KNIT-NET

Designing watermarks for papermaking through knitted textile structures.

Mary Laitinen Fransson
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AUTHOR

Mary Laitinen Fransson

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SUPERVISOR

Louise Christiansson

EXTERNAL OPPONENT

Caryn Simonson, senior lecturer, Chelsea College of Arts - University of the Arts London

STUDENT OPPONENT

Clara Bryant

EXAMINER

Delia Dumitrescu, professor in textile design

SPECIAL THANKS TO

Louise Christiansson
Erling Gustafsson
Richard Laitinen
Sara Björnström
Emilia Jensen
Karin Landahl
1.3 Abstract.

This work positions itself within the field of non-woven material design in a light and interior context.

The aim of KNIT-NET is to design watermarks for papermaking through knitted textile structures. Watermarks are conventionally produced by creating a variation in the thickness of the paper fibres during the wet-paper phase of papermaking. This design is clearly visible when the paper is held up to a light source. Usually weaving techniques are used in order to filter out the water from the cellulosic pulp.

Prior knowledge of plant fibre papermaking and traditional watermarking techniques was during the summer 2020. Subsequently, the ideas to explore the project further were raised during this degree project. The primary motive is to find other ways to produce water markings and texturizing to non-woven materials, by investigating knitted surfaces and yarns that will be functional in a wet process in papermaking. The material should provide organic structure and shaded pattern to the non-woven cellulosic textiles.

Several cellulosic fibres were explored during this study; long staple cotton and sisal hemp fibres were the final materials of choice. The fibres were boiled and beaten into pulp, then applied on top of the knitted net designs in order to shape the paper sheets. The various knitted structures guided the choice of fibres, since the textiles affected the material properties and aesthetics of the final paper designs.

The result is a collection of paper artefacts that visualise the value of non-woven paper material in an interior and light context. The muted colours becomes more visible and stronger when light is shining through. The knitted structures, in combination with the opaque and transparent cellulosic fibres, are perceived differently depending on the source of light, the direction of the light, as well as what time in the day. KNIT-NET is also a contribution to the method of utilising knitted textile structures to design watermarks for papermaking.
1.1 Representative Images.

"Snake skin"
"Snake skin"
"coffee beans or animal skin"
“Caterpillar skin”
“Caterpillar skin”
"Crocodile skin"
"Crocodile skin"
1.5 Keywords.

Textile design, nonwoven, papermaking, watermarks, knitting, light, interior.
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2.1 Introduction to the field

How does a watermark work? Commonly, the design of the watermarks is produced by creating a variation in the thickness of the paper fibres during the wet-paper phase of papermaking. This design is clearly visible when the paper is held up to a light source (Wilson 2011, fig. 1). In the traditional way of designing watermarks, two functional techniques are used; “wire design”, laid over and sewn onto the sheet old wire (Laitinen 2022, fig. 2). Or “shaded” watermarks produced by a depression in the sheet mold wire, which result in a greater density of fibres (Lessebo pappersbruk, fig. 3).

Historical cellulosic paper has been manufactured by utilizing woven nets in order to filter out the water from the cellulosic pulp (Barett 2022, fig. 4). The frames that form the sheet, called mould and deckle, are simply two separate frames of the same size. The mould has a woven net-material often made of stainless steel, brass or bronze. The deckle is laid on top of the mould that forms the edge of a piece of paper. The weaving technique is a good choice because it can evenly distribute tension to each thread (fig. 4).

The value of the paper has long been used in Japanese culture for interior and architecture designs. The paper washi is often made from strong fibres from the bark of kozo mulberry, gampi or mitsumata plants. It is characterized by the stability of its colour and durability (Aoyawashi n.d). The meaning of Shoji originally indicates a tool to obstruct. In its modern usage, shoji is the term used to refer specifically to translucent paper coverings. The paper covering acts as a screen that covers the wall, partition, sliding door (Minamoto 2022, fig. 5) or lamp and acts as a medium for the transmitting of light and should bring warmth for home environments.

Knitting is a textile technique in which knitting needles or a knitting machine are used as a tool together with yarn or thread as the main material to produce textile products of various knitting techniques. The art of knitting with the techniques as known today can create endless possibilities for designs to develop the purpose and design expression of knitting.
2.2 State of art

Michelle Wilson explores and challenges the possibilities of linear watermarks in a larger scale design language. In Ghost Tree (2008), the work is made from recycled paper and is presented as hanging panels with lighting from behind to clarify the watermark illustration (fig. 6).

The paper art Recoil 1 (2016) by Lesa Hepburn using hibiscus fiber twined into a string to make an impression on the wet-paper with a weight placed on the top. The hibiscus yarn leaves a permanently structural textured surface due to the twisting and fiber texture (fig. 7).

Erling Gustafsson is a papermaker artist from Eksjö that uses the traditional techniques inspired from Japan and Scandinavian papermaking culture. By boiling the cellulosic fibers from scratch, beating it into fiber pulp and then forming it into paper sheets. The usement of the paper is visualized in 3D sculpturing and visual art (PaperArt 2022, fig. 8).

The dreamlike paper sculpture by Peter Gentenaar (2017) (fig. 9) is based on a technique where the colored sheet of pulp has been placed wet on bamboo ribs on a vacuumtable in 2-dimensional form; when the pulp dries, the paper shrinks 40 % and the shape contracts to an organic sculpture. Gentenaars vision is to bring paper art to the public and to be inspired by fellow paper artists.
Eriko Horiki, is one of Japan’s preeminent washi paper designers beloved for her architectural creations that verge on contemporary art. Her paper art can be experienced in a literal slideshow with 15 foot long pieces of paper, showcased on ceiling tracks to more sculptural pieces in the forms of lanterns. The Cube goutment floor (Horiki, 2015) is based in Kyoto station (fig. 10). The washi panel screens are angled folded with an LED internal light system behind to give a dynamic element and allow colour changes in temperature for the different seasons and events in Kyoto.

The project wood waste by Peter Fjellman-Lätt (2020) is a project about to presenting different ways of using wood waste material, as a sustainable way for designing objects and products. His documentation is a guideline to a DIY project (“do it yourself”) (fig. 11).

Heather Matthew is a hand papermaker from Mexico, and the owner of his hand paper mills. In this piece, a woven rug has been used as an embossing to create an impression in the wet paper sheet. When the rug is pulled away, a textural imprint is left on the paper surface (fig. 12).

The designer Julien Macdonald shapes various materials against knitting. The dress from spring ready-to-wear (Tondo, 2014) (fig. 13) shows how small and large stitches with open and more closed fields run together and apart in an organic design language, a creative way to give structure and character to the textile material.
2.3 Motive and Idea discussion

The primary motive is to find other ways to produce water markings and texturizing to non-woven materials, by investigating knitted surfaces and yarns that will be functional in a wet-process in papermaking. Instead of using the traditional woven techniques as the basic material to shape the non-woven cellulose material, knitting techniques is used. As explained earlier in the introduction to the field p.13, the watermarks are normally constructed as a depression in the woven net or applied and sewed on the top of it. Textile structures have been used as embossing to give the cellulose material structures (fig. 7 & 12), how could knitting techniques be used to find methods that give both shaded pattern and structure to the cellulosic material at the same time?

Comparing woven with knitting, a jacquard machine would be needed to produce patterns quickly, which is not readily accessible if the project is to be done for domestic use. If a loom were to be used to produce patterns, the work would take a very long time. In knitting, several machines are made for home use. As long as there is prior knowledge of hand knitting machines, the project is feasible. With a silver reed machine it is efficient and quite fast to produce repeated patterns. However, knitted materials are naturally elastic, hence it can be difficult to get the same smooth surface for paper. The key is to find knitting techniques that add texture surfaces to the papers, this may well outweigh the results.

The presentation of references all demonstrate different ways of working with cellulosic fibers, with different methods and tools to give the material new life. Some of the references are made in the field of interior design, some in the art and hand craft, together they provide a wide multitude of ways to design paper artifacts in 2D or 3D compositions.

Michelle Wilson (fig. 6) is an example of how the reference as a designer in a challenging way uses watermarks as an expression in her art. Gustafsson (fig. 8), Gentenaar (fig. 9) and Fjellman-lätt (fig. 11) are examples of designers who have manipulated the cellulose material in the wet state to design a permanent 3D-shape and sculptural form. Both Wilson (fig. 6), Fjellman-lätt (fig. 11) and Horiki (fig. 10) have added light to the material.

In Knit-net the interplay between light, shadow, colour and material characteristics play an important role. Which can accentuate the shadows in the material and create a pleasant environment. When looking back at Japanese culture, paper and light has been and is a precious context. Why? The cellulosic material can create spatial surroundings to diffuse subtle light and warmth for residents. Like (fig. 5) p.13 shoji screen, where the paper feature lets day light through, and depending on the cellulose fiber, texture and color, the light will be perceived differently in the room.

Only a hand knitting machine is used in this investigation to produce the knit-net design. The idea is that the project should be able to be done by yourself i.e. should be able to be carried out in a home environment, as larger work areas and more expensive machines require greater resources. The vision is that the work will inspire readers to use the method. However, it requires prior knowledge in handcraft techniques for papermaking and knitting skills on hand knitting machines. Whether using advanced or non-advanced knitting patterns, the work shows potential to be able to shape non-woven materials in artistic use and open up opportunities for other textile usement.
2.4 Aim

The aim of this project is to design watermarks for paper making through knitted textile structures.
3.1 Watermarks and methods

The materials should provide organic structure and shaded pattern to the non-woven cellulosic textiles. Therefore, it was important in the prestudy to create an understanding of how a watermark is designed and what influences a thinning or thickening of the surface of the fibers sheet. Figures 14-17 show how a linear and shaded watermark is designed.

Figure 14. Construction of linear watermark (From Essays in Paper Analysis, Stephen Spector, p. 207)

Figure 15. Thin raising wire shaped watermarks sewn on the woven net material, create a transparent thinning in the paper sheet (Murphy 2021)

Figure 16. Original and watermarked mesh surfaces using grid representations in (a), (b), and after flat shading in (c), (d). (a) Original mesh. (b) Watermarked mesh. (c) Shaded original mesh. (d) Shaded watermarked mesh. (Bors 2022)

Figure 17. Shaded watermark in paper sheet (paperlurry 2013)
3.1.1 Process stages

The project consists of five process stages, which has been visualised and simplified in a linear process strategy according to the terminology of Jones (1992) (fig. 18). The five stages involve both exploration and investigations research, where choices are made and boundaries are determined for the project. Each of the stages had their own primary investigation, where the selection differs from stage to stage. During the exploration, selections are made where a few different tracks guide the project in the development of the degree work. For the final pieces the selections are made and the final designs are constructed.

The project is also divided in two main workspaces to enable work with both knitting and wet process. The workspaces follow a “cyclic strategy” (Jones 1992) to be able to achieve the aim and goal for the project (fig. 19). The cyclic strategy involves in the first stage: knit samples in handmachine, try the knit-net in the wet process, analysing the sheets with and without light source, discarding and selecting samples, then exploring the selected samples further in the knitting lab. The five stages involves both exploration and investigation research, where choices are made and boundaries is determined for the project. The circular stratigraphy also includes exploring the paper sheets against a light source, to see if watermark and transparency appear in the sheet. As well as how the different cellulose fibres differ with each other.

The third diagram (fig. 20) shows a methodology of how to processing the raw cellulose fibres into fibre pulp. Six cellulose fibres have been investigated in the project.
Figure 20. Process stages from raw material to fibre pulp.

- **Knit The Net**
  - Sisal hemp
  - Kozo (Japan)
  - Stable cotton
  - Abaca
  - Flax
  - Lokta (Nepal)

- **Cellulose fibres**
- **Boiling**
  - Boiling with Soda Ash, sodium hydroxide. Removes impurities and leaves cellulose fibre.
  - Boiling time: 3-4 hours.

- **Beating**
  - Beat into fibre pulp.
  - Fibre + water
  - Beating time: 1-3 hours.

- **Sheet formation**
  - Stretch the knitted net on the frame.
  - Lift the mould and deckle (knit) up through the slurry; a thin layer of pulp is left on the screen.
  - Couching, transfer wet sheet from screen to an absorbent surface.
  - Sheet formation time: 1 day

- **Pressing**
  - Remove the water by pressing, use a sponge.
  - Press the sheets with weights over night.
  - Pressing time; over night.

- **Drying**
  - Remove the sheets from the press, let dry separately.
  - Press the sheets with heat to flatten the surface.
  - Drying time: 1-2 days.

- **Analyse watermark with light source.**
- **Analyse texture and patterns.**

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Sisal hemp
Kozo (Japan)
Stable cotton
Abaca
Flax
Lokta (Nepal)
3.2 Development & Design rationale - Pre-study I

Learn the handicraft technique of papermaking

Prior knowledge of handcrafting techniques to produce paper from plant fibres was gained in pre-study I, summer project 2020. The cellulosic fibres were locally picked in the highlands of Småland. Where daylily, stinging nettle, reed, fern, iris, oats and horsetail were boiled, processed and formed into fibre sheets (fig. 22). The outcome of the project was that the fibres differ a lot in strength, fibre length, thickness, colour and structure. Depending on the fibre, different processing methods were required. The nettle was so strong that the bast needed to be separated by hand after boiling, the reed fibres needed to be beaten with a hammer to separate the fibers, whereas the oats could be processed in the blender immediately after boiling.

Not just paper
Paper can be made of almost anything but it is not certain that the end result will be writing paper, perhaps the value is intended for sculpting, craft or a textile object.

Sustainable lessons
The key to harvesting is to look for grass, bast or leaves fibers. Pick the plants when it is fresh in early summer when fibres are the strongest, or in autumn when the leaves have fallen from the trees and dry reeds. Only pick plants that are plentiful. When boiling, the water can be reused for the next fibre batch.

The six cellulose fibres (fig. 20.) selected for this project only need to be boiled and processed with a blender to become pulp. This choice was made because the working process also requires a great deal of investigation in the knitting lab. A standard household mixer was used to process the fibres, which was the cheapest and most efficient option. In order to process the fibres industrially a Hollander beater is used (fig. 21). The machine is developed by the Dutch in 1660 designed to beat cloth and plant fibers into high quality pulps to make a diverse range of Western style sheets and contemporary paper art techniques. A machine suitable for beating long fibres, flax, hemp or sisal, as well as for beating soft and short fibre like cotton linter (Lapp 2014). The machine is quite expensive and can be difficult to obtain today, therefore a blender has been used in this project. However, the purchase of this machine may be a development to the sheet's qualities in future exploration.

Figure 21. Construction of a Hollander beater (Nash 2014)

Figure 22. Draft from workbook (2020)
Construction of frame

In order to make this project possible, a construction needed to be developed to produce the deckle and mold for the wet-process in papermaking. The purpose of the sketches was to find a method that would work to clamp and unclamp the knitted material. Normally the woven net is clamped permanently to the frame and cannot be removed. It will be more sustainable if the knitted material can be replaced instead of several frames needing to be made. This will streamline the process as multiple tests on different materials and techniques can be done on the handknitting machine.

The design was selected in the value of best and most uniform tension with the knitted material over the whole frame. The choice fell on (fig. 24) by using the clamps as a tension tool, it was easy to distribute the knitted material in an even tension over the entire frame, the process was also quick and easy. The frames were then designed in two different sizes A5 (148 mm × 210 mm) and A3 (297 mm × 420 mm). The size model of the frames serves both as a set up for developing ideas and as a framework to evaluate design experiments against. The sizes of the measures were chosen to be manageable for only one person to use without help from someone else.

Figures 23, 25-26 shows the work under construction.

![Figure 23. Sketch 4, Mould and deckle constructed with metal clamps and sawn thinning in deckle frame, A5 size (deckle)](image)

![Figure 24. Sketch 1, Magnetic stamps with metal tiles](image)

![Figure 25. Sketch 2, Magnetic stamps with tension lock](image)

![Figure 26. Sketch 3, in-dept frame with attached magnets and reinforcing steel](image)
3.3 Pre-study II

Material study in knitting

During the pre-study II a quantity of different materials were explored on the hand- and industrial machine. The material was divided into two categories from stitch sizes 1-5 and 6-10, to fit the working frame in A5 size. The material was selected after a pre-study on material theory, according to the right tenacity, absorbency and elasticity (Hultén, Damberg, n.d) (Kadolph, 2014) (Reis, 2022). The properties of the yarns were valued based (fig. 30) p.24 on how the non-woven sheet could be transferred from the knitted material in the wet-process. How it acts in the wet state, if the sheets easily detach from the sample and if the knitted sample is easy to clean after the process and how the non-woven sheets look like in the dry state.

The value analysis has been based on one fibre type, long staple cotton. The fibres have much higher resistance and durability values than normally paper fibres. Long staple cotton is usually used to produce banknotes, because it is resistant to moisture and wear. The fibre used in this study comes from Tumba Bruk near Stockholm City.

After the value analysis this degree work narrows it down to only use the highest rated material for the knitted net, Pet/spun and polyester fibres. Stainless steel was also one of the highest rated but it was chosen to be discarded, because of its hard steadiness to knit within the hand knitting machine. The stainless steel had the potential in industrial machines but that would mean that the work could not be done by hand, which was one of the measures in the project. In addition, knitting with stainless steel in the industrial machine was time consuming as the thread often broke when making elaborate designs.

Result

In the investigation it was found that the best rated yarns worked well with both large and small stitch sizes from 1-5 and 6-10 (fig. 29 & 29.1). While the medium rated yarns showed no potential for larger stitch sizes and the lowest rated did not give any result on lower stitch sizes at all, as the cellulose pulp get stuck in the knitting. The variety of both manmade fibres and natural fibre was included in the process. The pre-study was limited to certain timeframes and not all materials could be examined in the lab, therefore quick selections had to be made.
Figure 30. Value-chart
What affects the paper sheets?

Exploring knitting techniques, to find what influences the transparency and structure of the non-woven sheets. By testing different contrast yarns in knit sizes, number of threads, stiff and soft material and the distance between the stitch fields. The samples were assessed according to texture, transparency, and wet process handling.

The thick yarn in (fig. 31.0) and (fig. 31.1) creates thinning in the sheet by the raised parts in the knitting. The texture differs slightly in the shaping of the lines and the result is clearly visible on both, knit side and purl side.

Low stitch size (fig. 31.2) creates transparency in the sheet, high stitch size creates shaded areas with more accumulation of fibre pulp. (Fig. 31.3) makes no impact on transparency areas in the surface, only results of clear textured surface between the stiff and soft material. (Fig. 31.4) have a great impact on transparency areas in the sheet, but difficult to handle in wet process in the stage of transferring the sheet from the knitted structure. (Fig. 31.5) Makes no impact on transparency, clear lines in the stitches of textured surface.

The exploration shows that a large difference between high and low stitch size affects results on transparent and shaded surfaces similar to the shaded watermarks (fig. 17) p.18. Raised knitting results in thinning of the fiber sheet, similar to the linear watermarks (fig. 15) p.18.
**Investigation of knitting techniques**

During stage *Pre-study II*, a large variety of different knitting techniques was explored on dubied- and silver reed machine. False lace, jacquard, partial knit, intarsia, huck-up stitches, and so on. After many tests it was found that three different knitted techniques affect the fibre surface and transparency, rib stitch, drop stitch and tuck stitch.

As described earlier, a typical watermark is formed in a linear shape. More advanced watermark is a gradient with small difference in depth and in that way creating a picture or pattern p.18. It was found that tuck-, rib- and drop-stitch demonstrates these properties. Tuck and rib-stitch have more linear apparence, with knitted level variation and drop-stitch becomes more shaded, due to the difference between small and large stitch sizes. The pictures illustrate how the knitted patterns look like for each knitting technique, how the paper sheets look like in dry stage with the knitted texture and the sheets analysed against a light table.
3.4 Pre-study III

Prepare the cellulosic fibres
During the first stage of pre-study III much time was spent in the wet process of boiling and preparing all the six cellulose fibres p. 30. Since the boiling time takes about three hours, the work was divided into two different steps, boiling two batches of fibre, beating the fibres and then testing the knitted structures with the cellulosic fibres in the wet process and after that starting the process again with some new fibre types. The two fibres that do not need to be boiled were long staple cotton and pressed abaca, the fibres are already pressed to thick sheets that only need to be soaked overnight to become soft. The fibres are then processed to fibre pulp in the blender, a faster process that does not require boiling, a bit like making paper from recycled material.

Recipes for boiling cellulosic fibers
To 1/4 pound (133 grams fibers); add 1 tbsp caustic soda (natriumhydroxide) to 1.892 L water. During the boiling process the fibres must be boiled with a black liquor alkaline substance that removes impurities (removes the lignin, a vegetable polymer contained in the cell walls). The lignin has a negative impact on the paper quality, because it binds the cellulose together and makes it stiff. In papermaking the aim is to achieve separated and soft fibers in order to make the pulp as fine as possible.

Step 1 preparation
1. The fibres are cut about 10 dm long, and then a desired amount of fibres weighed on a gram scale.
2. The fibres are soaked for 24 hours to soften before boiling.

Step 2 boiling preparation
1. The fibres are added to the pot, without water.
2. Cold or room temperature water is added to the pot.
3. Caustic Soda is added and dissolved, before boiling.

During the boiling protective clothing must be used, gloves and goggles, as the alkaline substance is corrosive. Ventilation cabinet was also used because of the steam that is unhealthy to breathe in.

Step 3 boiling process
1. Put the lid on the pot, the heating time for boiling is about 30 minutes.
2. Remove the lid when it starts to boil, cook the fibres for about 3 hours, stirring the pot every 15 minutes or 30 minutes. Why? To separate the fibres and not to cause overcooking as certain plant fibres creates foam during boiling.

During the boiling process pH level is measured of how acidic/basic the water is before and after. The pH-level must be below 11 to be poured down the drain. If the pH level is too high after boiling, citric acid or vinegar can be used to make the water more acidic. If the pH level is too high, it can damage the drainage pipes, so it is particularly important to rinse the fibres in warmer water or the pipes may become clogged.

Step 1 preparation - Sisal Hemp
Step 2 boiling preparation

Figure 35.1 Cut dried sisal hemp and soaked sisal hemp to soften
Figure 35.2 Adds the right amount of sodium hydroxide for the boiling process
Figure 35.3 Before boiling pH level 13
Figure 35.4 After boiling pH level 11
Step 4 rinse the fibres
The fibres were carefully rinsed into a mesh strainer, and rinsed with water until the water runs out clear. During this process the remaining water is collected in a bucket for a sustainable purpose to save the water for the next fibre boiling.

Step 5 beating
During beating one handful of fiber was added to the blender and filled with water until it is about 2/3 full. All fibres were blended for about 30 seconds at first and then more seconds if needed. You know the pulp is ready when the fibres do not clump and look very fine, almost cloud-like dispersed in the water. The length of the blending time depends on the fibre type. After each batch of blender you have to wait about 1-2 minutes so that the machine does not overheat or break down. The properties of using a blender is that it’s easy to get, quite cheap and easily accessible for domestic use, better tools are mentioned on p.21.

Step 6 sheet formation and couching
Water is filled in a tube larger than the mould and deckle. A few handfuls of pulp is added to the tube. With one hand the pulp is vat-stir so that the pulp distributed evenly in the water. “Almost so that the pulp disappears in the water”. The Knit-net is clamed to the frame (mould) and the mould and deckle is hold together and insert in 45 degree angle into the water. Then reached to the bottom of the vat and turned parallel to the water surface and pulled up out of the water. Next step is to shake it gently back and forth to settle the fibers before the water is drained of. Now the pulp has settled in a thin layer over the knitted material and leftover water is allowed to drip into the tub. When couching the deckle frame is lifted off, and the mould is laid upside down, onto an absorbent surface, in this process old sheets have been used. The surface, back side of the Knit-net, is gently pressed with a sponge to collect excess water and help the fibre pulp to be removed from the knitting.

Step 4 rinse the fibres

Figure 35.5 Rinse the sisal hemp
Figure 35.5 Clean and ready for beating

Figure 35.6 Add fibres to the blender
Figure 35.7 Ready sisal hemp pulp
Figure 35.8 Collect the pulp in a large bucket repeat the process until the bucket is full

Figure 35.9 Add pulp to the tube with water
Figure 35.10 Vat-stir the pulp
Figure 35.11 Sheet formation and couching
Figure 35.12 Pressing and collect excess water
**Step 7 pressing and drying**
The sheets can be laid parallel on top of each other with cloth in between when pressing. Simple pressing tools used are two wide boards and a weight on top. The sheets are pressed for some hours then left to dry separately on a flat surface. The drying time takes about one to two days depending on the indoor climate. Other methods used in the process are drying cabinets where the sheets have been dried hanging. However, this can cause the sheet to curl and needs extra care when ironing afterwards.

(Loventé, 2004) (Studley, 1978)

**Step 8 analysing the sheets**
After this stage the paper sheet is analysed against light and without to see how the fiber types and texture look like and how the transparent areas become.

During the wet process, fibre pulp has been filtered out from the tub and the water has been reused for the next fiber formation. During the boiling process it was also discovered that the water from the boiled fibres had been discolored from the cellulose. The water could be used for dyeing textile fabric or to dye the pulp for paper forming. For example, when boiling kozo the water turns out yellow, sisal hemp golden brown, abaca dark brown, flax grey/brown. The colors of the fibres also differed when wet and when dry, as did the feel of the paper in the hand.
The difference between the cellulosic fibres, personal experiences

*Sisal Hemp from Spain*
Type of fibre: Leaf. Characteristics: smooth, glossy, pearl-like, soft, strong fibre with leather-like formability in wet-stage. Sisal is mainly used for twining yarn because of its ability to stretch, the fibres are also used to make cloth that is softer and more luxurious than cotton. Blending time: 30 - 60 sek. Quality of the thickness of the sheets: Thin (good), medium thickness (strong), thick (strong, still soft surface). Natural color: beige-white.

*Kozo from Mulberry tree, Japan*
Type of fibre: Bast. Characteristics: long fiber length, strong, curly, crispy, slightly shiny surface. Fine translucency and absorbency. Blending time: 30-60 sek. Quality of the thickness of the sheets: Thin (strong), medium thickness (super strong), thick (super strong) hard to tear apart and pleasing to work with. Natural color: pale yellow.

*Raw Abaca, waste product from banana plantations*
Type of fibre: Leaves. Characteristics: Stiff, strong, long fibre length, flexible and holds its structure (like coir texture). Crispy feeling in hand. Highly resistant to saltwater damage. Blending time: 30-60 sek. Quality of the thickness of the sheets: Thin (good), medium thickness (Strong), thick (Strong, hard to tear apart. Natural color: brown.

*Pressed Abaca, banana tree*

*Long staple cotton*
Type of fibre: Pressed sheet from. Characteristics: long, strong, smooth fibre 3.5-4 cm, pill less, wrinkle less, and fade less, good absorptive capacity. Blending time: 50-90 sek. Quality of the thickness of the sheets: Thin (good), medium thickness (strong), thick (strong) the sheet becomes very stable. Natural color: white.

*Flax from Sweden*
Explore the paper materials

Pre-study III also focused on how the knitting techniques p.26 are affected by the different cellulose fibres. How the transparency and structure differs depending on the amount of fibre pulp added to the water bath during the sheet forming. Opportunities and boundaries was explored to challenge the cellulose material through pressing, dying and 3-D forming, to gather information and knowledge. During the investigation, the fibres were formed with the same knitted structures p.26 from prestudy II. Few different techniques were investigated.

The thinner the paper sheet is formed, the clearer the watermark becomes.

The thicker the sheet is formed, the clearer the structure of the paper becomes.

The cellulose material is easier to form in a wet state. The fibres work well to dye but the colour differ greatly when the sheet is dried, the colour is perceived stronger against a light source. After exposing the knitted structure to water for a whole day. It needs to be left to dry in order to be used again. Which differed if the net material had been made of steel wire, brass or copper. The knitted material made of polyester (studied during the prestudy II) reshapes the form after drying.

The research resulted in four tracks; four different ways of creating watermarks and structural surface.

• TRACK 1
Use Transparent watermarks in the sheets that change the appearance of the surface with and without light source (fig. 36.1).

• TRACK 2
Shape the paper sheet with 3D-structure, to get a relief surface (fig. 36.2).

• TRACK 3
Combine colour with non-woven instead of keeping it natural, combine selected light sources to highlight the watermarks (fig. 36.3).

• TRACK 4
Combine watermark with texture, by forming thicker sheets (fig. 36.4).
Summary of findings

The cellulosic fibres were chosen due to their different kind of materials fiber qualities. The work also had to be limited to the choice of cellulose fibres as more fibres need to be sourced from the papermaker.

The Sisal hemp fibre gave results on watermark surface both when forming the sheet thin and thick (fig. 36.2 & 36.3) The hemp has strong fibres which is durable if it will be exposed to counterforce. The fibres also had the ability to stretch and therefore it was easy and smooth to shape the material when wet without breaking the sheet. In connection with the knitted net material, the fibres was result with clear structures in the fibre surface, and also worked very well to dye, the pearl-like shade was appealing (fig. 36.1)

Long staple cotton was the most “formable” material with the knitted net that provided clear watermarks and structure lines in the sheet. Easy fibre to shape in 3-D (fig. 37.2), as well as one of the fibres that produced the strongest results when dyed (fig. 36.1). If comparing Sisal hemp with Long staple cotton, the fibres differ quite drastically in terms of the feel in the hand. The hemp is soft and smooth while the cotton is hard and stable. This pre-study narrows it down to only use Sisal hemp and long staple cotton in the degree work exploration.

After an analysis of the knitting techniques p.26. The choice was made to only use two knitting techniques in the development of the degreework. The option of rib stitch is therefore discarded due to its toilet paper-like expression. In order to get a more organic coherence, the choice landed on using drop stitch and tuck stitch for the development of knitting techniques in the degreework.
4.1 Development

Stage Degreework, continues with all the tracks from pre-study III p. 31 but scales it down to 3 tracks by including colour, light and surface pattern explorations. Track 1 (fig. 36.1) the sheet is formed with less fiber pulp and therefore also a little more sensitive to strain. The choice for degree work ends up to form the sheet a little thicker to make the non-woven more durable if it will exposed to strain over a longer period. The idea is that the sheet will be applied to a light source in the end, therefore the sheet must be able to be bent and mounted. In the development of the thesis, the sheets and the knit-net structure will be made in A3 size. The issue is that this has not been tested yet and is an important part of the process to get a larger scale of the patterns. The three selected tracks contain several parts. Track 1 two pieces, track 2 two pieces and track 3 one piece. The pieces differ in the design of color technique and structure. The common denominator is that each piece should imitate animal-like skin, the idea came from Sisal Hemp which is leather-like in its formability and structure (fig. 38.1). The organic expression of animal skin is also appropriate and fitting as animal skin is mostly protruding and structured.

A big challenge in the development of all pieces will be to find a way for the pattern to be in the right scale after the adaptation of the A3 size of the frame (mould). The knit-net is naturally elastic and will be stretched out over the frame therefore the pattern repetition will also be slightly distorted. With the right thread tension and margin, this can be resolved.

Presentation of the three Tracks

Track one ; Tuck stitch and 3D structure with long staple cotton
Track two; Drop stitch with sisal hemp
Track three; Folding & 3D structure with sisal hemp
4.2 Development Piece one - Track One -
Tuck with long staple cotton and 3D-moulding.

During the first stage of the development of piece one, different tuck numbers were investigated in the knitting lab on the silver reed machine, knit-net in A5 size was done. The questions to be answered by the study were how the number of tucks affected the structure and transparency of the cellulose material, long staple cotton. During the study it was found that tuck 1in1 (fig. 39.1) made no visible impact on the structure and also no visible transparency in the sheet, even though the pattern was divided into separate distances between tuck and plain knit which proved to give effect during the preliminary study p.32 (fig. 38.2). Being able to see the structure, sheet has to be seen at closer distance, at farer distance the sheet just looks plain white. When the pattern instead included tuck 2in2 (fig. 39.2), the effect on structure and transparency began to appear, the higher the tuck number is the more visible the structure and thinness of the sheet become, similar to linear watermark p.18. During the investigation tests were also made with different numbers of tuck together (fig. 39.4) this gave nice transitions of level in the sheet. However, (fig. 39.2 & 39.3) gave the most effect on structure and perceived patterns at a distance, as tuck and plain knit had marked distances between each other in the pattern, as tuck and plain knit had marked distances between each other in the pattern.

Tests were also done with the same tuck patterns with the sisal hemp fibres (fig. 39.5). It turned out that the tuck gave a better effect with Long Staple cotton. Thus, fibre selection in combination with knitting technique is very important to get a clear structure in the sheet.

Figure 39 Tuck-stitch pattern in A5 size staple cotton paper sheets; 1. 1i1 tuck, 2. 2i2 tuck, 3. 3i3 tuck, 4. 2i2, 3i3, 4i4, 5i5 tuck

Figure 39.5 Tuck-stitch pattern in A5 size with Sisal Hemp.
Develop tuck pattern and enlarge the scale

During the next step of the process it was time to design larger repeated tuck patterns in A3 size instead of A5. To know if it is really possible to go up in size of the knit structure a quick test was made. It turned out that it worked just as easily as shaping the sheets in A5. So shaping larger sheets might also work to go up in scale even more. As the project had to be manageable on its own, the studies were limited to A3 size.

Design idea
In previous pre-study different patterns were knitted, after looking through the various non-woven sheets the design idea landed on p. 32 (fig. 38.1 & 38.2) to design patterns from animal-like skin. Most animals usually have a texture and some raised area in the skin such as crocodile, alligator or snakes some animal species also have some kind of transparency in the skin such as caterpillars, butterflies or fishes p.32 (fig. 36.2).

Dimensions for knit-net structure in A3
A3 size 297 x 420 mm + marginell 40 mm in perimeter (500 mm width in knitting machine, 112 needles)

Used yarn
Polyester NE 32/1, 11tr

Tension gauge
To determine how large the pattern should be, tension swatches (fig. 40) are made. The method is used to see how many stitches was needed to cast-on, and how many rows needed to knit making 10 cm squares. It is also important to use the same yarn, pattern and stitch size when doing the test. After that the tension swatch is measured horizontal from A to B and vertical C to D (fig. 40.2). This method helped to understand how many repetitions could be done on the length and width in adaptation for the A3 size. The outcome from tension gauge was to limit the pattern repetats from two to five repeats in the width and four to seven in the length.

The pattern was designed in the computer program DesignAknit, since the program is a few years old, each tuck number had to be entered step by step beforehand.

Since the knit-net structure will be stretched over the frame, the marginal on the length and width must be included which is 4 cm, this will therefore not be part of the pattern repetition. Depending on the tension of the pattern, the number of rows varied from 300-400 rows to fit the A3 size.

The (fig. 40.3 & 40.4) does not use the correct ruler but the pictures show the difference in the size of the pattern from point A to B.
Figure 41.1 Alligator pattern knitted on silver reed machine with 4i4 tuck. Two repetitions horizontal and 4 repetitions vertical

Figure 41.2 Fish scale pattern design process stage in DesignAknit, fills in coloured pixels where the tuck should be, adds the tuck number beforehand and then erases the color

Figure 41.3 Fish scale pattern 2i2 tuck, finished pattern design to knit in the silver reed machine

Figure 41.4 Alligator pattern knitted on silver reed machine with 4i4 tuck. Three repetitions horizontal and four repetitions vertical

Figure 41.5 Reptile skin pattern knitted on silver reed machine with 3i3 tuck. Three repetitions horizontal and eight repetitions vertical

Figure 41.6 Snake pattern knitted on silver reed machine with 3i3 tuck. Five repetitions horizontal and eight repetitions vertical

Figure 41.7 Fish scale pattern knitted on silver reed machine with 2i2 tuck. Three repetitions horizontal and seven repetitions vertical

Figure 41.8 Fish scale pattern knitted on silver reed machine with 4i4 tuck. Two repetitions horizontal and four repetitions vertical
Analyze the pattern structure

After all the sheets have been formed with the knitted tuck structures, they are analysed with and without light behind. It turns out that results on the structures are very different from each other. Without a light source, the texture is clearly visible on all the sheets and the tactility is a bit the same as a textured wallpaper. The sheets are a bit stiff and robust in the feeling of the hand. Tuck (fig. 42.1) is the largest knitted pattern and the structure of the sheet was perceived very clearly at a long distance with and without a light source. (fig. 42.2) Started from the same pattern shape but made in a smaller scale, the structure is clear but was perceived less well at a long distance. When the light went on behind the pattern turn out more clearly at a longer distance, the light was highlighted the knitted lines and lets more light pass through.

The fish scale pattern (fig. 42.7) is not as clear as hoped. Perhaps because the lines between the layers are prepared. If the pattern is repeated with several sheets and is in a different colour, the scales may be more prominent. The tuck pattern (fig. 42.3 & 42.4) appealed the most, although the pattern was on a smaller scale compared to the other tuck pattern, the pattern was perceived larger at a distance. This is because the stitches in between the tucks have created a circular movement in the pattern, the circular movement makes the pattern more 3 dimensional and it creates a depth in the image. Pattern (fig. 42.3) chosen as the main piece for development of three-dimensional shaping and color progress.

Analyze the pattern structure

Figure 42. Soake the pressed long staple cotton sheets to soften. Next step beating the fibres into paper pulp in the blender togheter with water. Repeating the process until you bucket is full

Figure 42.1 The 4×4 tuck is very clear in the sheet, the large scale pattern can be seen clearly from a distance. Knit-net tuck pattern (fig. 41.1)

Figure 42.2 In smaller scale in relation to (fig. 42.1) the pattern is not as clear from the distance. But the tuck 2×2 pattern still has a clear repetition and structure surface. Knit-net tuck pattern (fig. 41.4)
Figure 42.3 The tuck stitch can be perceived in two different ways: the tucked dots and the circle stitches that run between the tucks. Tuck pattern (fig. 41.6.)

Figures 42.4-8 Variation of tuck patterns
3-D moulding

From previous pre-study III (fig. 37.2) p. 32 the long staple cotton fibres were tested to be shaped with different geometrical forms when the sheets were wet. The 3D-shape would now act as a detail to accentuate the pattern and volume of the sheet even more. Looking clearly at the design language of the pattern (fig. 42.3), the pattern contained mostly circles, the choice landed in using a round shape to reinforce the pattern structure at a distance. Larger circle of a simple porcelain plate (fig. 43) was tested to be placed in the middle of the sheet, the result was unfortunately surfaces with a lumpy structure (fig. 43.1) where the sheet is flatter because the fibres have been pulled out at the bulging surface. However, the large circular shape is clearly visible from a distance but unfortunately it did not enhance the structure of the pattern. In a closer look at the tuck pattern, they are in comparison a bit larger than a ping-pong ball, about 40 millimeters in diameter. The idea landed on using ping pong balls as a 3D-moulding tool, and cutting them in half (fig. 43.2) to put under and over the surface of the sheet to get an even pressing over the sheet. The ping pong balls were tested to be placed in two different places (fig. 43.4) at the tuck section and (fig. 43.5) between the tuck sections where the circular shape runs.

After analyzing both placements, the choice landed on (fig. 43.5), as the circular shape between the tucks was reinforced in the pattern even more. The structure of the tuck was enhanced more when the lighting was placed behind it (fig. 43.3).

Easily accessible and simple tools would be used as the 3D-form. The idea was that the tools would be easy to obtain if the project was to be done for domestic use.
Colour exploration

The cellulose fibres vary naturally in shade which is beautiful, but to develop the degree work further it was investigated to give the fibres a new colour. The shade should enhance the structure of the sheet and not cover the structure. As the work is aimed at lighting, colour will also vary when the lamp is switched off and on.

During the pre-study, different dyeing techniques such as pot dyeing, space dyeing and marbling were investigated. The cellulose fibres were compared and analysed for their reaction to the different dyeing techniques. During the pre-study III it was noticeable that some dyeing techniques included more water consumption. This would ideally be avoided as water was already used in boiling, beating and forming process.

Analysis of the dyeing techniques from the pre-study

Reactive Space Dye
The sheet is dipped in a solution of heated water, citric acid and soda ash. The solution acts as a fixative to make the paint last longer. Next step reactive dyes are dropped by pipette over the wet sheet, the paint then flows onto the paper surface. With this technique it is easy to control where the colours are placed. Once the sheet is dry and the paint has set, the sheet is rinsed under running water to allow the excess reactive paint to run off. During this stage, it was noticed that all cellulose fibres were particularly sensitive to water, as rinsing weakens the stability of the sheet and can thus dissolve the fibres again.

Figures 44. Space dyeing process pictures. 1. Reactive dyes, 2. Space dyeing with Kozo paper and knit-net structure, 3. Space dyed long-staple cotton paper with knit-net structure (dry), 4. Same as figure 3 but different colours
**Pot Dye**
The cellulose fibres are dyed in a pot together with reactive dye, heated water, Soda Ash, salt for fixation. The fibres are left in the dye bath for a while so that the fibres absorb all the dye. Afterwards, the excess dye is rinsed off in running water. In this dyeing technique, it was noticeable that unnecessary amounts of water were used just to give the fibres a new colour, both in the boiling and the rinsing process.

**Marbling**
A vat is filled with thick glue (e.g. wallpaper paste or gelatine) the paint is dipped over the surface and tools such as brushes, combs with needles are drawn over the surface to create a colourful pattern. The paper is placed over the pattern surface and when it is pulled out of the vat, the pattern has been transferred onto the paper surface. This dyeing technique worked well as the technique was very suitable for the cellulose and did not require excessive amounts of water. However, the technique requires prior knowledge and skills and since the degree work is time limited, there would not be enough time to learn a new dyeing technique from scratch. The other reason why marbling was not chosen was that the marbling would draw too much attention from the knitted structure and transparency of the sheet. In that case, a study would have needed to be done with muted marbling colours. This could be something to develop further in future studies to get a different colouring of the fibres. In the degree work, the focus should be on getting an even colour over the whole surface of the sheet.

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Figures 44.1 Pot dye with Aqua blue (Pressed Abaca fibres)

Figures 44.2 Suminagashi marbling 1 (Japanese technique) with sisal hemp paper and normal marbling 2 with long staple cotton and Kozo paper.
New dyeing solutions

To find a more sustainable alternative without using more water than is already consumed in the wet process. There were two options, dye the fibre pulp when it is processed in the blender, as water is already used to process the fibres. Or dye the sheet afterwards when it is dried. The idea was to use a spray bottle as a tool to apply the colours, where the spray bottle gave an even distribution of colour across the sheet. This method was more gentle for the fibres as the sheet does not need to be rinsed off after dyeing and can be dyed on a flat surface. With the spray bottle, it easily can control where the paint ends up and combine shades as liked. An important part of the process was that the colour should not take too much attention from the structure. The idea landed on using W&N watercolour paints where a certain amount of paint is mixed out with water in the spray bottle. With this technique it was easy to control where the paint would be placed and how the colours would flow onto the sheet. During the development of Piece One, various colour tests were made on the tuck pattern (fig. 42.3) p.38 with different budget watercolours (fig. 44.3). The colour were analysed with a white light source behind, during this stage the idea was to decide on a base colour which would then develop into the perfect shade. When the light illuminated the sheet, the colour became more intense and without light more subdued. The choice fell on the green tone soothing, organic and reptile like shade that is camouflage to look at. As the tuck pattern is reminiscent of snakeskin, the color green was chosen.

Winsor & Newton professional watercolor Olive green was chosen as the main color. The dye were mixed out with water by adding 1-5 dots of olive green approx; 1/2 cm in diameter to the volume of 1 dl water, which was then sprayed on small paper samples (fig. 44.4). The samples were then analysed in front of the light in the colour opacity, as the thinner parts of the fibre in the sheet would still be visible through the light as the dye should not be too opaque (fig. 44.5). When the light hit the sheet, the colour changed quite drastically to a warmer tone, with white lighting behind. The choice landed in using 4 dots in the 'spraying method’ for the large A3 sheet in combination with this, the 3-D structure was also formed with the ping pong balls (Fig. 44.6). In total, six identical A3 sheets were made.
How the structure and colour are perceived

In order to find the right lighting for the structure, various tests were made with the placement of the light and the choice of light source. As a light source, cold light LED tubes were mounted behind the sheets, which were placed in three different places in a vertical line with the six A3 sheets. The colour was perceived to be most accurate when cold/white light was chosen, as the warm light affects the colour nuances of the sheets. The three different light sources can be switched on and off individually.

Fig. 45 shows where no light is placed behind and fig. 45.1 where light is placed behind the sheet. The colours and the perception of the 3D shape are quite drastically different. Fig. 45 where the 3D shape is perceived more clearly and the colour is slightly lighter and also the texture of the structure is much clearer and visible. Fig. 45.1, where the green colours become much more intense in tone and the structure, watermarking of the tuck stitch pattern emerges. Fig. 45.2 and fig. 45.3 in these images the light is placed from the side of the sheet, creating shadows and depth in the 3D structure. While the watermark (tuck pattern) is more prominent in some places and slightly reduced where the light is not allowed to pass through the sheet. The photo is taken at different times of the day, the colour and 3D depth change as the room gets darker (fig. 45.3).

Fig. 45.4 shows the light placed in the middle of six A3 sheets, photographed from the side in a dark room, no interfering windows. When the sheet is viewed from this angle, the 3D structure is perceived more clearly. Some parts of the structure are more shadowed because the light does not hit these points. Fig. 45.5 here the light is placed at three points behind all sheets, photographed in a dark room. Like fig. 45.2 a lot of light is allowed to pass through the sheet so that the watermark is clearly visible but no shadows are added.

As observed the perception of the structure, colour and 3D shape of the sheet differs depending on the angles from which it is viewed, the position of the light behind the sheet and the environment in which the sheet is placed.
4.3 Development Piece two - Track Two
Drop-stitch with Sisal Hemp

During the first stage of development of piece two, different structures were sketched on animal skin-like materials. Two sketches (fig. 46 & 46.1.) were chosen to be further developed into drop-stitch patterns. The choice was made according to the animal skin scale, alligator skin has a slightly larger structure than caterpillar skin. Also they were the most suitable structure for the knitting techniques. As learned previously on p.18 drop-stitch technique creates a shaded watermark, the large stitches in the knitting will create the shadow as well as a slightly more bulging texture in the sheet.

The pattern is knitted with polyester NE 32/1 11tr, in the double bed on the silver reed machine. The rectangular (fig. 46.4 & 46.5) shape is where the drop stitch is formed. When the "rectangular"stitches are released from the front bed, the pattern becomes more oval in the shape (fig. 46.6 & 46.7).
Diverse pressures in the couching process

When the knit-net structure (fig. 46.6 & 46.7) is used in the sheet formation instructions on p.27-29 the next step is to couching the sheets. In the couching process a technique was used to make various hard compressions with the sponge on the surface structure, the backside of the knit-net, when excess water collects with the sponge. This technique was used to create an organic and irregular surface (fig. 47 & 47.1) where the sheet gets height differences by pressure. If looking back at the inspiration sketch (fig. 46) or search on Alligator skin, the skin does not look identical. There are some differences in the height of the skin. The organic expression is also inspired by something that is growing or protruding.

The pressure that is distributed through the sheet will also affect the transparent parts but not as drastically as the knit-net structure has already created the watermark at the stage when the sheet is formed in the water bath fibre process. When the frame is raised above the water surface with a thin layer of fibre pulp a vacuum suction is formed. This vacuum stage creates the permanent imprint from the knitted structure, thickening and thinning parts.

Colour Exploration with Sisal Hemp

In the next investigation a colour exploration was made with the Sisal Hemp fibres, by using Winsor & Newton watercolour (fig. 48). Here the process is based on much the same principles as the colour exploration p. 42 but instead of adding the paint in a spray bottle, the paint was added in the blender as the fibres were processed into pulp. To a handful of fibre, 1-5 or 1-8 dots of paint about 5 mm was added with ¾ parts water. The number of “colour dots” depends on the intensity of the colour.

Colour samples with Sisal Hemp:
1. Raw fibre
2. Fibre after boiling
3. Original colour of fibre pulp
4. Yellow Ochre Light 3-5
5. Rose Dore 2-5
6. Perylene Maroon 1-5
7. Terre Verte 1-6
8. Cerulean Blue Red shade 2-5
Two colour shades were selected, numbers 7 and 8. The remaining colour samples are further analysed for the next step in the examination process. Terre Verte and Cerulean Blue were compared with and without a light source. When the light hits the side or top of the sheet, the mother-of-pearl-like structure appears in the colour (fig. 48.2). When the sheet is placed in front of light, the thin longitudinal and crossed fibres are visible with aquarelle changing tones (fig. 48.5).

The perception of colour differs quite drastically depending on location and light source. When perceiving the colour in the fibre pulp (fig. 48) the shade seems quite intense in tone, but when the sheet is shaped and dried (fig. 48.2), the tone is instead perceived as slightly lighter. When the sheet was compared in front of a light source (fig. 48.3 & 48.4) the colour appeared to be quite different with the tones becoming slightly duller. After analysing the sheets, piece A was selected. Terre Verte which contained 6 dots and Cerulean Blue which contained 5 dots of watercolour, where the gray scale is slightly equal in tone.
How the structure and colour are perceived

The photographs show how the knitted structures in combination with the opaque and transparent sisal hemp fibres are perceived differently depending on the source of light, the direction of the light, as well as what time in the day. The muted colours become more visible and stronger when light is shining through. Colour, shade and texture are also altered by the spatial environment.
4.4 Development Piece three - Track Three - Folding
Drop-stitch with Sisal Hemp

The first stage of the development of piece three was to design a larger drop-stitch pattern than piece two and that this pattern should vary more in repetition of pattern size. The inspiration and starting point is taken from the sketch of the caterpillar (fig. 60.2) and previous projects where 3D models were made with partial knit technique to mimic the shell and shape of a beetle (fig. 60). The idea was that the pattern and shape would be mimicked by these sources of inspiration.

A pattern was sketched out in pixels (fig. 60.1), the technique works exactly the same as described on p.44. The idea was to produce an oval, growing and meandering structure (fig. 60.2). As we learned earlier on p.18, the larger stitches will create shadow and bulging texture and the thinner threads (the lop of the stitch) will create thinning parts in the sheet.

When the drop stitch holes cover larger areas, it is better to twine all the threads together. The knitting will hold better when used in the wet process, otherwise the threads can become slack after a while and affect the structure. 11 threads are used in polyester NE 32/1 with the stitch size 6.
Paper forming

In the stage of paper forming, about 15 clamps (10 cm long) have to be used to get an even tension around the whole frame. Fig. 60.3 shows how the fibre pulp of the Sisal Hemp has gathered in a thin layer over the whole knitting after the forming at the water bath. Afterwards, the thin fibre pulp is transferred to an absorbent surface and various compressions are made with a sponge over the backside of the knitted structure (same method as mentioned on p.45) then the sheet is allowed to dry overnight. Once the sheet is dry, the results on structure and compression will emerge more clearly (fig. 60.4).

Looking closely at the dried sheet (fig. 60.4) the larger stitches have formed a more bulging structure and elongated pattern shapes. This is where the fibre pulp accumulates the most, creating shadows and darker areas in the sheet. In the thin lines (plain knit) that run between the drop stitches, thinning occurs in the sheet and this is where more light will be let through.
3D shaping

In this part it was intended to create a self-supporting form. As the method of 3D forming had not been found yet, a workshop was made to test different shapes with Sisal Hemp using simple A3 sheets without KNIT-NET structure. Different objects were used to shape the sheet in wet state, using different wooden shapes, plastic lids, bowls, saucers etc. The forms were combined between and on top of each other with different distances etc. Many different quick tests were made, unfortunately not all are shown in the pictures.

After an analysis of all the tests, the result was not quite right. Looking back at the structure (fig. 60.4) the pattern is very detailed, therefore this method of 3D forming would take away much of the visual. Why? Because the larger and higher the 3D shape is, the more the sheet tends to warp (fig. 60.8 & 60.11) the more some of the structure will disappear. Some of the 3D shapes would certainly work like (fig. 60.7, 60.10, 60.13) where the shape is lower in height and the paper does not crease. Unfortunately, as the work was time limited, this was not an option as this would require a number of hours and days to create a large number of shapes, and may be a project for the future.

However (fig. 60.12) is the most self-supporting shape, although not visually unique as the shape is very reminiscent of a bowl. Fig. 60.10 would work for example if a number of shapes were put together. However, some of the material is wasted to produce the round shape and therefore some of the structure. Something that was discovered during the workshop was that the wooden shapes stained off on the fiber surface, giving a cool colour effect to the paper (fig. 60.7 & 60.11).
Folding And Pleats

In order to come up with another solution for self-supporting form, folding and pleats was tested, technical information (Jackson, 2011). The idea was that the sheet should be self-supporting but not too detailed, too many folds hiding the KNIT-NET structure. This method was much better as it was easier to take control over where and how the sheet would be formed. The choice landed in exploring the box pleats (fig. 70.5) further. Why? This shape was most appealing because the wider pleats which will give a nice effect to structure (fig. 60.4) p.49. Several box pleats were combined with each other (fig. 70.8) and a sketch was made of how the pleated shape could be placed upright (fig. 70.9). The idea was to put several A3 sheets together to create a larger shape, it was also tried to hang the shape, but as the folds added weight to the sheet the shape did not hold up as well. If the shape is upright, it is also easier to change the direction and combination of the form.

The rounded folds (fig. 70.2 & 70.4) were very appealing to make but since Sisal Hemp is very soft on the surface, the folds would not be as sharp as the writing paper made them. However, long staple cotton and kozo fibre would have been a suitable fibre for this folding technique. Fig. 70.7 shows how the box pleat fig. 70.5 is created, from a flat piece of paper with subdivided lines in cm where the folds are made.
To reinforce the stability of the box pleat in standing upright position. Various tests were made with steel wire before the paper is folded, placed on the backside of the lower and upper edge of the paper, with different distances from the edges. As the sheet gets roughened at the edges when it was formed in the wet process it was important to preserve these raw edges, without making a folded edge to fix the steel wire. Instead a thin strip of paper was glued with wood glue over the steel wire on the inside (fig. 80.4 & 80.5). It was also tried to attach the steel wire with stitches, but the small holes and stitches became very visible against a light source so this method was skipped.

Colour Technique & Exploration

For the colour exploration, the spray method was used (fig. 80.7) with the Perylene Maroon with different amounts of mixed paint to create colour shifts and depth to the sheets, from lighter to darker shade (fig. 80.8). The spray method was made before the folding. Fig. 80.9 shows the contrast between the lightest sprayed sheet and the darkest. Approximately six A3 sheets are sprayed, folded and assembled together.
How the structure and colour are perceived

During this process, the folded structure was photographed in different environments with different light sources. Looking at (fig. 90) the structure is photographed without an electric light source, this photo was taken in the morning in daylight. Fig. 90 clearly shows the texture of the drop stitch pattern as well as the shiny pearl-like surface that sisal hemp provides, when when the fibre meets the daylight this becomes particularly apparent. Fig. 90.1 here the structure is photographed in front of a window on a cloudy day, by placing the sheet in front of a window the shaded structure becomes apparent. Depending on the weather and sunlight, the result will also change, both in the shade of colour and how the watermark appears.

Fig.90.2 is photographed with an LED light loop (cold light) directed upwards near the fibre surface, this seems to be a good option for highlighting the shaded areas of the structure. Fig. 90.3 is photographed with a light bulb directed from the front behind the sheet, here the thinned lines running through the structure are highlighted.

Since the folded part is spray painted with a graduated color scale, the first four images differ in color scale because the folded structure is photographed in different places. Looking at the lightest sprayed sheets (fig. 90.4 and 90.5) the colour does not look the same in the pictures, but it is exactly the same colour although the photographs were taken in different environments. Looking at fig. 90.4 the sheet is placed in a studio environment while fig. 90.5 is placed in a room near a window under daylight. Fig. 90.4 has a light apricot tone while (fig. 90.5) is almost delineated to light pink or white.
4.5 Development Piece four - Tuck Stitch with Sisal Hemp - 3D structure

During the development of piece four the knitted tuck stitch pattern (fig. 41.4) on p. 36 was used to form the sheets. This pattern was chosen because it gave good results on linear watermarks (fig. 42.6) p.38. The base colour Rose Dore was added in the blender when the Sisal Hemp was processed into pulp. The focus during this part was to work with large scales, many sheets mounted together. As well as working with connections to the other work that has been done. The Rose Dore colour was varied from two to five colour dots (fig. 90.6) divided into nine sheets (fig. 90.7).

Why was sisal hemp chosen instead of long staple cotton? As some Sisal hemp had been left over from the previous process, this fibre was selected primarily for shaping with the tuck pattern. Tests were made beforehand to see if the tuck stitch pattern gave the same effect for watermarking as Long staple cotton gave.

The Sisal Hemp did not give the same result on edgy hard and matte finish as the Long Staple cotton (fig. 90.8) and the marked linear waterlines (fig. 100). The result was a softer, glossier (fig. 90.9) and a slightly more shaded result (fig. 100.1.) which was perfectly acceptable to see the watermarks and light penetration in the sheet.
3D sketching

During this process, a method was used to sketch and shape the 3D structure in advance using ropes (fig. 100.2), which were then taped to a plastic backing to keep their solid shape. The shape and lines of the rope were sketched according to the size of the substrate 1.26 x 1.19 m, nine A3 sheets. The idea was that the shapes of the rope would be continuous from the first to the last sheet (fig. 100.5). The ropes were also tested to be placed next to each other with 2-3 ropes in width in some selected places (fig. 100.4). This was done at the last moment, as there seems to be some difference in the volume of the shape.
As mentioned earlier on p. 54, this part would link all the project parts that have been done. Therefore the colours Olive green p.42, Cerulean Blue Red shade and Perylene Maroon were chosen p.46. These colours were sprayed on the surface where the ropes ran (fig. 100.8). Perylene Maroon was sprayed, with the function of providing a shaded effect to the Rose Dore tone of the sheet (fig. 100.6).
How the structure and colour are perceived

Figure 101. Without LED-light, 9 a.m. The knitted structure and 3D shape are clearly visible without light behind. The light pink tone and 3D shape can be seen from a longer distance. The hole piece consist of nine sheets placed 3x3 in a vertical line.

Figure 101.1 Without LED-light 2 p.m. close-up. The tuck stitch structure has to be viewed from a closer distance to be seen. As the photography is taken later in the day, the colours changes.

Figure 101.2 With LED-light 8 p.m. The light is placed in a horizontal line at the bottom in the middle of three A3 sheets. The light forms a prominent shadow effect on the 3D structure and colour changes to something more peach like. Looking at the structure at far distance the surface seems almost glassy.

Figure 101.3 With LED-light, close-up 8 p.m. Looking closely at the structure the linear watermarks appear more clearly, but with the placement of the light the structure almost seems like shaded. The 3D shape also perceived more indented.

Figure 101.4 With LED-light 8 p.m. The light is placed horizontally at the top of all A3 sheets. Here the 3D shape gets completely different expression where the undulating lines seem to bulge out more.

Figure 101.5 With LED-light close-up 8 p.m. When the light is placed at the top, more light is allowed to pass through the thinned parts of the surface. This make the linear watermarks clearly visible. No shadow play is visible in the structure only in the 3D shape.
4.6 Result & Presentation

Through self-produced cellulose fibre pulp shaped paper sheets, and with the help of knitted structures developed, adapted to the purpose of transferring designed patterns to paper sheets that meet the objectives of providing variation of light transmission like watermarking.

The project resulted in five light and interior designs. Each work includes a pattern of the basic knitting techniques of drop stitch and tuck stitch that are customised for the purpose and developed in the pre-study. Long staple cotton and sisal hemp were the fibres used for the final result. All five works were coloured with aquarell colour using either the spraying or dyeing technique in the processing of the fibre pulp or paper sheet.

In three pieces, 3D forms or folding has been used to clarify and change the structure of the light interior. The works are allowed to speak with and without a light source to see the differences in knitted structure, 3D shape and colour changes. During Presentation Exhibit 4.7, the works are presented with a light source.

A significant part of the result is the emergence of a functional method that can be expanded and explored further with other materials and textile techniques.
Snake skin - Result

Interior design: Wallhanging
Size: 1.26 x 0.59 m
Binding: Tuck-stitch 3i3
Fibre: Long Staple cotton
Colour: Winsor & Newtome Aquarelle Olive Green

Colour technique: Spray Bottle
3D-shape paper: Ping-pong balls
Assembly on: Welded steel rods & Wooden frame
Luminous source: Three LED-tubes
Number of A3 sheets: 6
Type of watermark: Linear

Figure 101.7. Final piece: Snake skin, close-up without light.
Figure 101.6. Final piece: Snake skin, with light.
Alligator skin - Result

Interior design: Ceiling lamp
Size: 0.30 x 0.52.5 m
Binding: Drop-Stitch
Fibre: Sisal Hemp
Colour: Winsor & Newtone Aquarelle Cerulean Blue Red shade

Colour technique: Fiber dyeing
3D-form & Assembly: Welded and shaped steel rods
Luminous source: One LED-bulp (white light)
Number of A3 sheets: 3
Type of watermark: Shaded

Figure 101.8. Final piece: Alligator skin.

Figure 101.9. Final piece: Alligator skin, close-up without light.
Coffee beans or larva - Result

Interior design: Table lamp
Size: 0.42 x 0.30 m
Techniques: Drop-Stitch
Fibre: Sisal Hemp
Colour: Winsor & Newtone Aquarelle Terre Verte

Colour technique: Fiber dyeing
3D-form & Assembly: Welded and shaped steel rods
Luminous source: One LED-bulp (white light)
Number of A3 sheets: 3
Type of watermark: Shaded
Catepillar skin - Result

Interior design: Folded and standing
Size: 0.29.7 x 0.90 m
Techniques: Drop-Stitch
Fibre: Hemp
Colour: Winsor & Newton Aquarelle Perylene Maroon

Colour technique: Spray Bottle
3D-shape paper: Folding
Luminous source: One LED-loop (white light)
Number of A3 sheets: 6
Type of watermark: Shaded

Figure 102.3 Final piece: Catepillar skin.
Figure 102.4 Final piece: Catepillar skin, close-up without light.
Crocodile skin - Result

Interior design: Wallhanging
Size: 1.26 x 1.19 m
Techniques: Tuck-Stitch 3i3
Fibre: Sisal Hemp

Colour technique: Spray Bottle and fiber dyeing
3D-shape paper: Rope
3D-form lamp: Welded steel rods & Wooden frame
Luminous source: Three LED-tubes (white light)
Number of sheets: 9
Type of watermark: Linear

Figure 102.5. Final piece: Crocodile skin.
Figure 102.6. Final piece: Crocodile skin, close-up without light.
Figure 102.7. Final piece: Crocodile skin, close-up without light.
4.7 Presentation Exhibition

The project consists of five examples. The examples are all created with the handmade papering techniques with the methods of using knitted textile structures to design watermarks and patterns for non-woven. The design is present in a light and interior home environment context, standing and hanging from the ceiling or placed against a wall. The fundamental idea is that the examples should all be strong and sufficient enough to clearly communicate the overall concept of the aim. A light source behind the sheet and a dark environment highlights the colour and thinned parts of the sheet most clearly fig.102.8-9, 103.2-3 and 103.5-6.

The exemples are meant to speak for themselves in the environment and location in which they are displayed. Structure, colour and 3D form will always be perceived differently depending on the direction of light, background and chosen environment. The ethical expression is based on a pattern construction that should mimic different kinds of animal-like skin, naming of mimicking animal skin can be seen under each part of figures.

The position of the light is also important in the presentation to perceive the watermark. Figure 103.3 is presented in a dark room with light directed upwards close to the fibre surface, which makes the structure visible from a longer distance.

One of the examples has chosen to be presented in a slightly brighter room where the daylight meets the structure of the armature, here the structure is perceived as something in between daylight and lit light face each other. The bulges of the knitting structure and the light penetrations of the thinned part of the sheet appear simultaneously fig. 103-103.1.

The folded example in Figure 103.4 is presented with only daylight as the light source. Here it is the light rays and the folded 3D shape that affect the impact and shadows on the surface of the sheet.
Figure 102.8. Snake skin presented as wallhanging in a home environment.

Figure 102.9. Snake skin close-up with light.
Figure 103. Alligator skin presented as a ceiling lamp, hanging over a kitchen table.

Figure 103.1. Alligator skin, close-up with light.
Figure 103.2. Coffee beans or larva, close-up with light.

Figure 103.3. Coffee beans or larva presented as a table lamp. Stands on a dresser in a bedroom. With light.
Figure 103.4. Catepillar skin presented close to a window in daylight.
Figure 103.5. Crocodile skin presented as a wallhanging at an altar. With light.

Figure 103.6. Crocodile skin presented as a wallhanging at an altar. Close-up.
5.1 Discussion

The aim of this project is to design watermarks for paper making through knitted textile structures. This study shows that it is possible to use knitted textile structures to shape watermarks for papermaking. By breaking traditional techniques for shaping non-woven materials and contributing to a method of textile use.

Knitting is an old craft with a long history that is still evolving today. Knitting in the past was mostly associated with peasant society and its labour, a past time for housewives and classified as a practical technique to provide a warm garment in people's emerging sport and leisure life (Mortensen, 2021). Today, knitting is a practical product but also a way to express one's artistic ability or a way to show one's thoughts on political issues and injustices. From being a necessity (Mortensen, 2021), knitting has now become a metaphor for exploring the creation of meaning in everyday life and offers a moment of relaxation (jonkopingslansmuseum, 2020).

From a technical point of view, knitting may not be the first thing you think of when it comes to papermaking and therefore weaving is more related to the subject (Barett, 2022). Perhaps some consider that strict rules should be followed in this field. However, if a knitted structure as well as a woven structure can shape paper, this certainly creates more opportunities for textile techniques. At the same time, the project offers a supportive development for the purpose of knitting to develop.

For the project to be feasible, the pre-study one was extremely important for the development of the design work p.22. Where a capable construction has been designed dedicated to papermaking. The design has the function of clamping the knitted structures with its characteristic of being able to remove the structure quickly, smoothly and obtain an even tension over the entire frame. This construction is certainly not traditional but all the more durable as the structures can be easily replaced and an infinite number of tests can be made, without wasting unnecessary material. A fun method of papermaking and could be an alternative for weaving as well? Since the material is not permanently attached, the process is also more playful as various tests can be done.

The basic idea for the project was that the process could be contributed to a creative method for home use. Therefore, the work was limited to using only a handknitting machine and weft knitting as basic technique.

To realise the work with weft knitting, the pre-study II was important for the development of a stable material and a capable technique for the use of papermaking. Where the material would withstand being subjected to stretching, pressure and wet conditions. The knitted structure was able to remain stable in A4 to A3 size. However, there were some limitations that were recognised during the paper forming process. As weft knitting is naturally elastic, there was a tendency for the pattern repeats to stretch when the structure was clamped to the frame structure in the wet state.

Since this project focuses only on weft knitting there is potential to try other textile techniques as well. An alternative could be to try warp knitting, basically in that each needle loops its own thread. The loops are made in a vertical way along the length of the fabric from each warp yarn. Thus, there will be a needle from each yarn. Properties with warp knit is that it shows less elasticity than weft knitting (Textile school, 2018). With less elasticity, it is easier to produce a repeated pattern that does not stretch and weaken.

If a fabric is to be weft knitted on a larger scale there is a tendency for the fabric to sag in the center if the fabric is to be stretched on the constructed frame p.22. This would require the yarn to be stiffer in order to be more stable, otherwise there is a tendency for too much fibre pulp to accumulate in the middle of the paper in the wet-process. With warp knit many different types of yarns can be processed like combed, staple, carded and filament which is not possible with weft knitting. Possibilities are also that the warp knit can be produced in many variants of patterns. Limitations are that warp knitting can only be done on industrial machines. Thus, warp knitting is not favorable for a home project and restricts creativity.

Other textile techniques that could be tested are bobby lace. The technique is made by twisting and braiding lengths of thread, which are wound on bobbins to manage them. The material can be made quite rigid but the process is quite time consuming. There are also gaps to explore the scale and the bindings further. Where larger repeats or figuratively placed patterns can provide more shaded areas in the paper sheet, and be seen at a greater distance. It may also be possible to weave repetitive patterns that are functional for watermark as well, possibly this could be a simpler option to work with stiffer materials that are not as elastic as knit.
The project was mainly focused on finding functional bonds to give shaded patterns to non-woven cellulose textiles. The “non-functional” tests were rejected. However, these bonds had the function of providing texture to the non-woven material but not watermarking. Which could also be used to give the non-woven material an embossing similar to Hepburn’s (2016) and Paperlurry (2015) design methods. Then simpler tools and techniques could be used, such as using hand sticks to create different textures or other textile techniques.

During the process, it was found that other placements of the light direction had a greater impact on the appearance of the structure and shade of the non-woven textiles. Since the luminaire body was already designed in a certain light placement, there was not enough time to develop a new lighting placement during the degree work. This could be further developed to bring out the structure of the sheet even more clearly. For example, how should the light be placed, depending on the function of the light in the spatial environment. It may also be necessary to develop the design language of the luminaires to further emphasise the structure.

Some questions that can be answered to further investigate by light source: what would happen if the light behind the structure was in motion? Since the light is in motion, both watermarking and the knitted texture of the surface will be perceived, perhaps also changing the perception of the 3D shape. Another option could be to work with different light strengths by raising and lowering the light. Possibly also that the light is switched on and off to perceive the material with and without lightsource. There is also potential to play with primary colours in the lighting and in the dying of the cellulose fibres. For example, if the cellulose material was dyed in yellow and the light source red, some parts of the material would have been perceived as orange and other surfaces where the light does not penetrate, yellow. There is also further research into how the cellulose material and colour react to UV light. If the lamp is to be placed standing or hanging by a window, the material and colour must be able to withstand sunlight for a longer period, so the lamp does not fade.

As the work was limited to the cellulose fibre that was available, there are several possibilities to explore other cellulose materials for functional bindings. Imagining that the project would need a large amount of fibres to produce sheets, it would require that the material be indigenous. It is possible to pick plants out in nature to produce pulp as mentioned in pre-study one, but if the work requires a lot of fibres, picking too many plants out in nature is not a good alternative. Looking at an alternative plant fibre that could be grown in Sweden and used for paper production, it is hemp. Advantages of the plant are that it does not require pesticides and herbicides and that it extracts pollutants from the soil. The plant also does not need as much water as other natural fibres, which makes it possible to grow the plant in a very resource-efficient way here in Sweden. Hemp as a plant has higher levels of cellulose than trees and also a lower proportion of lignin, which makes it more environmentally friendly for paper production (Hampaforbundet, 2022) (Hansson, Larsson 2020) (Österlen hampa 2022).

For the project to be commercialised, the basic material must be produced locally. The demand of buyers or spectators usually requires a better and more sustainable alternative in the present. During a study visit to a paper manufacturer (Gustafsson, 2022), where the fibres were purchased for this project, Gustafsson told us that it was very difficult to find retailers of cellulose fibres in Sweden. However, there were advantages to finding recycled material. The hemp fibres used in this project were obtained from yarn residues from a hand weaving mill in Skåne. An alternative could therefore be to reuse the fibres if the project is to be commercialised.

Apart from social sustainability, paper itself is quite moisture sensitive and brittle depending on the paper thickness and fibre length. Further tests would need to be done on how different cellulose fibres withstand light, tension, moisture, pressure and folding, etc. It may be necessary to add reinforcing agents in the preparation of the pulp to make the material more durable. During this work, no glue or reinforcing agents were added to the pulp, the fibres were selected according to their original qualities. However, it is important to carry out further tests on the base material if the project is to be commercialised to ensure that the product has a longer lifespan. Another suggestion for further development is to replace paper with something else, such as recycled fabric like fibrous plastic or denim fibres. Which can perhaps be used to create clothing, curtains, venetian blinds or fabric for furniture. There is much more to explore here.
There are great potential to commercialise the design method by starting own business, but in small-scale operations, the process is expensive to apply because it includes many different time-consuming process steps. For example, heating and boiling the cellulose plant requires energy to break down the fibres. One option to shorten the process could be to buy pre-pressed fibre sheets that are only soaked to prepare them for pulping. However, if the project was applied to large-scale operations, these time-consuming steps would disappear. Another time-consuming step in the work was to produce models for the lamp design, where the material had to be bent and welded together as a frame for the assembly of the paper sheets and the lighting. A more efficient option would be to create a self-supporting mould from only the paper sheets, like (Gentenaar, 2017) (Fjellman-lätt 2020). There are also other options to facilitate the design process by cooperating with companies that can manufacture the frames for the luminaires, so that only the paper material needs to be assembled in the final process.

A third option could be to sell the design method to companies by producing a range of different material samples with different fibre qualities and patterned structures. This would allow more time to be spent on the production of knitted structures and the creation of fibre qualities. Collaboration with companies could open up doors for further exploration and usefulness of the design method in textile applications.
5.2 Conclusion

The project KNIT-NET is about exploring the design possibilities of giving structure to non-woven materials. By using knitting as a basic technique to achieve an expression that challenges the non-woven cellulose materials through structure and watermarking.

The project has been placed in the area of designing non-woven materials in a lighting and interior design context. Where paper artefacts are made from raw cellulose fibres that have been boiled and beaten into pulp and then applied on top of the knitted mesh structures to design the sheets. Depending on the source and direction of light, the knitted structures and colours appear in different ways. Light was a very important context to add to the project as it made it easier to observe the watermarks. The possibilities of using the method for this study could lead to a wider range of applications in fashion- and interior design. Further studies could therefore be explored where the different steps of the process could change the overall concept. Choice of bindings, yarns, fiber materials, colours and applications.

Similar to Wilson, 2011 and paperlurry, 2013 patterning was achieved with linear and shaded watermarking. The knowledge to construct a watermark with a hand knitting machine was developed in pre-study. Two important parameters emerged from the study that provided the basic development of the thesis. Knitting technique for creating shaded watermarks: differences between high and low stitch sizes (drop stitches), more fibre pulp is collected in the high stitch sizes. Knitting technique to create linear watermark: altitude differences in the knitting (rib- and drop-stitch), the raised stitch thins some parts of the non-woven by reducing the amount of fibres collected in the raised areas.

The project also shows efficiency improvement to give structured repetitive patterns in papermaking. As well as producing watermarks in a fun way, using the capable construction developed during the pre-study, p. 22 to easy clamp and remove the knitted structure. The practical and theoretical model is also a useful template for people to observe, in the knowledge of the learning to make paper from plant fibres or develop design ideas around the framework.

A recommendation for further work within a similar time frame would be to limit the investigations one step further, for example choosing only one knitting technique and developing the pattern library. Or take advantage of these methods available in the project and do a further investigation with the non-woven fibre material and its area of application. In this way, the technique can be explored more deeply and thoroughly.

The results from the light interiors show that certain placements of the light direction affect the perception of the structure and the 3D shape. If more time had been available for the project, other lighting schemes and placements of the light would have been changed to better emphasise the structure.

Examining small changes in the process, such as the preparation and boiling of cellulose material, would have enabled more thorough investigations of the material. No reinforcing agents were used in the preparation of the fibre pulp to make the material more durable, but the fibres were examined for their original fibre quality. If more weeks had been added to the project, more studies could have been done on the strength and endurance of the fibres. This is to produce a material that has a long lifespan.
6.1 List of images

Front page
Photo by Ainhoa Cortés

Representative images work
Photographs by Mary Laitinen Fransson

Fig 1

Fig 2

Fig 3
Photography by Mary Laitinen Fransson

Fig 4

Fig 5

Fig 6

Fig 7

Fig 8

Fig 9

Fig 10

Fig 11

Fig 12

Fig 13
Fig 14
[Accessed 14th April ]

Fig 15

Fig 16

Fig 17

Fig 21
6.2 References


