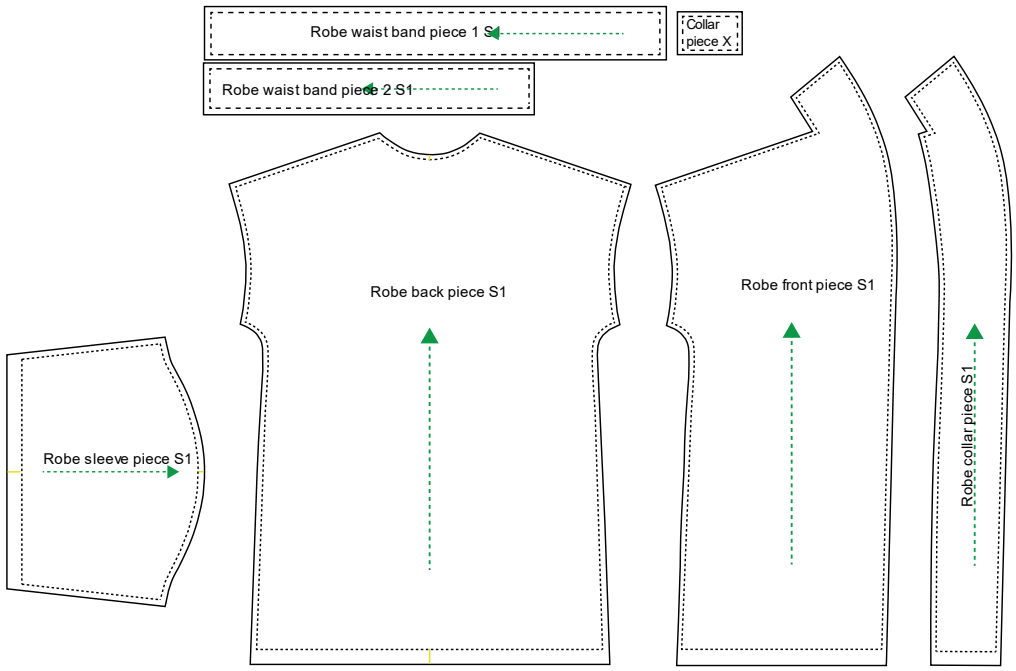
A3.3 Green natural silk specimen visual pilling test results

Nr of pilling rubs	Pilling results for natural silk
0 rubs	
125 rubs	
500 rubs	
1 000 rubs	
2 000 rubs	
5 000 rubs	
7 000 rubs	

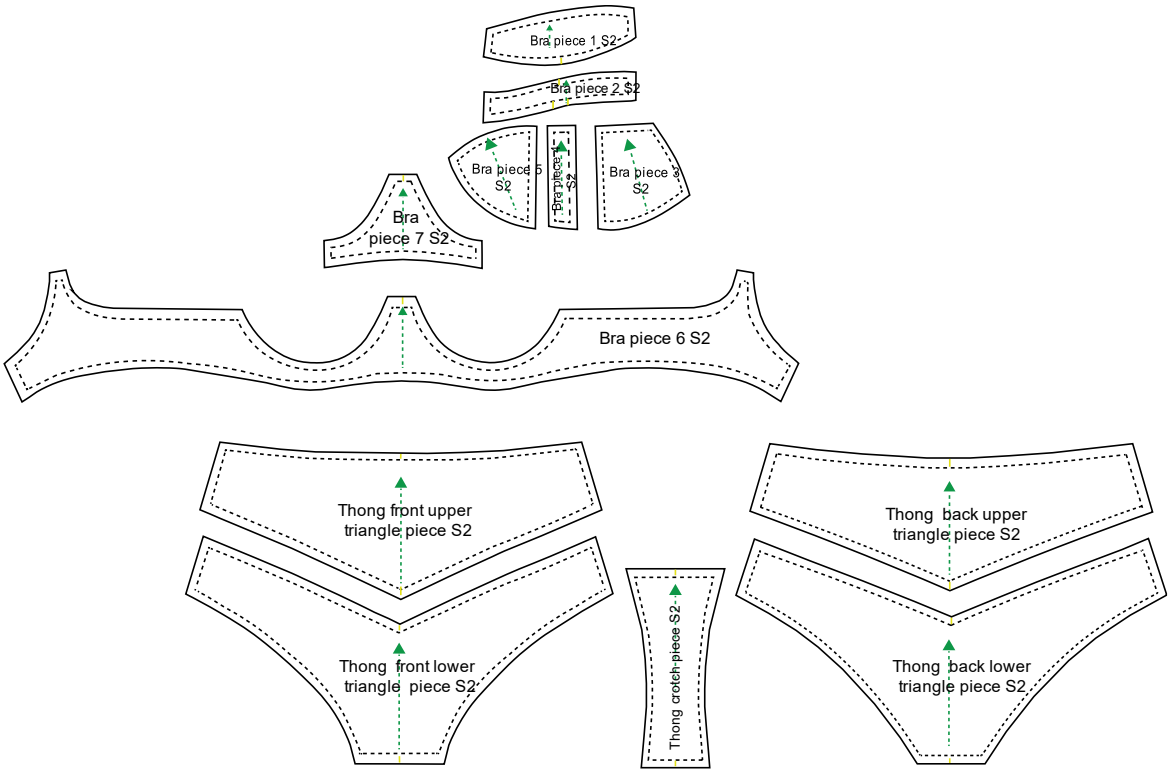
Appendix 4 Set 1 and 2 patterns



A4.1 Set 1 lingerie patterns



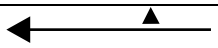
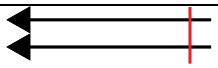
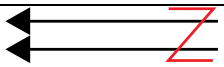
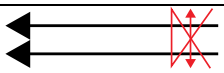
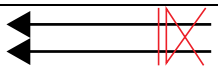
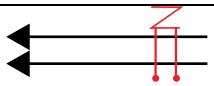
A4.2 Set 1 robe patterns

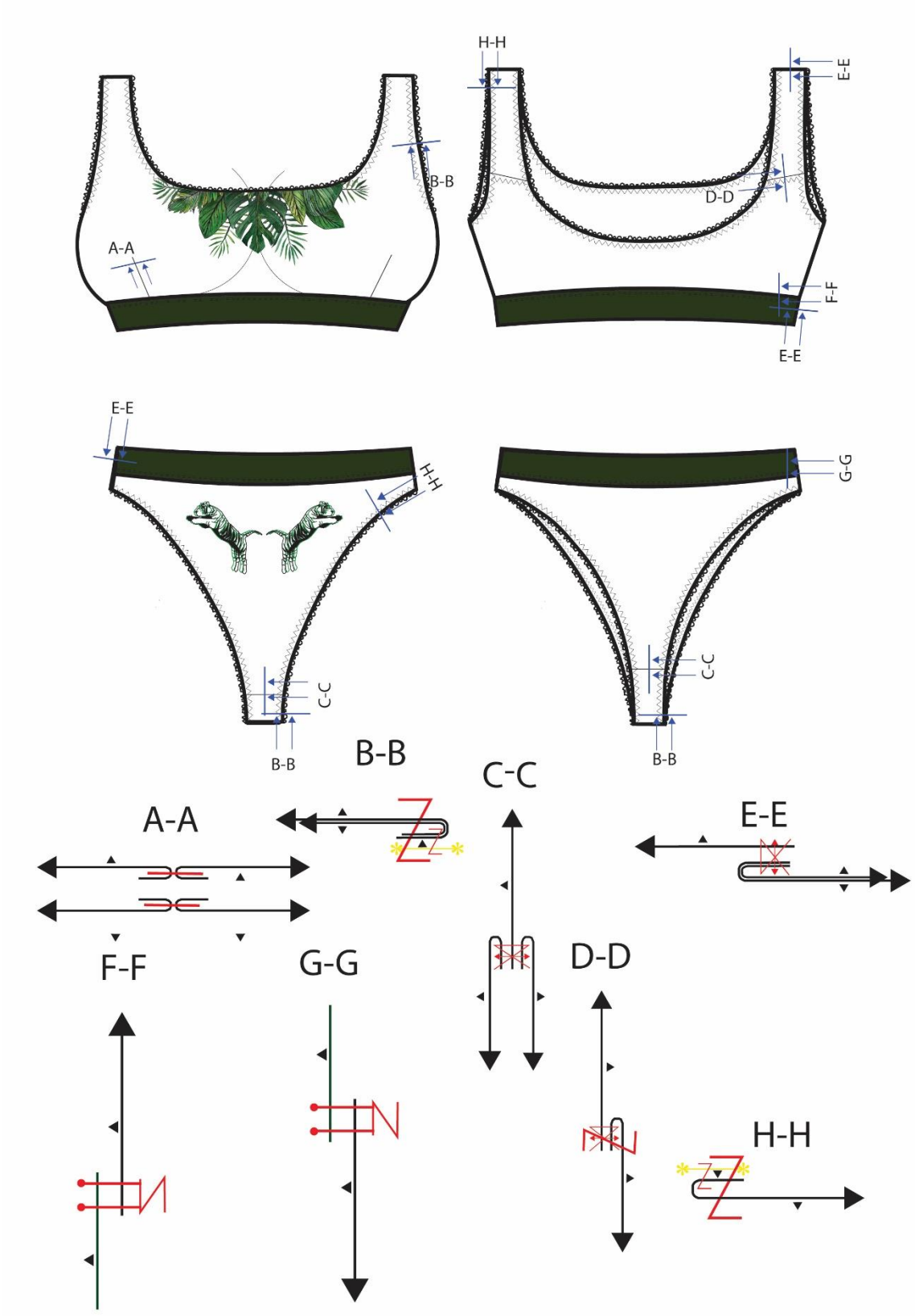


A4.3 Set 2 lingerie patterns

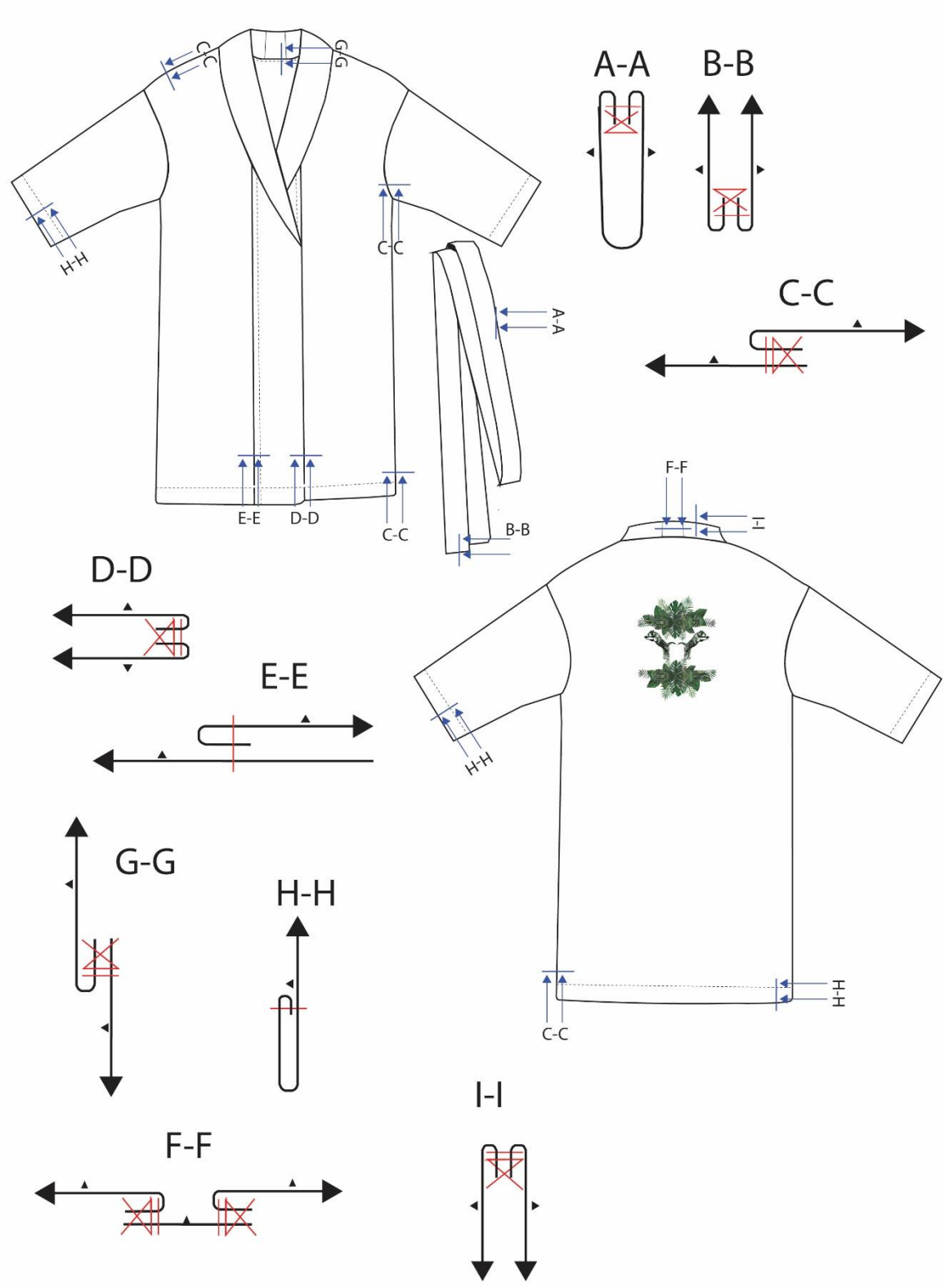
Appendix 5 set 1 and 2 sectional drawings

A5.1 Sectional drawings symbol and description

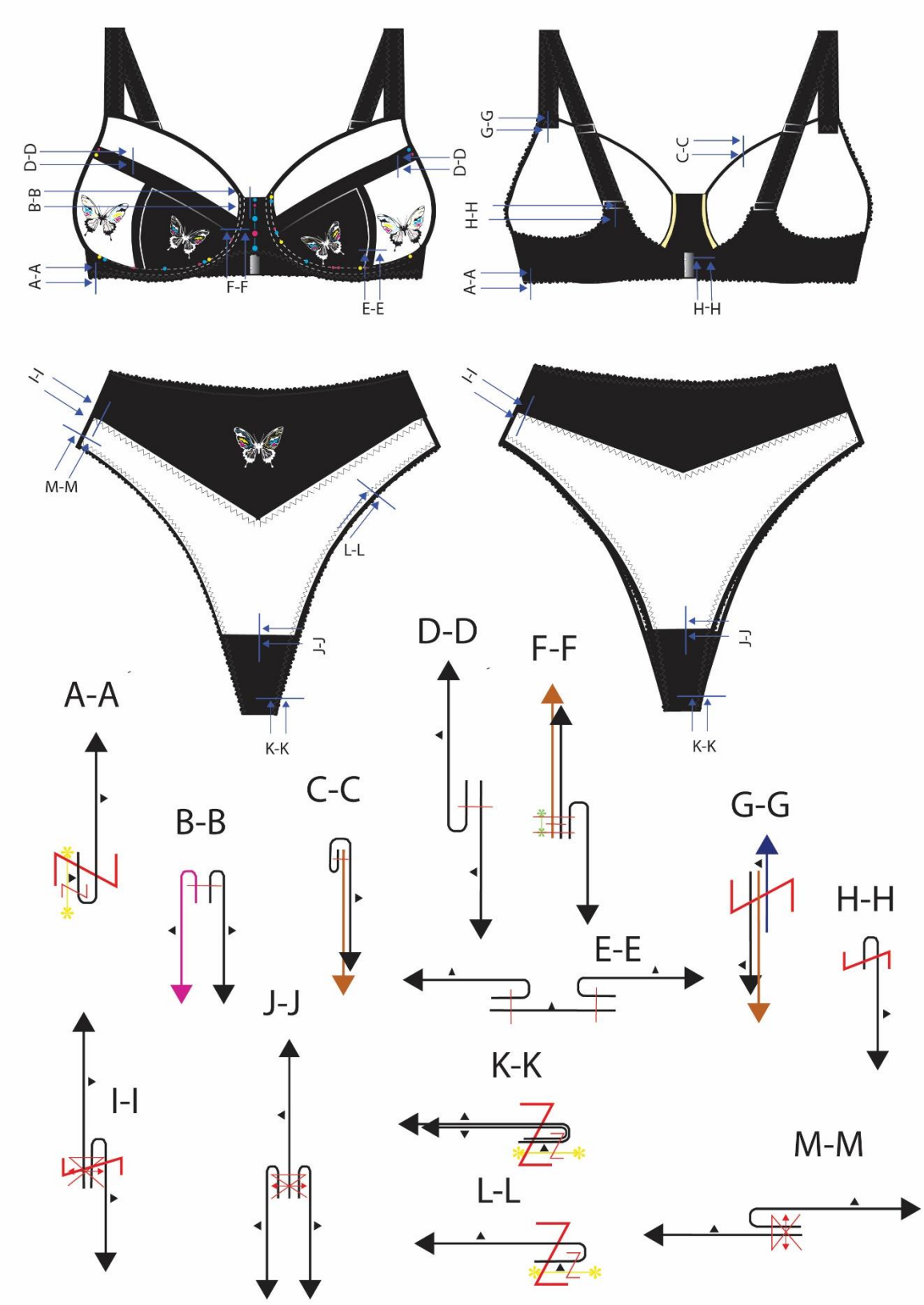
Sectional drawing	Description
	Right side of the fabric
	Regular stitch
	Zig zag stitch
	4-thread overlock machine
	3-thread overlock with 301 lockstitches
	Two-needle cover stitch
	Narrow elastic band
	Underwire pocket
	Wide elastic band
	Bra cup
	Tulle material
	Bra strap



A5.2 Set 1 lingerie cross sections



A5.3 Set 1 silk robe cross sections



A5.4 Set 2 lingerie cross sections

Appendix 6 Collection results

A6.1 Set 1 lingerie, photos by Markus Vares (Vares Stuudio OÜ)

A6.2 Set 1 silk robe, photos by Markus Vares (Vares Stuudio OÜ)

A6.3 Set 2 lingerie, photos by Markus Vares (Vares Stuudio OÜ)